Final report

1.1 Project details

Project title	Markets – Actors – Technologies: A Comparative study of smart grid solutions (MATCH)
Project identification (program abbrev. and file)	ERA-Net SES 77251
Name of the programme which has funded the project	ERA-Net SES
Project managing company/institution (name and address)	Danish Building Research Institute (SBi), Aalborg University, A. C. Meyers Vænge 15, DK-2450 København SV
Project partners	International partners: Norwegian University of Science and Technology (NTNU), NCE Smart Energy Markets, Institute of Technology Assessment (Austrian Academy of Sicences). Danish partners: Samsø Energiakademi, ProjectZero A/S, Eniig Holding A/S
CVR (central business register)	29102384
Date for submission	26.02.2019

1.2 Short description of project objective and results

English

The overall objective of MATCH was to expand the understanding of how to design and implement comprehensive smart energy solutions that consider the complexity of factors influencing the effectiveness and success of smart energy initiatives targeted at small consumers. Based on detailed case studies in three countries and comparative analysis, key factors related to technology, market and the involvement of social players or actor groups in developing integrated and workable smart energy solutions were identified. In addition, system implications of the studied solutions were analysed through energy system scenario analyses. The results from the project inform designers, system planners and policy-makers about how to develop better smart energy solutions for small consumers like households and SMEs.

Danish

Det overordnede formål med MATCH var at udvikle viden om, hvordan smart energy-løsninger målrettet mindre forbrugere kan designes og implementeres, så det sikres at løsningerne tager højde for kompleksiteten af faktorer med betydning for deres succes og effektivitet. Med afsæt i komparativ analyse af detaljerede casestudier i tre lande identificeredes nøglefaktorer knyttet til teknologi, marked og involvering af sociale aktører for udviklingen af integrerede og brugbare smart energy-løsninger. Dertil blev de systemmæssige konsekvenser af de studerede løsninger analyseret vha. modelbaserede scenarie-analyser. Projektets resultater informerer designere, systemplanlæggere og policy-makers om hvordan bedre smart energy-løsninger målrettet mindre forbrugere som husholdninger og SMEs kan udvikles.

1.3 Executive summary

As mentioned in Section 1.2, the overall objective of MATCH was to expand the understanding of how to design and implement comprehensive smart energy solutions that consider the complexity of factors influencing the effectiveness and success of smart energy initiatives targeted at small consumers. This was mainly done on basis of a comparative study of in total 9 case studies carried out in Denmark, Austria and Norway (three case studies per country). As the core idea was to make a comparative study of cases and between countries in order to identify and explore the role of key factors related to market, technology and involvement of social actors, it is in many instances difficult to distinguish the "pure" Danish results from the results of the case studies in the other countries. This goes especially for the more overall and theoretical findings of the project related to WP3-WP5 (see later presentation of WP structure, Section 1.4). Therefore, we present the overall results from the comparative analysis in this section, while we in the later and more detailed presentation of results (Section 1.5) will expand more on the results related to the specific Danish case studies.

The nine cases studied in MATCH were: Model Village Köstendorf, HIT Housing project (HiT Rosa Zukunft) and VLOTTE in Austria; PV demo Trondelag, Smart Energy Hvaler and ASKO midt-Norge in Norway; and Innovation Fur, ProjectZero and Samsø Energy Academy in Denmark. Through the nine case studies, solutions targeted a varied group of small consumers were studied, including households, local community (sports) centres, shops as well as larger companies such as a Norwegian grocery wholesaler (ASKO Midt-Norge). See later Table 1 for overview of cases, target groups etc.

The methodological approach was interdisciplinary and mainly qualitative, based on in-depth case studies of existing smart energy pilots and demonstrations employing qualitative interviews in combination with collection of other relevant data through existing documents/reports about the cases as well as visits and observations by the researchers. Much of this work was – for the Danish part – carried out in close cooperation with the Danish non-university partners who contributed through providing data, access to relevant key persons to be interviewed and contributing to the analysis with feedback etc. The qualitative approach was complemented by a model-based energy system scenario analysis (WP4), which explored the system implications of upscaling three selected solutions studied in the case studies.

The nine cases were selected strategically in order to cover three overall types of smart energy solutions:

- Demand-Side Management (DSM) or Demand Response (DR), including both increasing energy efficiency and time-shifting consumption (load management)
- Micro-generation (i.e. distributed production of renewable energy)
- Energy storage solutions (i.e. thermal storage or chemical storage in batteries)

Several of the cases included two or even three of the solution types above. This is due to the complex nature of many smart energy pilots, as these often combine several technical approaches in one trial.

The overall findings and related recommendations of MATCH are:

- **Smart energy solutions work because they are designed as socio-technical configurations from the outset:** We have pointed out that successful implementation of smart energy solutions depends to a large extent on a well-designed interplay of social and technical elements. We have furthermore argued that smart energy solutions should be considered as heterogeneous configurations from the very beginning. That means that designers need to address both technical as well as social aspects in developing smart energy solutions.

- **The development of workable solutions depends on social learning processes:** We have addressed the issue of balancing consumption and demand, and pointed out that the success of such approaches essentially depends on the extent to which social learning is implemented. In relation to this, activities such as meetings and information can be useful for supporting such learning processes.
- **Technology users play a multifaceted, decisive role:** We have studied the role of users in innovation processes and seen that successful solutions are simultaneously influenced by a variety of user roles already during early phases of development. Based on this knowledge, we recommend that it is important to ensure diversity of different user roles and their associated perspectives, interests and requirements from early on.
- **Smart energy solutions work because they are supported by local anchoring activities:** We have shown that successful solutions must rely on local anchoring activities and, based on our case studies, have made suggestions as to how this can be achieved. Thus, the most successful cases were part of a long-term and community-led energy transition initiative involving a diversity of local actors – and often with one local key actor acting as a facilitator and coordinator of the energy transition.
- **The effectiveness of tariff systems and price incentives depend on their social, legal and technical context:** We have discussed the role of tariff systems and price incentives (Time-of-Use pricing) and have concluded that financial incentives often work as a "marker" or "signifier" that may attract consumers' attention, but the actual effectiveness of pricing schemes is determined by the wider context of the schemes, i.e. the overall socio-technical configuration the pricing scheme is embedded in.
- **Solutions that work well locally can have negative effects from the point of view of the entire system:** On the basis of our energy system scenario modelling, we have suggested that it is important to examine the various systemic effects of locally successful solutions for existing energy systems (regional, national) before replicating or upscaling them.

These overall results are detailed further, together with other more specific results, in Section 1.5.

1.4 Project objectives

The overall aim of MATCH was to contribute to developing smart grid solutions through increased understanding of the complex interplay of factors influencing the effectiveness and success of smart energy[1] solutions targeting small consumers. The specific objectives were to:

- Provide knowledge about how technology design, stakeholder involvement and market solutions influence the success of smart energy demonstration projects.
- Explore the potentials and limits for the active involvement of small consumers (prosumers) in electricity generation and balancing the grid (supply and demand).
- Develop recommendations for designers, energy system planners and policy-makers on how to develop comprehensive smart energy solutions that integrate technology, market and stakeholders.
- Develop energy system analyses on basis of the findings from the specific case studies in order to explore how different solutions will work together on an aggregated system level.
- Disseminate the results across Europe

The project focused on lessons learned from existing pilot and demonstration projects in Norway, Denmark and Austria and compared these in order to identify the characteristics that influenced the degree of successfulness and efficiency of these projects. By following up on existing demonstration and pilot projects instead of developing new solutions and demon-

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[1] The term "smart grid" was used in the original project application, however, it was decided to widen the scope to include smart energy solutions more broadly (and not focusing only on the electricity grid). For this reason, we are also using the term "smart energy" throughout this report.

strations, MATCH could cover a larger number of demonstration projects, which substantiated the comparative studies and knowledge exchange among the partners.

The analytical approach was interdisciplinary, covering expertise related to the following research fields: Consumer practices (practice theory), the interaction between users and technology (Science and Technology Studies), social learning and experimentation in development of new technologies (Constructive Technology Assessment) and energy system analysis. Originally, it was also anticipated to apply a living lab perspective in the project, but this was in practice covered through studies of the role of local community-anchoring of the studied cases for the evolvement and success (or possible failure) of the studied cases.

As the approach was interdisciplinary and cross-sectorial, MATCH did not take departure in one specific theoretical model or framework. Instead, we integrated various theoretical perspectives related to the research domains of technology, actors (stakeholders), system analysis and – to a smaller degree – markets and business models. The latter was mainly covered through our analysis of the role of price in promoting demand response in households (see later) and through discussions of the organization of technology innovation/development within companies. The analytical approach was therefore relatively open, although it was in particular inspired by the traditions of technology assessment, Science and Technology Studies (STS) and practice theory.

The project applied a "mixed methods" approach to study the cases from different perspectives and ensure a qualified and elaborated analysis on how the specific smart grid solutions depend on different factors related to technology, market design and actor involvement. Thus, the project applied qualitative methods (e.g. interview with small consumers and other relevant stakeholders), existing secondary data (e.g. evaluation studies or technical reports) and quantitative methods (in relation to energy system analysis). In total, about 80 semi-structured, qualitative interviews were performed, transcribed and analysed.

The project was divided into seven work packages (WPs):

WP1: Design of overall analytical framework for case studies

This WP developed the overall analytical framework for the case studies (reported in D1.1/Skjølsvold et al., 2016). The framework reflected the shared analytical approach and ensured that the outcome of the specific case studies (WP2) fed into the comparative analysis (WP3) and the final energy system analysis (WP4). WP leader was Norwegian University of Science and Technology (NTNU).

WP2: Detailed case studies

Detailed case studies of demonstration projects were carried out as "follow-research". The main responsible for the case studies in each country was the research partner of this country (ITA in Austria, NTNU in Norway and AAU in Denmark). The case studies were guided by the analytical framework developed in WP1. WP leader was Danish Building Research Institute (SBi), Aalborg University (AAU).

In each country, three cases were selected for study (9 cases in total). The cases were existing pilot projects and they were selected strategically in order to cover three overall types of solutions often present within the smart energy field (and identified in WP1):

- Demand-Side Management (DSM) or Demand Response (DR), including both increasing energy efficiency and time-shifting consumption
- Micro-generation (i.e. distributed production of renewable energy)
- Energy storage solutions (i.e. thermal storage or chemical storage in batteries)

On basis of these criteria, the following nine cases were selected (see Table 1):

Table 1. Overview of cases: Description, applied technologies, key actors and main target group

Country/ Case	Description	Applied Technologies	Key Actors	Main Target Group
Austria				
Köstendorf	Pilot and demonstration project with smart distribution grid field test	Local grid PV integration, combination of PV systems and batteries, PV systems and e-vehicles, testing smart grid Infrastructure	Regional DSO & ESCO, research institute, industrial group	Households, SMEs, public authorities
Rosa Zukunft	Pilot and demonstration project with Building-to-grid solution and DSM field test	PV systems without research focus, testing smart grid infrastructure, household level DR and energy feedback, heat-pumps, CHPs	Regional DSO & ESCO, research institute, housing association	Households
VLOTTE	E-mobility business implementation	Combination of PV systems and batteries, PV systems and e-vehicles, PV systems without research focus, testing smart grid infrastructure	Regional DSO & ESCO	SMEs & employees
Denmark				
Innovation Fur	Piloting and demonstration of balancing local energy exchange at the community micro grid level	Local grid PV integration, combination of PV systems with heat pumps or/and batteries, testing smart grid infrastructure	DSO & Municipality	Households
ProjectZero	Promote and facilitate energy efficient measures and local renewable energy to decarbonize consumption	PV systems without research focus, EVs and heat pumps as well as "smart" building energy renovations to achieve higher energy efficiency	DSO, regional Bank-Fund, Municipality	Households and SMEs
Samso Energy Academy	Community participation project to increase energy autonomy of the island	Testing potentials for reduce energy demand by regulate temperature and install energy efficient equipment (energy efficiency measures)	Dedicated Organization for project implementation	Households and SMEs
Norway				
PV demo Trondelag	Two related regional PV demonstration projects	Local grid PV integration, testing smart grid Infrastructure	Two regional DSOs	Households
Smart Energy Hvaler	Testing the potential for balancing the local grid	Local grid PV integration testing demand response and impact of smart technologies as PVs and e-vehicles	Regional DSO, Municipality, University	Households
ASKO midt-Norge	Large PV for decarbonisation of vehicle fleet and for on-site electricity use	PV systems without research focus, hydrogen production, hydrogen driven trucks	Large grocery wholesaler	SMEs & employees

For each case (pilot), detailed qualitative studies were carried out in order to document and analyse how complex sets of factors influenced the effectiveness of smart energy initiatives in order to contribute to better and more comprehensive smart energy solutions. More specifically, the case studies analysed both the direct implications of smart energy solutions on the (everyday) practices of the users as well as how the solutions (and how they were used in practice) were integrated in a network of mutually dependent actors. A particular focus was on solutions that "work in practice". Here, we applied a broad definition of what it means to say that solutions "work". Overall, we defined the studied solutions as working successfully when relevant actor groups had been able to define, set up and test the studied solutions in real-life settings.

As part of the case studies carried out in WP2, prominent socio-technical configuration(s) were identified, mapped and described in detail. The results were reported in three country reports (see D2.1/Ornetzeder et al. (2017), D2.2/Christensen et al. (2017) and D2.3/Throndsen et al. (2017)). These deliverables included a mapping of the country-specific context relevant to the analysis of the specific cases (e.g. the energy system, existing smart grid landscape, market structure, etc.).

WP3: Identifying determining factors for integrated and successful smart grid solutions
This WP identified the critical factors related to market (price and organization), technology and actor involvement that were decisive for designing integrated smart grid solutions for small consumers that work under real-life settings. It was a comparative analysis of the findings from WP2. WP leader was Institute of Technology Assessment (ITA), Austrian Academy of Sciences.

The comparative analysis involved close collaboration among all partners, including also non-university partners for comments and feedback. The identification of the critical factors was done through identifying several "clusters of solutions" across the nine cases, i.e. solutions with one or more similar characteristics in common (e.g. similar phase of innovation, similar target group, similar function, or similar project aim). Each cluster consisted of at least two working solutions (socio-technical configurations) applied in at least two different cases. By developing such clusters of solutions, we provided a more stable basis for comparison and allowed for the discussion of aspects and patterns that help better understanding the success across projects and solutions.

Three clusters of solutions were identified and analysed in detail. In addition to this, a cross-cutting evaluation of the role of users in the studied solutions were carried out. The four thematic fields of study were as follows:

- **Balancing generation and demand:** In this cluster, the focus was on solutions to better deal with variable renewable generation. The studied cases applied and tested several strategies for matching supply and demand, ranging from energy feedback & DSM (Rosa Zukunft) to smart charging (VLOTTE), the use of heat pumps and batteries at the household level (Innovation Fur) and the use for cooling or hydrogen production (ASKO).
- **Renewable powered company fleets:** In this cluster, the focus was on the development of solutions converting vehicle fleets to renewable energy sources through in-house developments aimed first at the companies' own needs. Two cases were analysed in direct comparison: VLOTTE project (a regional DSO developing a smart e-car park) and ASKO (a large grocery wholesaler establishing a hydrogen infrastructure for hydrogen-powered commercial vehicles).
- **Comprehensive energy concepts:** This third cluster included cases aimed at providing complete solutions to achieve a maximum in terms of energy saving and use of renewables. The solutions of this cluster focus on households (100% renewable household in Köstendorf), apartment buildings (Rosa Zukunft), supermarkets (Samso, ProjectZero / ZERObutik), and sports facilities (Project Zero / ZEROsport) – in some examples as part of a regional energy transition plan (Samso and ProjectZero). Common for these cases is that a number of technologies, rules and practices work together in a custom-made manner to achieve ambitious energy targets.
- **User integration:** An additional topic for cross-country, cross-project and cross-solution comparison was user integration. As users are essential in all studied cases, a cross-case analysis offered a complementary perspective on the success of the solutions.

Results of WP3 has been reported in D3.1 (Ornetzeder et al., 2018).

WP4: Energy system analysis
This WP ran in parallel with WP3 and analysed the dynamic relations between different smart grid solutions for small consumers in order to provide recommendations on how to combine and integrate solutions on a system level. A number of scenarios were developed that visualized the system-related consequences of upscaling and combining different of the studied solutions in MATCH. The results were reported in D4.1 (Marczinkowski & Østergaard, 2018). WP leader was The Sustainable Energy Planning Research Group, Aalborg University (AAU).

WP5: Recommendations for designers, planners and policy-makers
Finally, the research of MATCH concluded with WP5, which synthesised the findings from the previous work packages and developed recommendations for designers, planners and policy-makers. Preliminary recommendations were presented to and discussed in detail with stakeholder audiences in each of the three partner countries (through national workshops). The results of these workshops were incorporated in the final recommendations reported in deliverable D5.1 (Ornetzeder et al., 2018b). WP leader was Institute of Technology Assessment (ITA), Austrian Academy of Sciences.

WP6: Dissemination and knowledge sharing (Knowledge Community)
In parallel with the previous WPs ran WP6, which facilitated the dissemination of the project results. Specific activities included contributing to the ERA-Net Smart Grids Plus Knowledge Community, setting up and maintaining a project website (www.match-project.eu), supporting the dissemination activities of the partners etc. WP leader was Danish Building Research Institute (SBi), Aalborg University (AAU).

WP7: Project management
This WP facilitated the collaboration between the partners and the overall advancement of the project. Activities included supporting internal communication and setting up physical meetings approximately every six months for the partners – and in addition a number of virtual meetings. This also included the formal evaluation and administrative deliverables related to the Knowledge Community Standard Work Package. WP leader was the Danish Building Research Institute (SBi), Aalborg University (AAU).

Risks and challenges
A general risk of a comparative study like MATCH is to ensure that it is possible to compare across the individual case studies. This requires a systematic approach towards the collection of data and the analysis of the individual cases. This risk was in MATCH mitigated through having a separate work package (WP1) dedicated developing the analytical framework for all case studies as well as setting up shared criteria for the selection of relevant cases to be studied. In addition to this, several of the physical partner meetings (as well as virtual) were mainly dedicated discussions of our individual case studies and how to compare them. In this way, the partner meetings to a high extent worked as "working meetings" (workshops) feeding into the progress of both the individual case studies and the comparative analysis related to WP3 and WP5. We believe that we managed to mitigate this risk and ensure a productive comparative analysis across cases and countries, which provided a number of important insights (see also next section). This said, preparing the comparative analyses was time consuming and contributed to some delay in the finalising of in particular WP3 and WP5.

Another (unforeseen) challenge related to a few parental leaves at SBi (AAU) and ITA and a long-term illness among the key staff of one of the research partners (ITA). Both things created some challenges in relation to keeping to the original time-table, and the long-term illness eventually resulted in an application for a three-months extension of the final deadline of the project (submitted in June 2018). The extension was granted and thus the project concluded in October 2018 (instead of July 2018, as originally planned).

Despite delays in the completion of some milestones, they were all completed at the end of the project. Below is the list of milestones with information on original planned and actual realizing:

Milestone	**Planned**	**Realized**
Kick-off meeting with all partners	March 2016	March 2016
Launch of project website	May 2016	Sept 2016
Analytical framework for case studies ready (D1.1)	July 2016	Sept 2016
Preliminary results of case studies ready and presented for commenting by all partners at 2-day workshop	January 2017	March 2017
Individual case studies concluded and reported according to analytical framework (D2.1-D2.3)	July 2017	Nov 2017

Preliminary results of comparative study (WP3) ready and presented for commenting by all partners at 1-day workshop	January 2018	March 2018
Outline for Energy system analysis (WP4) ready and presented for commenting by all partners	January 2018	March 2018
Results of comparative study (WP3) ready (D3.1)	April 2018	Oct 2018
Energy system analysis completed (D4.1)	April 2018	August 2018
Recommendations for designers, planners and policy-makers (D5.1) ready.	June 2018	Oct 2018
Present findings and recommendations for researchers, designers/system planners and policy-makers at one national workshop in each country.	June 2018	Oct 2018
Project concludes	July 2018	Oct 2018

1.5 Project results and dissemination of results

In the following (section 1.5.1), we will first detail the overall MATCH findings that were also described in Section 1.3. These findings were the result of the comparative analysis across countries and cases and did not, in that sense, relate only to the Danish part of the project. Next, we will present the findings from the Danish case studies in more detail (section 1.5.2). This is followed by a more detailed presentation of the findings from the energy system scenario analysis, which does not relate only to the Danish case, but were performed by the Danish AAU partner (section 1.5.3). We conclude with commenting on the dissemination of the results (section 1.5.4).

1.5.1 The findings of the comparative study in MATCH

The following describes the key findings from the analysis of the three clusters of solutions, identified across cases and analysed in WP3, and the user integration in more detail (see also deliverables D3.1 and D5.1 in the Annex for the full analysis):

- **Balancing generation and demand using solar PV and storage:** The success and viability of the studied solutions were highly dependent on a high degree of social interaction, learning, and exploitation of issues in local context. The projects that were most successful were the ones having made extensive and varied recruitment efforts consistent with aspects of social learning. Town hall meetings, involving different user groups, education and information campaigns were all useful for both recruitment and teaching people about the benefits of time shifting (and how to avoid expensive peak loads). Active participation and a positive judgment of the overall project could be seen in projects like Köstendorf, Innovation Fur and Smart Energy Hvaler, where users felt a sense of ownership with the project. They identified with the project aim or the larger vision of energy transition behind it.
- **Renewable powered company fleets:** The supportive political context and pre-existing resources and competence building in the region were crucial for the success of both solutions studied (VLOTTE and ASKO). For VLOTTE, this was the early success of the project as well as the network of research and university institutes. For ASKO, it was the intensive networks of innovation and manufacturing. In addition, the corporate culture functioned as an innovation driver: The ESCO of VLOTTE ventured into an unknown business field, and ASKO saw the promotion of an environmental solution as part of strengthening their own (market) position and to promote changes in the framework conditions for such socio-technical solutions. Furthermore, the "real-life" conditions of the demonstrations were important. For instance, the real-life conditions of VLOTTE helped to validate first ideas and to check employees' acceptance and adoption of solutions. Related to this, the studied companies acted as user-innovators who benefitted from their own innovations.
- **Comprehensive energy concepts:** Common for the studied solutions is that they are part of comprehensive, ambitious, and community-led transition strategies that involve a wide range of interconnecting initiatives, technologies and multiple actors. An essential factor for establishing and anchoring successful solutions was that they were community-

driven. Thus, successful solutions are part of longer history of previous experiments, implementations and initiatives. Hence, the studied solutions represent single elements in a much wider spectrum of energy transition initiatives. Except for the Austrian case Rosa Zukunft, these solutions often build on pre-existing networks of actors, though one local key actor seems to be necessary for leadership on designing the solutions as well as driving and facilitating the processes and initiatives of cooperation, network building and communication (e.g. the Project Zero Secretariat in Project Zero or the Samsø Energy Academy on Samsø).
- **User integration**: The most remarkable finding of this analysis was that, in most cases, a variety of different user types or roles contributed to the functioning of the solutions. Six different user roles and their respective characteristics were identified: Research partners, traditional or ordinary users, prosumers, energy citizens, affiliated users, and user-innovators. Since the different roles often occur in various combinations with each other, the resulting principle is a "bundle of user roles". These bundles were able to inform the technical functioning, to influence the way in which problems were solved, and to support the social and political stabilisation of the solutions. In summary, the diversity of perspectives, interests and requirements had a positive impact on the development and operation of the solutions.

In addition to the above analyses, we also made a comparative study of the role of economic incentives (price) for households to time shift consumption (demand response), which led to the following main findings:

- **The role of price in demand response for households:** The role of price-based incentives, like time-of-use pricing, for demand response in households was studied and reported in Christensen et al. (Submitted). Based on a comparative analysis of experiences from Smart Energy Hvaler (combining capacity-based tariffs and micro-generation), Rosa Zukunft (combining variable tariffs and visual feedback) and Innovation Fur (combining hourly net metering with micro-generation), the study showed that economic incentives under certain conditions do influence energy-consuming practices of households, but not in ways as anticipated by economic-rational conceptualisations widespread within economic, engineering and policy-making approaches. The effectiveness of price-based incentives is highly dependent on *other* elements of engagement, devices and competences that are – one way or the other – decisive for the actual impact of the pricing scheme. Also, the specific design of the time-of-use pricing scheme itself is important, as those designs that appear to work best are easy to understand for the users (households) and provides predictable variations in electricity prices. The study also showed that the material context plays a decisive role for demand response actions, as it is in general more difficult to time-shift consumption (especially to night hours) in multi-storey blocks of apartments than in detached houses (because of problems of bothering neighbours due to noise in apartments). Also, prosumption seems to have a positive influence on households' engagement in demand response.

One topic repeatedly addressed over the course of the project and discussed in more detail in the three national MATCH workshops carried out in 2018 relates to **the upscaling and increased dissemination of already available and well-working smart energy solutions**. Given the ambitious energy policy goals within the European Union, this is a legitimate issue. A few observations can be made in relation to this on basis of the MATCH findings:

- Although we have presented configurations that are successful, there is hardly any one solution in our sample that could be distributed on a large scale in its present form. There are three main reasons for this: *First*, the success of these solutions depends on a coordinated interplay of elements and well-functioning local anchoring activities.
  This means, on the other hand, that replication depends on appropriate adaptation services: in another local or regional context, the elements of a successful configuration would need to be arranged differently. *Second*, from the point of view of the system as a whole, the widespread dissemination of a solution often does not appear to make sense,

but rather the combination of many different solutions. *Third*, an explicit recommendation for the accelerated dissemination of solutions would have to include an external assessment of the direct effects and possible unintended consequences on the system level, something that could not be achieved in the present project.

- However, we were also able to observe diffusion processes in the context of this research. Some operate mainly via traditional *market mechanisms*, others essentially via locally established *social networks*. An example of the first type of distribution is the building-to-grid solution in the city of Salzburg. Following the example of the Rosa Zukunft project, the local energy supplier has already implemented similar projects in cooperation with local housing developers. Another example is the electric vehicle fleet solution from the VLOTTE project: the experience gained over the years is already being offered as part of a consulting service. ProjectZero in Sønderborg represents an example in which solutions are predominantly disseminated via social networks. ProjectZero is a public-private partnership between several local (energy-related) companies and the municipality of Sønderborg. The project acts as an intermediary that promotes and coordinates all relevant actions that support the local energy transition. The dissemination of solutions is very effective with this model, but remains limited to the respective region.
- Another way in which the results of local demonstration projects can be disseminated is by *generalising* specifically selected experiences. We found such an example e.g. in the case of the low-voltage grid field test in the municipality of Köstendorf in the province of Salzburg. The conducted real-world experiments showed that – at least up to a certain extent of PV distribution – the existing grid is sufficiently protected against overloading by phase shifting (phase-shifted current is fed into the low-voltage grid). Consequently, high investment costs for controllable transformers can be avoided with this measure in the future. The grid operator translated this result into an obligatory requirement for all new PV systems in the area.

1.5.2 The Danish case studies

In this section, we describe the main findings from the three Danish case studies (Innovation Fur, ProjectZero and Samsø Energy Academy/Renewable Energy Island Samsø) in more detail.

The Danish cases represent different solutions related to the future smart energy system, even though there are also similarities between the cases regarding the aspects addressed and the approaches pursued. Two of the cases are focusing on the general transition of a geographical area to a post-carbon energy system; these are *ProjectZero* in Sønderborg municipality and the *Renewable Energy Island* of Samsø. In both cases, the aim is to facilitate a thorough transition of the energy system to make it based entirely on renewable energy. Also, in both cases, an independent organisation plays a key role in facilitating this transition (ProjectZero in Sønderborg and Samsø Energy Academy on Samsø). Finally, in both cases, there is a wide range of activities covering both the energy consumption and production side. However, in our empirical study, we have chosen to focus on slightly different types of activities (so-called socio-technical configurations) for each case. Also, ProjectZero and the Renewable Energy Island of Samsø differ with regard to the size of the geographical area and population, among other things.

The third case studied – *Innovation Fur* and the related *GreenCom* project – differs from the previous two cases by having a much more thematically focused approach; the GreenCom case is targeted households and aimed to create demand response and load control through micro-generation (rooftop PVs) in combination with various smart energy solutions (heat pumps, home battery storage and Home Monitoring and Control). In the GreenCom case, the local DSO Eniig was a key stakeholder in setting up the demo, which was located on the island of Fur.

The following Table 2 compares the key characteristics of the three Danish cases:

Table 2. Danish cases in comparison

	Innovation Fur (GreenCom)	ProjectZero	Samsø Energy Academy (Renewable Energy Island Samsø)
Main focus	Test area for developing future smart grid	Transition to a post-carbon energy system	Transition to a post-carbon energy system
Type of consumers addressed	Households	Households, SME, community buildings	SME, community buildings
Demand-Side Management	Demand response	Increase energy efficiency, building energy management systems	Increase energy efficiency
Micro generation	Rooftop PV systems	PV systems, waste heat recovery	*Not in focus in MATCH study*
Storage	Stationary battery storage	(Car batteries)	*Not in focus*

Innovation Fur (GreenCom)

Innovation Fur is a private-public partnership (established in 2011) between the Fur citizens, the Municipality of Skive and the local electricity utility and DSO company (EnergiMidt, now Eniig) aiming to create a mini model on Fur of the future sustainable and energy-efficient welfare state. The initiatives on Fur focus on how modern technology, digitalization and energy-efficient solutions can support Denmark's vision on energy and welfare. The ambition is to make Fur carbon neutral in 2029 (originally by 2020) through various initiatives. Innovation Fur was originally a spin-off of a citizen-led project called *Branding Fur*, which aimed at bringing the decline in population size of Fur to a halt and make it more attractive for people to move to the island.

One of the projects affiliated with Innovation Fur was the EU-funded demonstration project *GreenCom*, which has been using Fur as an international test area for developing the future smart grid (the project was concluded in 2016). The goal of GreenCom was to "utilise the flexibility and intelligence in the low-voltage demand and local supply side infrastructure to create increased regulation capacity and reserve power in the centralised power grid by extending the means to effectively and securely manage and control the demand and supply within defined boundaries". In other words, the project aim was to "balance the local exchange of energy at the community microgrid level"[2]. By combining smart grid and IT technologies, GreenCom tested the balance in the energy system through technological equipment installed in "The Intelligent Home" coupled with strategies to increase user awareness. The demonstration included 33 households; of these, 19 were equipped with a home monitoring and control system (HMC), 11 had heat pumps installed (7 air/water, 1 air/water and 3 air/air heat pumps), 20 had PVs installed and 5 had batteries installed with Intelligent Energy Storage (IES) monitoring equipment. The overall experiences from GreenCom were that it is possible for private households to be flexible with PV systems and batteries and PV systems and heat pumps, and that the house owners are interested and cooperative in being flexible if it can help the local DSO.

In our study of the Fur case, we specifically focused on two socio-technical configurations, both targeted households and both part of the GreenCom project. The first includes households with a combination of solar power (PVs) and home batteries (for local storage), while the other includes households combining solar power (PVs) with heat pumps.

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[2] Quotes from project website, http://www.greencom-project.eu/ (accessed 28-07-2017)

The households in general reported to be happy with participating in the demonstration. With regard to the influence of the demonstration on their everyday life and consumption patterns, the interviews show that many households to various degrees incorporated new routines of time shifting (load shifting / demand response) their electricity consumption. In particular dishwashing and laundering were shifted to daylight hours in order to optimize the consumption of their own PV generation. This was motivated by mainly two reasons: First, the project partners behind the GreenCom demonstration had through information meetings and workshops conveyed the message that the householders would save most money by time shifting their electricity consumption. This – in combination with the householders' general commitment to the trial – appeared to influence their daily habits. Second, the hourly net metering scheme was mentioned by many as a reason for time shifting, as this would save them most money. In addition, the notion of "consuming one's own electricity" also appears to have an influence on the householders' motivation to time shift. Typically, the households would develop new daily routines in relation to time shifting their consumption.

Interestingly, the motivation for time shifting consumption was less prevalent among the households with home batteries; these households to some extent delegate the activity of balancing (synchronizing) PV generation and consumption to the batteries and the IES control unit.

On a more general level, it appears as the GreenCom demonstration project strengthens already existing local ties and networks among the citizens on the island. This happens in two ways: First, the information meetings and workshops held by the project owners worked as a setting for people to meet (an additional setting to the other settings on this island, e.g. in relation to the islanders' participation in local associations). Second, some of the participants explained how they on an informal basis exchanged personal experiences with the new technologies with their neighbours or work colleagues when meeting these. In particular the production data of the PVs was something that several shared, partly – it appears – as a friendly "competition" among households with regard to who produces the most electricity (e.g. on a sunny day). It was only male interviewees, however, who told about this kind of habits. In this way, these technologies – and the trial setting – appeared to invite to informal knowledge exchange (and perhaps even shared learning) within the local community.

With reference to the MATCH framework of technology, actors and market, the main findings of the Innovation Fur/GreenCom case study were:

- Technology: The GreenCom demonstration provided important R&D insights in relation to smart grid solutions in homes. It was shown that the PV + battery combination reduces peak loads significantly (35-70%) as well as increases the level of self-sufficiency at the household level. And even though the remote control of heating in the PV + heat pump combination was not tested under ordinary operation (due to technical challenges), the calibration tests indicated a potential flexibility of 1 kW in load demand per household (i.e. 1 kW that can be shifted from peak hours to other hours). However, due to a general over-dimensioning of the low-voltage grid in Denmark, grid capacity is not expected to become a major challenge in the near future (even with more EVs and PVs). Therefore, demand response is not expected to become needed for grid capacity management.

- Actors: The DSO (Eniig) to some extent lost interest in the technical solutions due to the above-mentioned over-dimensioning of the low-Voltage grid. The households were in general happy with participating in the trial and believed they had benefitted from it economically. Also, some saw the trial as part of the larger vision of a renewable energy system and the branding of the Fur island. Further, several householders were actively engaged in time shifting their electricity consumption (mainly dishwashing and laundering) in order to optimise the utilisation of the PV generation. Also, the community of the island might have benefited from the trial in more general terms through strengthened local networks and publicity in Danish media.
- Market: The tested solutions (business models) were not commercial viable without public subsidies (the funding of the project). The households benefitted economically from participating in the trial through increasing their level of self-sufficiency (saving money on the electricity bill) and by getting new equipment to reduced prices. More generally,

the hourly net metering scheme has a positive influence on households' motivation and engagement in time shifting (some of) their electricity consumption.

Project Zero

ProjectZero was founded in 2007 as a public-private partnership between the local DSO and energy provider SE, the Bitten & Mads Clausen Fund (related to Danfoss), the Danish energy company DONG Energy (now *Ørsted*), the Nordic bank Nordea and the Municipality of Sønderborg. The aim of ProjectZero is to promote and facilitate a transition of the municipality of Sønderborg to a CO_2-neutral community by 2029 through a variety of initiatives facilitated by the ProjectZero Secretariat. In 2009, a masterplan for this transition was published. The goal only relates to CO_2 emissions (not other greenhouse gases, e.g. methane). Further, only CO_2 emissions from direct energy consumption within the Sønderborg area as well as related to imported/exported energy are covered by the ProjectZero vision and strategy (i.e. CO_2-emissions related to import of goods, e.g. food, and transport outside of the area, e.g. citizens on holidays, are not included). The end goal of CO_2 neutrality in 2029 is complemented by mid-term CO_2 reduction goals; 25% reduction by 2015, 50% by 2020 and 75% by 2025. The baseline year is 2007. In addition to the climate goal, the vision also aims to create new and keep existing work places within the "knowledge-intensive business". This is thought of as a spin-off of the activities related to the realisation of the CO_2 neutrality vision. More generally, the vision is anchored within a market-driven and growth-based paradigm, as also stated on the website of ProjectZero: "We will show, how a market-driven and growth-based energy and climate transition to a CO_2 neutral society in 2029 can be done in practice"[3].

The ProjectZero initiatives are facilitating new business concepts, new partnerships and new solutions that are climate friendly. The initiatives are strengthened by involvement and participation of local citizens, shops, institutions, businesses, craftsmen and others, which through cooperation aim to create local "green" jobs and economic growth. Hence the strategic efforts to reduce CO_2 emissions through energy efficiency improvement and smart grid solutions are based on participation from local stakeholders. Moreover, energy retrofitting, conversion to district heating, installation of PVs and heat pumps comprise some of the pivotal solutions to accommodate the reduction.

In the MATCH case study, we have focused on three of the ProjectZero initiatives: ZERObolig (in English: ZEROhome), ZEROsport and ZERObutik (in English: ZEROshop). As indicated by the names, ZERObolig targets the residential sector, ZEROsport the local sport centres and sport facilities and ZERObutik the local shops. All initiatives are primarily focusing on promoting energy saving.

ZERObolig motivates homeowners to energy retrofit their homes (partly by offering free energy consultant visits). However, in MATCH we focused on homes, who had invested in PVs in combination with electric vehicles (EVs) and heat pumps (four households were interviewed). ZEROsport aims to make the sport facilities in the municipality more energy efficient and green by engaging sports associations. Together with the Leisure Department in the municipality, the secretary has developed the ZEROsport-programme, which is a two-years certification targeting sports facilities and clubhouses working to reduce their energy consumption and CO_2 emissions. The initiative's purpose is to increase awareness and daily energy management in the buildings through active participation of the users in their leisure time. The core assumption is that the network around leisure activities have a crucial impact on consumers' energy awareness and activities in general. In MATCH, we made site visits to and interviews with the sports centre Diamanten and the local rowing club in Sønderborg.

Finally, ZERObutik offers a certification of local shops according to the size of their realized energy saving. The shops can get different types of certificates, ranging from a white certificate (10-20% reduction) to a green certificate (more than 70% reduction). At regular public events, the certificates are handed over to new members of ZERObutik. So far, about 135 shops have got a certificate. As part of the ZERObutik programme, the shops are offered a

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[3] http://www.projectzero.dk/da-DK/TopPages/Om-ProjectZero/Hvad-er-ProjectZero-.aspx (accessed 01-08-2017)

free visit by an energy consultant (a so-called "ZERObutik partner"), which is done by local electricians who have followed a course in energy advisory. The most typical measure done by the shops is replacing traditional light spots with LED spots. However, some shops also do more comprehensive measures like changing the heating system. For the MATCH study, we visited two ZERObutik certified groceries (both local branches of COOP) and interviewed staff members. For the analysis, main focus was on the largest of the two groceries that had done the most advanced and comprehensive measures in order to reduce their energy consumption. The middle-sized supermarket had made a thorough renovation, which included replacing the old cooling system for the refrigerated counters with a new one based on CO_2 instead of Freon. Furthermore, the waste heat from the new cooling system was utilized for space heating and, later, the system was connected to the local district heating grid in order to make it possible to deliver excess heat from the cooling system to the local district heating system. The latter was carried out as a pilot in close cooperation with the local company *Danfoss*.

On an overall level, the ProjectZero (with its many and varied initiatives), and the goal of Sønderborg becoming a CO_2 neutral area by 2029, appears to be rather successful. The overall CO_2 emissions have been reduced with 36% by 2016 (compared to 2007) and the energy consumption by 18%, which is both well above the national reductions (31% and 11%, respectively).

The interviewed shops and sports centres regarded their measures as successful in the sense that they had realized significant energy savings – and thereby also economic savings. The interviewees talked about economic savings as the primary motivation for implementing the saving measures, whereas environmental reasons were mentioned more sporadically. However, it is interesting to notice that competitions and rewards in several ways played a key role. The ZERObutik is built almost entirely on the idea of promoting action through the public recognition of energy saving actions by issuing public certificates. Also, it was originally a call (competition) for funding applications that played a key role in initiating the ambitions of creating a low-energy building at Diamanten. This indicates that competition, recognition and general publicity can motivate organisations like shops and sport centres to take part in energy saving initiatives.

Regarding the households, they also appeared to view the outcome of their investments and efforts as successful. Again, money savings were most often mentioned as a reason for doing the measures (even though the householders in general found it difficult to say how much they had actually saved), but also environmental reasons as well as considerations of being part of the overall energy transition were mentioned. In addition, some talked about developing individual solutions that would make them more energy-independent and resilient to external threats.

Compared with the households on the island of Fur, the awareness of time shifting electricity consumption in order to balance PV generation with consumption did not feature high in the Sønderborg household interviews. It appears that the main reason behind this is that most of the Sønderborg households were on the annual net metering scheme, which does not incentivize time shifting economically. The only Sønderborg household on the hourly net metering scheme was actually also the only household reporting that they time shifted daily consumption.

ProjectZero clearly plays a key role in facilitating, promoting and communicating the energy transition of the Sønderborg area. Based on the study of ZERObolig, ZERObutik and ZEROsport, it appears, however, that this role is less about *direct* consulting or implementation of measures, but more about supporting knowledge sharing, keeping energy savings and CO_2 neutrality on the local agenda and promoting publicity around measures taken by local actors. In a sense, a key contribution by ProjectZero is to ensure that "the pot is kept boiling".

It is interesting to compare the role of ProjectZero with the role of Samsø Energy Academy (see later), where the active contribution by the latter appears to be much more "substantial" in the sense that the Energy Academy is often directly involved in developing and carrying out energy measures locally. ProjectZero identifies their own role and activities as being "transition management" or "transition leadership" (in Danish: omstillingsledelse). In their own interpretation of this, transition leadership incorporates a number of key skills and approaches, especially: Network building (engaging local actors and facilitate their mutual cooperation), being a catalyser for change (initiate and facilitate rather than design and control), bring the vision and strategies into focus and to debate locally, and create collaboration between universities (knowledge institutions), companies and authorities (the Triple Helix idea).

It was evident from our visits to the Sønderborg area that the vision of Sønderborg becoming CO_2 neutral was something that also "regular citizens" of Sønderborg had heard about and knew. In this way, ProjectZero has succeeded in creating and anchoring the vision within the local community as a shared vision.

With reference to the overall MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: The solutions developed at Diamanten (ZEROsport) and the Supermarket (ZERObutik) were quite innovative and were in both cases developed in close collaboration with local companies. This shows the importance of the collaboration between companies and local consumers in the ProjectZero case, which also feeds into their vision of the green transition as contributing to local economic growth. The technical solutions applied in the households were not in a similar way innovative.
- Actors: Seen from the perspective of the actors, the initiatives were regarded as successful. Economic savings was in most cases reported as the main reason for engaging in these initiatives, although also considerations for the environment or the overall energy transition were mentioned (and increased resilience through self-sufficiency with energy in some of the households). ProjectZero plays an interesting role in relation to developing and maintaining existing networks of actors and, in particular, nurturing the awareness of the CO_2 neutrality vision and goals.
- Market: Like on Fur, subsidies played a role in most of the studied examples (except for the ZERObutik sites). Thus, households got their investments subsidized through general tax exemption on EVs and favourable account settlement schemes (implying tax exemptions), while the sports centres received funding from private and public funds and programmes for their investments. In this way, most of the solutions studied are not "truly" commercial in the sense that they would work without subsidies of various kinds. But given these subsidies and external funding, the solutions were in general profitable to the households and sports centres. However, the Supermarket is an exemption from this, as the technical solution (utilising "waste" heat from refrigeration for space heating) was profitable even without subsidies. This is also seen in that the solution developed and demonstrated at the Supermarket is now being implemented in other local supermarkets.

As part of MATCH, the partner ProjectZero has integrated and promoted findings and learnings from the case studies (including those above) in their work with strengthening the local SME's engagement and collaboration through the ZEROButik in order to increase their awareness of smart solutions and energy savings within their field.

Samsø Energy Academy (Denmark's Renewable Energy Islands Samsø)

Energy savings and renewable energy transition has a long history on Samsø. As early as in 1997, work was initiated to become a (net) renewable energy island. This was achieved by 2007. Even though the formal goal was to realize the Renewable Energy Island (REI) plan, the transition was by the key initiators very much framed within the context of addressing local threats and challenges, such as local job creation, as a strategy to combat the decline in the island population. Among other things, cooperative ownerships of renewable energy facilities have increased the public acceptance of energy projects. More recently, Samsø has taken up the challenge of making the island entirely rid of using fossil fuels, i.e. in particular replacing fossil fuels for transport with renewable alternatives.

The Samsø Energy Academy (opened in 2007) is a demonstration and meeting place for local citizens, guests and visitors with a general interest in sustainable energy, community power and sustainable development. The Samsø Energy Academy (SE) is owned and managed by the association of the same name (Samsø Energy Academy) with the purpose to be "instrumental in the development of competencies within sustainable community development and the communication of knowledge about holistic processes of co-operation. The association is to promote and encourage co-operation between citizens, businesses, public authorities and research and educational institutions on the basis of Samsø as a sustainable local community."[4]

Lately, the SE has set out a range of initiatives to reduce the energy demand. Some initiatives focus on installation of smart electricity loggers in buildings to identify unnecessary consumption, decrease heating demand and increase energy efficiency. Also, as part of an EU-funded international project called *Night Hawks*[5], the Academy visited 16 shops and other local businesses during 2014-15, offering them consultancy about possible energy savings. Moreover, the business staff was offered education about energy saving. During the visits, temperature data-loggers were installed in different places in the buildings to gain information about the opportunities to reduce the heating or cooling. These visits have resulted in concrete advices to save energy and, all in all, reduced the average energy consumption by 11% since 2014.

The MATCH analysis focused on the shops and other local businesses taking part in the Night Hawks initiative. In total, two shops (a supermarket and a convenience store), one community centre and a small restaurant & hotel have been visited and interviewed as part of MATCH project.

The original idea behind the Night Hawks project was to do so-called "night walks". As the (now closed) project website explained: "Night walks are on-site energy surveys held at times when businesses are closed to the public. Energy experts conduct the survey with a view to identifying areas of energy waste within a business, in order that a bespoke action plan can be produced and implemented so as to enable direct and significant energy savings."[6] However, the SE slightly modified and adapted the concept to the local context on the island. First of all, they visited the businesses during day hours, which made it possible for them to talk with the business owners and staff members about their daily routines etc. With regard to identifying areas of energy waste, SE instead used smart meter data and data from temperature data-loggers to map the 24 hours energy performance of the buildings. The latter were used to identify (unnecessary) high energy consumption and develop suggestions for energy saving measures. Focus of the site visits and the analysis of the measured data were in particular on options for energy optimising the heating system (e.g. by night setback), cooling (e.g. by turning off bottle coolers during night hours) or replacing inefficient lighting with LEDs etc. In explaining the underlying approach behind the initiative, SE emphasises that it was important to come up with ideas that would not compromise comfort, sales or the daily work routines at the supermarket.

On one hand, the Night Hawks project certainly appears as a success: Significant energy reductions were achieved through rather simple socio-technical solutions and typically with very small investments in new equipment (if any). Often, the savings were achieved simply by a more energy efficient management of the energy systems of the businesses. Also, the businesses taking part in the project appear to be happy about the interventions and believing that they save energy expenses. The successfulness of the initiative appears to a high extent conditioned by the general history of the REI and, specifically, the trust in the SE that

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[4] http://arkiv.energiinstituttet.dk/71/ (accessed 08-11-2017)

[5] See https://ec.europa.eu/energy/intelligent/projects/en/projects/night-hawks

[6] Quotation from: http://www.night-hawks.eu/night-walks/ (accessed 03-08-2017)

has been developed on the island over the years. However, this might also limit the extent to which the method and lessons learned from Samsø can be transferred to localities without the same level of trust in a local entity like SE.

At the same time, the Night Hawks approach appears to be a relatively expensive method, as it required many hours of work (of SE) to develop and implement the measures – as well as continued help and supervision afterwards. At least if compared to solutions based on "do-it-yourself" check lists or instructions, although the latter methods might not be as efficient as the approach of Night Hawks and SE. It is therefore an open question to what extent this could work on market conditions and without public funding. However, if the objective is to campaign for better energy awareness, the approach is a shortcut into shops and households.

Finally, it should be noted that the case study shows differences between the sites (businesses). Compared with the community centre and the restaurant & hotel, the Supermarket appears to be the most complex site; both in terms of material and technical complexity (many relatively advanced energy systems, partly interrelated and interfering with each other) as well as organizational complexity related to the size of the staff (many practices and many people to involve), ownership models (e.g. coolers owned by third parties) and the role of the central office at the supermarket chain (of which the Supermarket is a branch). By contrast, the other sites typically had one person in charge of the energy system and the decision-making related to doing changes.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: Only "conventional" technologies were applied in this configuration, because focus was not on technology development as such. The innovative aspects of the Night Hawks project were on the approach of identifying and realising (organising) energy saving potentials, for example by placing temperature loggers in the shops.
- Actors: Seen from the perspective of the actors (SE and the businesses), the initiative was rather successful. The relations between SE and the shops etc. are embedded within the local social networks on the island, and are in particular shaped by the long history of the REI and SE (including a high level of trust in the SE).
- Market: Like on Fur and in Sønderborg, subsidies play a key role for this configuration. It is questionable if this initiative could have been realized without external funding. The realized energy savings can be considerable and do not require significant investments in new equipment or installations. However, the costs are mainly related to working hours connected with identifying, carrying out and maintaining the saving measures.

On basis of the empirical findings of the Samsø case study, a further, and more overall, analysis was made on how to integrate the social and technical aspect of thorough energy transitions such as the one on Samsø. The results of this analysis have been reported in Jantzen et al., 2018. The analysis applies a causal loop diagram of an urban model in order to explain the inner workings of the island community. The analysis illustrates many planning elements, such as political energy targets, sociotechnical priorities, energy vision, energy balance, energy action plan, and examples of demand-side management. The analysis shows that the current Samsø municipal plan is comprehensive, but not coherent. It will be necessary to consider trade-offs, that is, set a goal that would balance housing, jobs, agriculture, tourism, biomass and energy. In this way, the analysis opened for a wider perspective on local and regional energy transitions. One of the key findings relates to the possible conflicts between the goal of more jobs and citizens, both involving increased surface area for industry and homes, and the goal of becoming carbon neutral and self-sufficient with renewable energy (also increasing the area used for, for instance, providing biomass for energy purposes). Thus, land use becomes one of the key strategic issues in the future decarbonization of energy systems, such as on Samsø.

1.5.3 Energy system scenario analyses

The energy system implications of upscaling three studied smart energy solutions were explored in WP4 by use of the energy system modelling tool EnergyPLAN. Three types of solutions were studied:

- Combined Heat and Power (CHP) and/or Heat Pumps (HP) replacing individual heating with PV support (ESA1)
- Electricity demand time shift based on DSM (ESA2)
- Electric Vehicles (EVs) and charging variations: dump charging versus smart charging with V2G, in all cases under the assumption of EVs covering 25% of the driving demand in the country (ESA3)

For each type of solution, an Energy System Analysis (ESA) was carried out. The ESAs show the dynamic relations of not only the different smart energy solutions, but also the impacts on the electricity sector and the heat sector, as seen from the national perspective. To do this, the case studies were rescaled and extended to the national scale of Austria, Denmark and Norway.

The visualization of the system-related consequences of combining different solutions did not show clear tendencies of advantages and disadvantages of the different approaches, but rather the variation they can have in different contexts.

Generally, all approaches have the tendency to reduce CO_2 emissions and fossil fuel consumption, but not all improve the electricity exchange (import/export) significantly, which is also an important indicator for a successful technology. Being able to supply a country locally without depending on other countries increases security of supply and stability in the local market.

While the energy systems analyses do not focus on the market implications – i.e. how the units will operate in an electricity market – the general costs for the systems also have a positive tendency, because for example fuels can be saved.

Regardless of the initiatives studied, due to a general electrification of the society, more electricity production capacity is required, preferable based on renewable energy sources. With the current energy systems, the increased demands would otherwise lead to increased fuel consumption in the currently fossil-fuelled production units, like old condensing-mode power plants. This is the situation for the reference systems of Austria and Denmark, while the impact on Norway would be the possible exhaustion of the hydropower production. While the renewable electricity production in Norway is currently above the local demands, the ESA3 reduces the excess production by 45% already, indicating a limit in the increase of electricity consumption without other improvements in the electricity sector.

Overall, the ESAs give an indication to evaluate seemingly good technologies and approaches more carefully. While HPs and EVs are considered in a positive light, they can have negative consequences on certain energy systems or constellations, shown in ESA1 and ESA3. In addition, the DSM idea of aiming at peak reductions should be well considered, as the ESA2 shows. Energy planners and decision makers need to take hourly demands, seasonal changes and the possible consequences of certain DSM approaches into account. The complexity of different technologies and approaches in different energy systems is shown with this MATCH WP4 by evaluating the same ideas in different contexts. This shows the importance of carefully designing and evaluating markets, actors and technologies.

In general, however it may be concluded that the CHP & HP combination has a role to play particularly in the Austrian energy systems; that HPs are well-suited in the Norwegian context and that EVs must be well integrated using smart charging and possibly also V2G facilities – as proven valuable for Denmark – to minimize negative impacts and maximize positive impacts on the electricity system.

The detailed results and figures can be found in deliverable D4.1. To illustrate the type of results, Figure 1 shows the results of the ESA3 analysis. In this scenario, it is assumed that EVs will cover 25% of the driving demand by car (of total distances covered in each country, not energy demand). On basis of this, three alternative scenarios have been calculated for each country: A reference scenario (based on national 2015-data) and two scenarios with a "dumb" versus "smart" charging behaviour. "Dumb charging" means that charging happens in the evening between 17 and 24, which corresponds to a situation where people plug in and start charging their EV immediately after returning at home in the afternoon. In contrast to this, "smart charging" assumes that charging takes place whenever it makes sense from the energy system's point of view (e.g. in situations with excess production of renewable electricity) and when there is a driving demand. In addition to the smart charge option comes the V2G (vehicle-to-grid) ability. For this, an additional discharge connection capacity of 6 kW per car is added in the model at a 90% discharge efficiency.

Figure 1 shows, among other things, that even with "dumb" charging, the CO_2 emissions will be reduced in both Denmark and Austria compared to the 2015-reference. The reason for this is that the dumb (and smart) charging scenarios assume that 25% of the driving demand is covered by EVs, which is a significant increase compared to the current situation in Austria and Denmark. This implies a significant electrification of automobile driving, which implies CO_2 reductions (electrification of the transport sector was modelled in parallel with expansion of renewables in the electricity sector). However, if smart charging is applied, the CO_2 reductions increase – particularly in Denmark. Thus, for Denmark, the CO_2 reduction is increased from 3.7% (with dumb charging) to 5.4% (with smart charging). In comparison, the differences between dumb and smart charging is much lower in Austria and, in particular, in Norway, which is mainly due to the fact that these countries have a high level of hydro power, which is a far more flexible renewable energy source than, e.g., wind, which is a major renewable source in the Danish electricity system. In other words, the ESA demonstrates how the actual relevance and impact of smart charging highly depend on the type of energy system and energy mix. For countries with a high level of intermittent renewable energy sources, smart charging is much more relevant than for countries with high levels of "flexible" or "controllable" renewable energy sources.

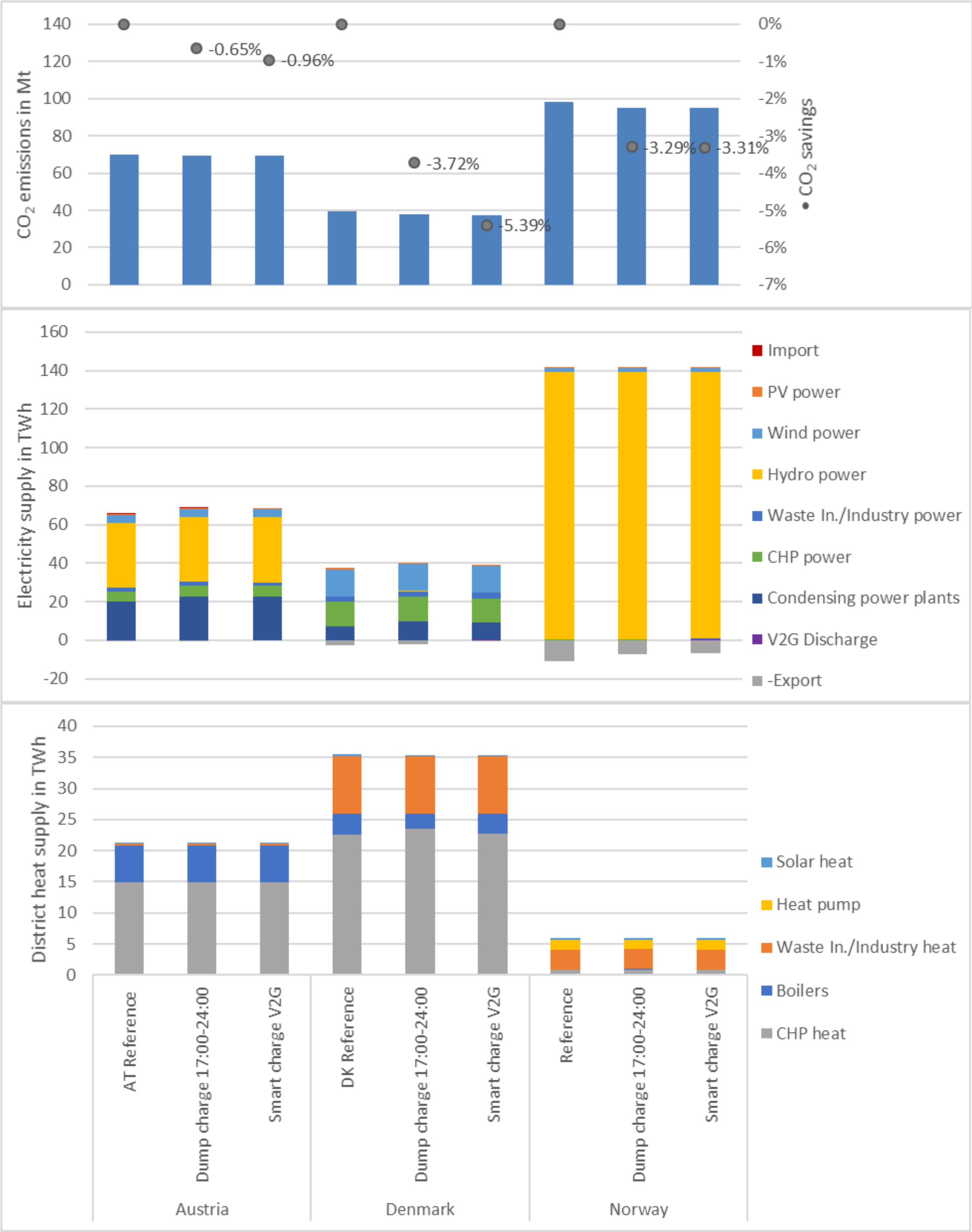

Figure 2: Energy System analyses of dumb versus smart charging of EVs in Austria, Denmark and Norway.

1.5.4 Dissemination of results

Dissemination for non-academic audiences (focus on dissemination by Danish partners)
In addition to the project deliverables (published on the project website), the results of MATCH have been disseminated to non-academic audiences in the following ways:

- National workshops in Denmark, Austria and Norway held in 2018. At these workshops, the main findings of the project were presented and an outline to the overall recommendations for designers and policy-makers were presented for commenting and discussion. The workshop in Denmark was held in June 2018.
- The project website https://www.match-project.eu/

- News stories published regularly on the project website, see: https://www.match-project.eu/news/. In total, seven stories were published.
- Press releases from partners, e.g. "Intelligent styring af boligens energiforbrug" by the partner Eniig, see: https://eniig.dk/privat/om-eniig/nyheder-og-presse/intelligent-styring-af-boligens-energiforbrug_12312926/
- ProjectZero has published a number of news stories on their website and for their newsletter, see e.g. http://www.projectzero.dk/da-DK/Artikler/2016/November/Forskere-p%c3%a5-smart-energi-tur.aspx and http://www.projectzero.dk/da-DK/Artikler/2017/Oktober/Det-perfekte-MATCH-til-S%C3%B8nderborg.aspx
- Samsø Energy Academy has made several presentations of MATCH results to visitors at the Academy and at international conferences, e.g. at the conference "Greening the Islands" 2016, Canary Islands, Spain
- To students at the Sustainable Cities master at Aalborg University in Copenhagen. E.g., Samsø Energy Academy presented the Samsø case and insights from MATCH on the course "Challenges and Planning for Sustainable Cities" in October 2017. Toke Haunstrup Christensen (AAU) has been course coordinator of this course and in general presented results from MATCH.
- Publications targeted the wider public:
    - Christensen, Toke H.: Kronik: Op ad bakke at flytte forbruget med variable elpriser. In: *Ingeniøren* February 2, 2018.
    - Christensen, Toke Haunstrup (2018): Borgere i omstilling. In: *Nyt Fokus* vol. 11, p. 26-29 (http://www.nytfokus.nu/nummer-11/borgere-i-omstilling/)

See also previously submitted Annual reports for more examples of dissemination.

In addition, the MATCH partners (especially the research partners of AAU, ITA and NTNU) have been involved in sharing results via the ERA-Net Knowledge Community. This involves the following activities (focusing on the contributions by the Danish partners):

- Meetings for ERA-Net SES projects and working groups, in all cases including presentations of the MATCH project and findings:
    - Kick-off meeting for ERA-Net SG+ projects and Working Group meeting in Split (Croatia) in June 2016 (AAU together with ITA and NTNU)
    - ERA-Net SG+ Working Group meeting in June 2017 in Bucharest, Romania (AAU together with ITA)
    - ERA-Net SES Working Group meeting in Malmö 24-25 may, 2018 (AAU)
    - ERA-Net SES Family of Projects Event in Magdeburg on September 17-19, 2018 (AAU). Included presentation in the Working Group on Consumer and Citizen Involvement.
- Participation in ERA-Net Working Group webinars (all AAU):
    - "Working Group on Consumer and Citizen Involvement" on November 10, 2017.
    - "Knowledge Community Reflection Workshop" on 26 of June 2018
    - "Virtual Working Group Meeting Consumer and Citizen Involvement" on 5 of December 2018. Including presentation of MATCH findings.
- Written contributions to (all AAU):
    - Spotlight and policy brief on "Consumer and Citizen Involvement" (October 2017)
    - "Virtual Working Group Meeting Consumer and Citizen Involvement" on 5 of December 2018
- Organizing a "Dialogue session" at International Sustainability Transition (IST) 2017 conference in Göteborg 18-21 June 2017 in collaboration with the ERA-Net SG+ project ReFlex. The session was titled: "From local experiments to large scale energy transitions". MATCH participants were: SBi (AAU), ITA, NCE Smart Energy Markets and Samsø Energy Academy.

Dissemination for academic audience

The following peer-reviewed papers have been published (or have been accepted or are under review at time of writing) as a result of MATCH:

- Christensen, T.H.; Friis, F.; Skjølsvold, T.M. (2017). Changing practices of energy consumption: The influence of smart grid solutions in households. Paper presented at *ECEEE Summer Study 2017*, 29 May – 3 June 2017, Presqu'île de Giens, France. LINK: https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2017/9-consumption-and-behaviour/changing-practices-of-energy-consumption-the-influence-of-smart-grid-solutions-in-households/
- Throndsen, William; Skjølsvold, Tomas Moe; Ryghaug, Marianne; Christensen, Toke Haunstrup (2017): From consumer to prosumer: Enrolling users into a Norwegian PV pilot. Paper presented at *ECEEE Summer Study 2017*, 29 May – 3 June 2017, Presqu'île de Giens, France. LINK: http://vbn.aau.dk/da/publications/from-consumer-to-prosumer-enrolling-users-into-a-norwegian-pv-pilot(1962d957-6664-40fa-976e-cd96f211cf36).html

- Marczinkowski, H., Østergaard, P. (2017): Residential vs. Communal Combination of PV and Battery in Smart Energy Systems. *Energy* 152, 1 June 2018, Pages 466-475. Also presented at *12th conf. on Sustainable Development of Energy, Water and Environment Systems, SDEWES 2017*. LINK: https://doi.org/10.1016/j.energy.2018.03.153
- Jantzen, J., Kristensen, M., & Christensen, T. H. (2018): Sociotechnical Transition to Smart Energy: The Case of Samso 1997-2030. *Energy* 162: 20-34. LINK: https://doi.org/10.1016/j.energy.2018.07.174
- Khalid, Rihab; Christensen, T.H.; Gram-Hanssen, K. (2019): Time-shifting laundry practices in a smart grid perspective: A cross-cultural case-study of Pakistani and Danish households. *Energy Efficiency*. First online: 05 January 2019. LINK: https://link.springer.com/article/10.1007%2Fs12053-018-9769-7
- Skjølsvold, Tomas Moe; Throndsen, William; Ryghaug, Marianne; Fjellså, Ingvild Firman; Koksvik, Gitte (2018): Orchestrating households as collectives of participation in the distributed energy transition: New empirical and conceptual insights. *Energy Research & Social Science* 46: 252-261. LINK: https://doi.org/10.1016/j.erss.2018.07.035
- Skjølsvold, Tomas Moe; Ryghaug, Marianne & Throndsen, William (2019): Islands as test beds in smart and renewable energy transitions. Forthcoming in *Science as Culture*.
- Ryghaug, Marianne; Skjølsvold, Tomas Moe; Heidenreich, Sara (2018): Creating energy citizenship through material participation. *Social Studies of Science* 48(2): 283-303. LINK: https://doi.org/10.1177%2F0306312718770286
- Christensen, T.H.; Friis, F.; Bettin, S.; Throndsen, W.; Ornetzeder, M.; Skjølsvold, T.M.; Ryghaug, M. (under review): The role of price in energy demand response: Findings from three smart energy pilots. Submitted to Energy Policy.

In addition, the following papers are planned or under preparation:

- Skjølsvold, Tomas Moe et al.: The role of experiments and demo-projects in fostering whole systems change: an analysis of two demo projects attempting to reconfigure production and consumption in energy, housing and mobility. To be submitted to "sustainability", 2019.
- Sinozic, Tanja; Bettin, Steffen; Ornetzeder, Michael: Digitalisation of energy systems in urban and in rural areas: Comparing residential developments in a smart city and a smart village in Austria

- Ornetzeder, Michael; Bettin, Steffen; et al.: The role of users in smart energy innovation: New evidence from a cross-country comparative study.

Furthermore, there has been a number of paper presentations at scientific conferences by the research partners. Those that AAU has been involved in have been reported in the Annual reports.

Finally, the following MATCH deliverables have been published:

- Skjølsvold, Tomas Moe; Ryghaug, Marianne; Throndsen, William; Christensen, Toke Haunstrup; Friis, Freja; Ornetzeder, Michael; Sinozic, Tanja; Strauß, Stefan (2016): *Studying smart energy solutions for small to medium consumers*. Norwegian University of Science and Technology, Danish Building Research Institute, Institute of Technology Assessment (Austria). Deliverable D1. (See Annex 1)

- Ornetzeder, Michael; Sinozic, Tanja; Gutting, Alicia; Bettin, Steffen (2017): *Case study report Austria - Findings from case studies of Model Village Köstendorf, HiT Housing Project and VLOTTE*. Institute of Technology Assessment, Austrian Academy of Sciences. Deliverable D2.1. (See Annex 2)

- Christensen, Toke Haunstrup; Friis, Freja (2017): *Case study report Denmark - Findings from case studies of ProjectZero, Renewable Energy Island Samsø and Innovation Fur*. Danish Building Research Institute, Aalborg University. Deliverable D2.2. (See Annex 3)

- Throndsen, William; Skjølsvold, Tomas Moe; Koksvik, Gitte; Ryghaug, Marianne (2017): *Case study report Norway - Findings from case studies of PV Pilot Trøndelag, Smart Energi Hvaler and Asko Midt-Norge*. Dpt. of Interdisciplinary Studies of Culture, Norwegian University of Science and Technology. Deliverable D2.3. (See Annex 4)

- Ornetzeder, Michael; Bettin, Steffen; Gutting, Alicia; Christensen, Toke Haunstrup; Friis, Freja; Skjølsvold, Tomas Moe; Ryghaug, Marianne; Throndsen, William (2018): *Determining factors for integrated smart energy solutions*. Institute of Technology Assessment, Austrian Academy of Sciences. Deliverable D3.1. (See Annex 5)

- Marczinkowski, Hannah Marike; Østergaard, Poul Alberg (2018): *Energy system analysis*. Department of Planning, Aalborg University. Deliverable D4.1. (See Annex 6)
- Ornetzeder, Michael; Bettin, Steffen; Christensen, Toke Haunstrup; Friis, Freja; Marczinkowski, Hannah Mareike; Skjølsvold, Tomas Moe; Ryghaug, Marianne; Throndsen, William (2018): *Recommendations for researchers, designers and system planners*. Institute of Technology Assessment, Austrian Academy of Sciences. Deliverable D5.1. (See Annex 7)

1.6 Utilization of project results

Due to the character of the results of MATCH, these are not easily fed directly into existing commercial or business activities as such (through patents or the like). But through the dissemination to both academic and non-academic audiences and the direct collaboration with the non-university partners of MATCH (Samsø Energy Academy, Project Zero, Eniig – as well as NCE Smart Energy Markets in Norway), the main findings, conclusions and recommendations of this project become part of the "knowledge foundation" for commercial actors such as DSOs and transition facilitators (like Samsø Energy Academy and Project Zero). In this way, the results contribute to the design of more comprehensive and successful smart energy solutions that are more likely to "work-in-practice".

This said, a number of results have already been utilized in practice among partners. Thus, Samsø Energy Academy has utilised this as a theoretical foundation for a better understanding of the energy transition of Samsø and how to strategically navigate within this in order to combine social and technical objectives in workable solutions. The earlier mentioned paper by Jantzen et al. (2018) led to a system dynamics model of the population 25 years ahead. It is used for shaping policies on land use and resource management on Samsø. Students of urban, energy and environmental planning at Aalborg University are to visit Samsø Energy Academy in April 2019 to work with this. Also, ProjectZero has integrated the findings to strengthen their methods to ensure local SME's engagement and collaboration through the already established programme ZERObutik in order to make them being aware of smart solutions and energy savings within their field. Finally, the findings from Innovation Fur have informed the business strategies of Eniig in relation to how the households (customers) can be part of the future smart energy system.

Results of MATCH will continue to be used in teaching activities at both NTNU and SBi/AAU. At SBi/AAU, results have already been integrated in the international master Sustainable Cities at AAU-Copenhagen, as described previously.

1.7 Project conclusion and perspective

It is almost by definition difficult to condense a multi-disciplinary research study like MATCH, which covers a thematically wide field, into a few concluding sentences. However, we think that the project has enhanced the theoretical and empirical understanding of how smart energy solutions are being used and integrated by small consumers. It has demonstrated how we need to broaden the perspective in order to make smart energy solutions work better in practice. It is not enough to focus on technical development, market aspects or actor involvement separately. Instead, it is important to acknowledge how these three fields are closely interrelated and co-dependent, and how comprehensive and workable smart energy solutions therefore must be developed in close cooperation with the prospective users and taking into account the social as well as technical aspects studied in MATCH.

From the comparative analysis of MATCH, we can make the following key observations:

- We have pointed out that successful implementation of smart energy solutions depends to a large extent on a well-designed interplay of social and technical elements. We have furthermore argued that smart energy solutions should be considered as heterogeneous configurations from the very beginning.
- We have shown that such solutions must rely on local anchoring activities and, based on our case studies, have made suggestions as to how this can be achieved in practice.
- We have discussed the role of tariff systems and price incentives (ToU pricing) and have concluded that financial incentives often work as a "marker" or "signifier" that may attract consumers' attention, but the actual effectiveness of pricing schemes is determined by the wider context of the schemes, i.e. the overall socio-technical configuration the pricing scheme is embedded in.
- We have addressed the issue of balancing consumption and demand, and pointed out that the success of such approaches essentially depends on the extent to which social learning is implemented.
- We have studied the role of users in innovation processes and seen that successful solutions are simultaneously influenced by a variety of user roles already during early phases of development. Based on this knowledge, we recommend that it is important to ensure diversity of different user roles and their associated perspectives, interests and requirements from early on.
- Finally, on the basis of our energy system modelling, we have suggested that it is important to examine the various systemic effects of locally successful solutions for existing energy systems (regional, national) before replicating or upscaling them.

For each of these key observations, we have developed a number of recommendations for designers and policy-makers, which has been detailed in D5.1 (See Annex 7).

ANNEX 1-7

The seven deliverables of MATCH

Studying smart energy solutions for small to medium consumers

Version 1.0

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About ERA-Net Smart Grids Plus

ERA-Net Smart Grids Plus is an initiative of 21 European countries and regions. The vision for Smart Grids in Europe is to create an electric power system that integrates renewable energies and enables flexible consumer and production technologies. This can help to shape an electricity grid with a high security of supply, coupled with low greenhouse gas emissions, at an affordable price. Our aim is to support the development of the technologies, market designs and customer adoptions that are necessary to reach this goal. The initiative is providing a hub for the collaboration of European member-states. It supports the coordination of funding partners, enabling joint funding of RDD projects. Beyond that ERA-Net SG+ builds up a knowledge community, involving key demo projects and experts from all over Europe, to organise the learning between projects and programs from the local level up to the European level.

www.eranet-smartgridsplus.eu

1 Introduction

This is the first report from the project *Markets, actors, technologies: a comparative study of smart grid solutions* (MATCH). Its purpose is to outline an analytical framework for how to comparatively study smart energy solutions for small to medium customers. We will primarily work with electricity solutions, but are also open to solutions involving more hybrid set-ups. The framework primarily targets MATCH-researchers, but its content should also be of interest to others studying the smart grid from socio-technical perspectives. The framework will inform the work conducted in subsequent work packages.

On a basic level, the framework will ensure that we sufficiently cover "markets", "actors" and "technologies", and that we ensure comparability across countries and cases. This should allow us to analyse and assess how the smart grid solutions are configured, both in terms of social and technical elements involved, as well as how these socio-technical configurations "work" in a given context. The focus on work suggests that we have a process-oriented view on smart energy system solutions. In other words, they are not static or fixed entities, but rather shifting and fleeting, changing as actors learn, as practices are changed, as technologies are introduced or changed, as meaning is ascribed to technologies etc.

Thus, when we aim to assess how the solutions "work", we also have to ask for *whom* the solution works, and be open to the possibility that we might find diverging answers for different actors, even within the same context. As an example, a solution that is deemed "successful" from the point of view of a grid operator, might be seen as intrusive or exploitative from the perspective of small-to-medium consumers.

Based on case studies in the three countries we will gain impressions of how different socio-technical configurations work under different conditions, and how they work for different actors. This will most likely paint heterogeneous images of the studied solutions. This, however, does not mean that we will not search for patterns and similarities across the cases, which might allow us to formulate more or less explicit advice on what solutions to choose under which circumstances. For instance, are there types of actor and technology constellations that seem to work better than others? Are there examples of configurations that should be avoided? Further: are there lessons to be learned from the studied solutions that relate to the up-scaling or system effects of individual (local) solutions?

The remainder of this report will be structured as follows: We begin with a brief note on the research perspectives of the MATCH-partners, before we move on to a general discussion about how we understand the current smart energy system. This includes a discussion of three core "solution foci" of MATCH: DSM/DR, Micro generation and integration of storage. This is followed by discussions of how we should understand the categories "markets", "actors" and "technologies". Finally, we have a set of methodological discussions: How can we study such matters?

2 MATCH-perspectives

The MATCH consortium consists of three core research partners, who will study smart grid solutions targeting small to medium customers. The cases will be analysed individually as well as comparatively in order to develop a framework which can be used to assess projects by how well they work, for instance through developing a loose typology of solutions that illustrate the solutions' core social and technological characteristics, in order to be able to compare and assess configurations across contexts.

The three MATCH research partners come from somewhat different, but related theoretical and analytical backgrounds. In common, we share an interest in the social and the technical, and the role of technology in society. The three perspectives also share an ambition of analysing these in relation to each other. Technology is an integral element of society, which means that we cannot analyse society without a view to technology. This argument also goes the other way, we cannot analyse technology without accounting for "the social".

Combined, these three perspectives allow the consortium to generate a set of research questions for our case studies, which it would have been difficult to do without our combined strength. At the same time we should also recognize that the differences between our perspectives could lead us to pick up on different aspects of the studied solutions, and that we might analyse similar cases differently. In order to begin grasping these issues, this report begins with a brief discussion of the respective perspectives of the partners.

2.1 Science and Technology Studies (STS)

Historically, Science and Technology Studies (STS) have primarily been concerned with the production or construction of (science and) technologies, highlighting the non-deterministic character of the relationship between the development of technology and society. In other words, technology is not an autonomous force, unilaterally affecting social affairs. As an example, instead of asking how "TV has changed society", one would ask something in the lines of "which social developments created the conditions for the development of TV?" Thus, STS has asked how social processes influence technological development, and in turn, how this development feeds into social processes (e.g. Bijker, Hughes, and Pinch 1987, Russell and Williams 2002, MacKenzie and Wajcman 1985). In this context it has been argued that technology does not develop as a result of some inner logic, but rather as a function of social, economic, technical, and political factors. Using historical data Bijker has argued that relevant social groups contribute to the construction of technology, and that there are no criteria to attribute a special status to specific actors or social groups. In a similar but less strict way, Collins and Evans (2002) have pointed out that laypeople have contributory expertise that shapes the future design, form and function of technologies. In Actor-Network Theory (Callon 1986b, Latour 1987), often shortened ANT, the argument of how technology is shaped has been taken one step further, as a radical kind of symmetry is employed to explore how innovation is the outcome of assemblage work in hybrid collectives of humans and non-humans.

In the early 1990s, many STS-scholars turned their attention from the production and development of new technologies to the way that these technologies became parts of the everyday lives of technology users (Sørensen 1994, Pinch and Oudshoorn 2005). This signalled a more active role for technology users, where they were not only considered passive consumers or non-consumers of ready-made technological artefacts. Instead, it was highlighted how users are central to technological innovation processes through their active engagement with, ascription of meaning to and further development of technologies. One way to conceptualize this process is as domestication, a metaphor that highlights how technologies are shaped by their users, while shaping and influencing the very same users.

The MATCH project will study smart energy solutions, with a focus on the experiences of small and medium consumers. To this end we will draw inspiration both from the literature on the construction of technology, as well as the literature on user engagement with technologies. First, we have an interest in the work conducted by various actors to assemble or construct smart grid demonstration projects. Many of these solutions are relatively new, which means that they are subject to interpretative flexibility (Pinch and Bijker 1984). This means that different social groups, different groups of actors, might have different understandings of the solutions at hand, and different understandings of what their purposes are, what the goals are with the trials etc. Thus, it is interesting to study the translation (Callon 1986a) strategies employed by involved actors, as they try to enrol other actors from various spheres as allies working for specific versions of what the smart grid could and should be. One potential outcome of this is that the smart energy solutions end up looking radically different, because they have been constructed by different kinds of actor groups and technologies, with different understandings and expectations.

More generally, this can also be related to an interest in energy transitions, with a focus on the many controversies involved in such transformation processes, as well as the work done to overcome such controversies, and the many sites that needs to be mobilized across society to cater for shifts in complex systems like the energy system (Jørgensen 2012, Pineda and Jørgensen 2015, Farla et al. 2012, Åm 2015). Smart energy system demonstration projects and solutions studied in MATCH could be considered a kind of transition experiment, where various actors negotiate how potential futures could look.

On the other hand, we have an interest in the technology users, and the experiences of the users with the smart energy solutions we study. However, with an ANT-inspired perspective, distinguishing between "users" and "producers" of smart energy system solutions might be somewhat misleading. Users of different kinds are part of a collective "solution", and it is through the relations between the various elements of a solution (e.g. solar panels, feedback monitors, humans, organizations, buildings) that a working or non-working outcome is produced.

For this reason, it is interesting to look at how other actors frame potential user groups, how they attempt to enrol them in demonstration projects, and which issues the smart grid solutions are understood to address. This is related to an interest in understanding how technologies such as those associated with the smart grid might (or might not!) cater for public material participation (Marres 2012) in processes such as an energy or sustainability transition. An interesting route to explore could be if the kinds of solutions studied in MATCH might serve as conduits for the production of new kinds of energy citizenship (Devine-Wright 2007), something which has been argued to be necessary to achieve low-carbon energy transitions.

As a practical entry to the study of users and their interaction with technologies, the concept of domestication stresses how technology users ascribe meaning to technologies, establish new practices in association with technologies, and that there is a constant process of learning in the interaction with the new technologies (Sørensen 1994). The concept is sensitive to the fact that there is interpretative flexibility amongst different user groups, something which means that a solution might work very well for some, while alienating others.

- How are strategies employed to configure smart energy solutions for small to medium users differently (including the role of users) and how do different configurations work in practice?
- What are the implications of our case studies for the wider European work of "doing" sustainable energy transitions?
- What are the relationships between different ways of engaging small to medium users in the smart energy solutions and the relative success of the solution?

2.2 Technology learning approaches (constructive technology assessment)

Innovation studies, transition research and transition management, as well as technology assessment approaches, put much emphasis on learning and experimentation in socio-technical niches. According to these approaches innovation depends on practical experiences as well as theoretical reflexion in early phases of technology development. In MATCH we will build on these ideas in a twofold manner. On the one hand, our cases will be viewed as niche experiments aiming at processes of learning and articulation. On the other hand, learning and reflexion will be stimulated and facilitated as part of the project. In the following we will give a brief overview of learning oriented approaches that will guide the empirical analysis within MATCH.

The concept of socio-technical niches plays an important role in transition research (Kemp, Schot, and Hoogma 1998, Schot and Geels 2008) and design-oriented forms of Technology Assessment (Schot, Hoogma, and Elzen 1994). According to these early approaches, niches are defined as temporary protected spaces to support the development of more sustainable technologies; as a kind of local breeding spaces that enable learning and experimentation. Once the technology is sufficiently developed, in a broad sense, initial protection may be withdrawn in a controlled way (Kemp, Schot, and Hoogma 1998).

A similar notion of the niche concept is applied in the multi-level perspective (MLP) approach, an analytical framework to conceptualize and explain long-term transitions of socio-technical systems towards greater sustainability (Geels 2002). Here, niches are conceptualized as less structurated spaces that offer conditions for action: the numbers of actors involved are small, the degree of alignment between elements is low (Geels 2011), and existing rules and standard procedures are put up for negotiation. Literature on niche innovation (Schot and Geels 2008) defines a number of core processes that are essential to transform inventions and ideas into robust socio-technical configurations. Accordingly, niches have to support three crucial processes, (a) the articulation and the adjustment of expectations and visions; (b) the building of social networks and the enrolment of a growing number of actors; and (c) learning and articulation processes on dimensions such as technical design, user preferences, or symbolic meanings (Geels 2011). Taking this perspective, smart energy system pilot and demonstration projects can be described and analysed as niches, which – to be successful regarding their output – have to provide and maintain these core processes to a certain extent. Activities at the niche level may influence the more stable configurations of prevailing socio-technical systems only if the activities gain internal momentum, become more visible and therefore attract an increasing number of actors (Geels 2011). To learn from our case studies we hence should not only ask whether the mentioned core processes are fulfilled but we should also explore generalisability of our findings by asking how and why and in which wider context the cases are able to meet these hypothetical requirements.

Constructive Technology Assessment (CTA) aims to support the development of technologies that have desired positive impacts and few or at least manageable negative impacts (Rip, Misa, and Schot 1995). The general idea of CTA is to 'manage technology in society' by narrowing the gap between innovation and the societal evaluation of new technology and by putting technology on the socio-political agenda. CTA therefore has to:

> "*integrate the anticipation of technological impacts with the articulation (and promotion) of technology development itself. The co-production of impacts must become reflexive, i.e. actors – whether they see themselves as "promotion" actors or "control" actors – must realize the nature of the co-production dynamics, and consciously shape their activities in terms of shared responsibility*" (Rip, Misa, and Schot 1995, 3-4).

Since broadening the design process should enrich the discourse and improve the quality of the results, Schot (2001) argues that the performance of CTA should be monitored using three process-oriented criteria: (1) anticipation, defined as the opportunity for involved social groups to be able to define problems by themselves and take long-term effects into account, (2) reflexivity, a dimension to measure the ability of social actors to consider technology design and social design as one integrated process, and (3) societal learning, a criterion to assess to what extent first-order learning (the ability to articulate user preferences and regulatory requirements and to connect such conclusions to design features) and second-order learning (the ability to question existing preferences and requirements in a more fundamental way and perhaps come up with very different demands or radical design options) have occurred. These criteria are intended to monitor whether the design process itself is changing, or whether a modulation of the network and actual content of the interaction is required.

In the context of CTA, strategic niche management (SNM) has been developed as to organise and understand processes of learning and experimentation in socio-technical niches. SNM (Weber et al. 1999, Hoogma 2002) directly refers to the creation and growth of protected spaces for promising technology. A central aim of the development of niches is to enable learning, in realistic social contexts (e.g. market niches, controlled field experiments), about the needs, problems and possibilities of the technology under experimentation, and to help articulate design specifications, user requirements or unexpected side effects of new configurations. SNM is a comprehensive and advanced form of managing technological innovations through the organisation of social learning processes, involving producers, technology designers and users in a joint long-term process.

In a similar vein, Vergragt and Brown (2004, 2007) put a special focus on small-scale experiments aiming towards sustainable solutions. They propose a conceptual framework for social learning within what they call ‘Bounded Socio-Technical Experiments’ (BSTE). In a BSTE learning may occur on four different levels: On the first level, learning is conceptualised as a problem-solving activity, on the second level as a discourse about the problem definition (with regard to the particular technology-societal problem coupling), on the third level as questioning of dominant interpretative frames, and finally on the fourth level as a debate on fundamental preferences for social order. Compared to other conceptions of social learning in the context of BSTEs, the range of possible results for learning clearly surpasses the narrow limits of a given technology and provides room to refuse given alternatives and move to completely different solutions.

Research in CTA is also contributing to the question of how to define and predict the impacts of future technologies. If technology is socially constructed, its impacts are open to diverging interpretations as well. Sørensen (2002) has pointed out that the evaluation of impacts operate on a rather fragile basis because the interpretations of technologies are dynamic and situated, and thus inherently flexible. Thus, CTA treats the impacts of technology as dynamic, as involuntarily co-produced during the implementation and diffusion stage. CTA researchers also argue that societal consensus on which impacts are desirable is rarely present and/or achievable (Rip, Misa, and Schot 1995). Because of this dynamic nature of technology impacts, CTA is conceptualised as a process of learning and experimentation (Grin and Van de Graaf 1996). Possible impacts are to be discussed and anticipated earlier and more frequently (Schot 2001) and assessments are seen as integrated and repeated parts of the innovation process, applied at preferred loci for intervention.

Based on these conceptual and theoretical considerations, the following research questions are proposed to guide the investigation of learning processes in smart energy innovation niches:

- What has been learned about the technology, social implications and wider system effects and what is needed to further broaden the innovation process?
- How do structural conditions affect learning in smart energy niches? What is the role of local and national conditions?
- What is needed to support processes of replication and scaling up? How do actors involved assess their achievements?

2.3 Practice theories

Practice theories are not a new or common agreed upon, unified theory, but rather an approach or “turn” in sociological thinking, which places “social practices” as the central unit of analysis (Gram-Hanssen 2011, Schatzki, Knorr-Cetina, and Von Savigny 2001). In the words of Schatzki, a social practice can be defined as a “temporally unfolding and spatially dispersed nexus of doings and sayings” (Schatzki 1996, 80).

The practice theories approach seeks to overcome the structure-actor dualism regarding whether human behaviour is primarily determined by social structures or individual agency. Instead of seeing practices as individual acts, practices are seen as collective actions where the individual can be viewed as a carrier (Reckwitz 2002).

An important observation from practice theories is that consumption of energy (and resources more generally) is the outcome of *performing* practices. As Alan Warde observes: “(…) consumption is not itself a practice but is, rather, a moment in almost every practice.”(Warde 2005, 137). Thus, everyday practices such as cleaning, preparing food, doing the dishes, washing clothes, commuting and many entertainment activities (like watching television) all involve some form of energy consumption. Consequently, the timing of energy consumption (*when* energy is used) is closely tied to the temporality associated with the performance of practices.

Within practice theories, a common understanding is that a practice (the "nexus of doings and sayings") is hold together by heterogeneous and mutually dependent elements, which together constitute the practices. Reckwitz (2002) defines a practice as "a routinized type of behaviour, which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (2002, 249). Different authors have suggested different typologies of these elements. Within consumption studies, Shove and Pantzar (2005) developed the most widespread typology, which distinguishes between three forms of elements: meanings, competences and materials. These elements are specified as:

> "(…) 'materials' – including things, technologies, tangible physical entities, and the stuff of which objects are made; 'competences': which encompass skill[s], know-how and technique; and 'meanings': including symbolic meanings, ideas and aspirations." (p. 14)

Using car driving as an example of an energy-consuming practice, this practice entails some physical "materials" (e.g. the car, but also the material infrastructure), "competences" (e.g. the embodied competences and skills of driving) and "meanings" (e.g. understandings of driving as associated with freedom or necessity). Through the performance of driving, the practitioners (the "drivers") activate and perform different links between these elements and in this way reproduce and change the dynamics of the collectively shared driving practice (Shove, Pantzar, and Watson 2012, 8).

Practice theories depart from the dominating human-centred psychological and economic theories often applied within consumption and environmental behaviour studies. Instead of placing the individual actor (and his/her preferences, values and attitudes) as the key to understand behaviour and behaviour change, practice theories shift focus from the individual actor to the complex of elements (including material elements like technologies) that constitutes practices. Thus, interventions aimed at changing practices, e.g. within households, should ideally address all elements involved in performing the everyday practices of the residents.

From a practice theoretical perspective, the key research questions of the MATCH project can be phrased as:

- How are the specific configurations of elements in the studied demonstration projects decisive for how the smart grid solutions work out in practice (the "success" or "failure" of solutions)?
- Can the "lessons learned" in relation to the role of specific configurations of elements in a specific case be transferred to other contexts/countries? And under what circumstances?
- What implications do the changes in practices have for the energy consumption (size and timing) of households and other small-medium customers?

3 Smart grids and smart energy solutions: what do we mean?

The overall objective of the MATCH project is to "*expand our understanding of how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers*" (from project proposal). To do this we will conduct at least three case studies in the three countries involved in the project: Austria, Denmark and Norway. The cases will be compared, and based on this exercise we will develop recommendations based on the results from our studies. These recommendations will feed into discussions on how to design and implement future smart grid solutions in the three countries and beyond.

In order to do so, we need a more or less coherent understanding of what we mean when we say that we want to study the "smart grid", as well as what we mean when we want to study how to make specific "solutions" work better. Thus, we will now briefly discuss how we understand the smart grid, as well as the associated "smart grid solutions" that we will study variants of in MATCH. This discussion will also take into account earlier relevant research on such solutions, and through this lay the ground for discussions and decisions on how to choose case studies later in this report.

3.1 The smart energy system

Energy systems across Europe and beyond are changing, and many of the changes tend to be discussed under the umbrella heading as the emergence of a "smart grid". The term has countless definitions. As an example, the council of European energy regulators highlight that a smart grid is:

> *"an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to its generators, consumers and those that do both in order to ensure economically efficient, sustainable power systems with low losses and high levels of quality and security of supply and safety"*[1]

The Norwegian national research strategy on smart grids rather stresses that there is no short, clear and concise definition of the term, which do justice to the many meanings that it has taken on.[2] Thus, rather than aim for a new and precise definition of what is likely to be a moving target, our goal in the following is to give a practically useful description of some elements, or "solutions" typically associated with the smart grid. In this way we are close to the understanding fronted by the U.S. office of electricity delivery and energy reliability who point out that:

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[1] CEER status review on European regulatory approaches enabling smart grid solutions, p. 10 http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Electricity/Tab3/C13-EQS-57-04_Regulatory%20Approaches%20to%20Smart%20Grids_21-Jan-2014-2.pdf

[2] Norwegian smart grid research strategy, p. 5 http://smartgrids.no/wp-content/uploads/sites/4/2015/08/Norwegian-Smart_Grid__Research_Strategy_DRAFT_June10_WT_ks_hii.pdf

> *"the 'Smart grid' generally refers to a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing [technologies]"*[3]

In part, the understanding of the smart grid in the MATCH project has emerged from a previously funded ERA-Net project. In the project *Integrating households in the smart grid* (IHSMAG) many researchers involved in the MATCH project wrote the following:

> *"our approach has been relatively open as we understand the smart grid as basically characterised by:1) An increased integration of new ICTs (including an Advanced Metering Infrastructure, AMI) that enables new ways of communicating between different actors. 2) The integration of new actors in the electricity system as well as the assignment of new roles to existing actors (e.g. households as both consumers and producers of electricity)"* (Christensen et al. 2016, 6).

In MATCH, we build on this, and continue to pursue a relatively open approach to what the smart grid is, what problems it is set to solve and what it can offer. However, this broad focus actually means that we look at many things that are strictly speaking not part of the "grid". Thus, we find it fruitful to shift our attention slightly, from a previous focus on "the smart grid" to change focus a bit to highlight that what we are actually studying components of broader, smart or distributed energy systems. In practice, we might end up using the words interchangeably, but there are good reasons for the slight change of focus. While the word "grid" literally deals with transmission of electricity through wires, smart energy systems can be much more comprehensive. They are expected to change the historically quite stable relationships between production and consumption through introducing a broad range of new technologies, modes of organization, market structures, new roles for actors across the system, rules, configurations, etc. This might include technologies that do other things than deliver electricity, e.g. combined heat- and power plants (CHP), solar collectors or bioenergy installations. Hence, our shift to a focus on smart energy systems rather than smart grids imply a broadening of scope and perspective.

The starting point for discussions about smart grids and smart energy systems are often the digitalization of data about electricity consumption and production, and new modes of two-way-communication between what has traditionally been described as the supply and the demand side of the electricity system, the overarching goal being to *"better align energy generation and demand"* (Goulden et al., 2014) to provide for a more flexible grid. Therefore, while this is not a precondition for all smart energy system solutions, many projects over the last years have had "smart" or advanced electricity metering infrastructure as their starting point, replacing the old, mechanical electricity meters of the past with new, digital meters.

On a basic level, smart electricity meters might help illustrate the difference between "smart grids" as a generic concept, and what we will study in the MATCH project, namely "smart grid solutions". The meter is a component in the smart grid, one of countless potential technologies. For some actors, simply "rolling out" smart meters could be considered implementing a "smart grid solution". In what follows, we will turn to such solutions,

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[3] http://energy.gov/oe/services/technology-development/smart-grid

while discussing some past research relevant to the MATCH project. Our primary focus is on solutions that are relevant to small and medium sized customers.

3.2 Smart energy solutions for small and medium sized users

In what follows we will outline three proposed “solution focus areas” that are intended to help MATCH researchers navigate the field studies of their native smart energy solution trials, in a similar fashion as a botanist might bring along a flora, a handbook of flowers on her quest to discover the forests botanical life. However, just as the botanist, we should not see this as a forced straight jacket, for what could be more exciting than discovering a new breed of flowers? That said, even new flowers are likely to contain some elements that are known from the flora: the color, the shape, the numbers they come in, etc. The point of this metaphorical de-tour to the forest is to highlight that we should also keep our eyes open to different and unexpected configurations, and to new combinations of humans and technologies that work in other ways than pointed out in the discussion of solution focus areas.

From the beginning, much focus has been put on the rollout of “smart metering”. Advanced or “smart” electricity meters typically measure the use of energy and the power output (effect) (Löfström 2014) from consumers, and send this information to the electricity suppliers. At the same time, the meter has the capacity to provide real-time data to consumers about the levels and costs of consumption. One practical outcome of this is that meter readings do not have to be done manually, the process is automated. In some countries such as Denmark and Norway, this has in the past been done by the customers.

However, research quite clearly indicates that stand-alone smart meters do very little to achieve reduced energy consumption, shifting the time of energy use or increase customer engagement with the energy system more generally (e.g. Bertoldo, Poumadère, and Rodrigues Jr 2015, Darby 2010, 2001). Actually, some studies have suggested that the use of smart meters without additional technologies might do more harm than good since it allows for complete automation of the relationship between householders and electricity providers, and therefore potentially limits engagement with the electricity system (Jørgensen 2015, Throndsen and Ryghaug 2015).

For us in the MATCH project, it is therefore unlikely that we will be interested in studying smart meters as such. On the other hand, the smart meter quite often serves as a sort of technological hub, facilitating the connection of many other technologies as well as the construction of new services and tariffs etc. related to households or small-medium businesses. As such, it is quite likely that smart meters will be one of many components of the several solution constellations that we study in MATCH. For us, then, it will be important to try to understand what role they play in the specific solutions studied, how they are made sense of or interpreted, how they enable or disable certain modes of action, etc.

With these introductory words about smart metering etc., we will now present the three solution focus areas, which will be in focus for this study.

3.2.1 Demand side management/Demand side response

Demand-side-management refers to a set of technologies or technological set-ups, where the goal, as the name indicates, is to manage or steer the demand of electricity by reducing it and/or shifting it away from peak load periods. Thus, it concerns trying to trigger change amongst consumers in some way which means that it is highly relevant for MATCH. As Fell et al. (2015) state, it refers to creating "*change in electricity consumption patterns in response to a signal*". A "signal" often refers to the price in combination with some sort of information device, but in principle the signal can be any impulse meant to trigger change, including automated response.

Such schemes are typically built "on top of" smart meters, and in line with the definition above involve some sort of technology that sends a "signal", and often also some sort of technology meant to facilitate the consumption change. Broadly speaking, it is possible to differentiate between two ideal typical strategies. In the first, the active choice of changing consumption is left to the consumers, in the other, making this choice is delegated to technologies, i.e. they are automated. In practice, of course, solutions are often placed somewhere between complete automation and complete active engagement. Thus, the level of automation or agency given to users is something we should study empirically, because choices made with respect to this issue tends to produce very different smart energy system solutions, with different expectations for the actors involved. In turn, this will most likely also influence how different actors evaluate the solution, and ultimately how the solution "works" with the present actor constellation and in the present context.

An example of the first strategy includes providing customers with in-home-displays (IHD) or other direct feedback technologies (Hargreaves, Nye, and Burgess 2010, 2013, Wallenborn, Orsini, and Vanhaverbeke 2011). These technologies use the data generated from smart meters to provide customers with feedback (signals) e.g. about the cost of their current consumption, about the environmental impact of the consumption or about the level of current electricity use. Such feedback can be given at an aggregate level (household), but earlier research indicates that achieving energy savings is more likely if the feedback is given in a non-aggregate way, e.g. broken down per appliance (Hargreaves, Nye, and Burgess 2013), which facilitate both ease of use and understanding (Darby 2010).

Another point which has been made in the past is that the feedback given should provide information deemed relevant to the users. One way to achieve this could be to ensure some sort of comparability: how does the current household perform compared to neighbors and other relevant households? (Christensen et al. 2016). Another potential example: what are the current environmental "expense" of the households' consumption, compared e.g. to other phenomena such as air travel or driving a car? On a general note, it should be pointed out that "what is relevant" will most likely differ between user groups and contexts, a point that highlights the importance of trying to design solutions inclusively (Sørensen, Faulkner, and Rommes 2011), e.g. through actively incorporating the competences of prospective users and their everyday practice in the design of smart grid solutions (Jelsma 2003, 2006, Skjølsvold and Lindkvist 2015). On a cautionary note, it should be added that the positive effects of feedback seldom reach the optimistic assumptions provided by engineers and some economists, because raised awareness levels do not necessarily translate into altered practices.

Solutions like IHDs can be implemented as a stand-alone technology or in combination with other technologies, incentives and modes of organization. One example of this is the implementation of new incentive structures such as time-of-use pricing (TOU), e.g. making electricity much more expensive during peak hours. This can be done in different ways.

As an example a recent study from Denmark shows that schemes based on fixed price intervals (also called *Static time-of-use pricing*) are easier to understand for the households compared to schemes based on prices that change continuously from hour to hour and day to day (also called *Real-time pricing*). Static time-of-use pricing makes it easier for the household members to develop new routines and shift electricity consumption on a permanent basis. The Danish study indicates that the time-shifting in electricity consumption was not so much depending on the actual cost savings (which were in general small), but rather because the static time-of-use pricing conveyed a general knowledge about at what times it would be most suitable for the system and for the participants personal economy to consume electricity (Christensen et al. 2016)

The other strategy focuses on delegating the response to signals to pre-programmed technologies. This can be done quite crudely through reducing the allowed volume of electricity consumption at any given time, often described as load capping. Another alternative is so called direct load control (DLC) where operators are allowed to remotely switch off electrical appliances such as water heaters when this is deemed necessary. Other prospective technologies involve washing and drying machines, freezers and refrigerators, which may provide some flexibility. Studies that MATCH researcher have been involved in earlier, however, suggest that this has limited effects on the grid (Meisl et al. 2012). Still, many actors argue the case that making these applications become “smart”, interacting directly with new price signals or other pre-programmed settings, and limiting the need for user involvement, is a feasible strategy.

Some earlier studies have indicated that for many users, such solutions might entail a sense of loss of control of vital elements of everyday life (Rodden et al. 2013), while other studies (Fell et al. 2015) suggest that this is an area where users are quite open to relatively radical innovations and change. To us this indicates that there is significant interpretative flexibility here, both across cases and contexts, which we should explore empirically. Another consideration to make is that while automation might facilitate change, it might also entrench and solidify new practices to the extent that they become even harder to change, more “naturally” integrated in everyday life than pre-existing patterns (e.g. Strengers 2013 for a critical discussion).

When we discuss how solutions meant to trigger changes in energy usage patterns work, it is in light of the above likely that we will come across different formulations of what the “goals” of implementing such solutions are. Some might see these technologies as components of strategies meant to empower end-users to become more engaged in the energy system[4], or even producing new forms of energy citizenship (Devine-Wright 2007). For others, these technologies are part of a strategy where the primary goal is to reduce consumption and shift loads, for instance as a way to reduce peaks, or to cater for new intermittent renewables.

In sum, the discussion indicates that technologies meant to change consumption patterns on the so-called “demand side” (DSM or DR) is a broad class of technologies, often targeting the kinds of consumers that are of interest to the MATCH project. While they have been extensively studied, discussed and criticized in the past, there is little indication

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[4] This is at least rhetorically stressed in many of the calls from the European Commission in the Horizon 2020 work programme. For an example from an upcoming call, see EE-07-2016-2017 “Behavioural change toward energy efficiency through ICT”, http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/5059-ee-07-2016-2017.html

that they are disappearing or that there will be fewer experiments with them in the years ahead. We thus make this one of the key MATCH solution focus areas.

3.2.2 Micro generation

Another frequently discussed option for the smart energy system is to turn the attention towards micro generation of electricity. Typically, this can be done through rooftop solar PV, micro wind turbines, small CHP-systems or in some instances even small-scale hydropower.

For MATCH, this development raises interesting questions with respect to the role of actors in the energy system, new technologies, as well as the market structures of the energy system. As far as the actors go, a key issue to ponder is the relationship between actors at what has traditionally been called the supply and the demand side of the electricity system. With the introduction of micro generation, the small and medium sized electricity consumers might actually become suppliers of electricity, both producing electricity that they can use in their own buildings, and selling electricity to the grid. Thus, this is a potentially disruptive development, which includes technological changes, huge implications for market structures, and changed roles for many different actors in the electricity system. In a recent paper discussing the emergence of so-called "prosumers", Parag and Sovacool (2016) highlight:

> *"Fundamentally, markets for prosumption services are different from existing engagement platforms, such as demand-reduction or demand-response programmes. That is because, in prosumer markets, users on the demand side not only react to price signals, but also actively offer services that electric utilities, transmission systems operators, or other prosumers have to bid for"* (p. 1)

While micro generation will often be accompanied by many of the technologies discussed under the header of demand side management, it is a more novel smart energy solution, which has so far been less studied in practice. However, there is currently much experimentation going on in demonstration sites, which is also one of the main reasons for making this one of the key solutions studied in MATCH.

How the prosumer-energy system relationship will look like, and how prosumer markets and actor-relationships will unfold, will likely depend on local context, on the goals set by operators of smart grid demonstration processes, on the potential for renewables like wind and solar in a given area, the levels of trust amongst electricity users, between electricity users and utilities, pricing structures, national regulation (e.g. taxes), etc. As an example, one can easily imagine situations where groups of citizens who distrust the government, central grid and traditional electricity market want to develop prosumer models to become independent and go "off grid", while other groups might use the very same technologies to create new social and business opportunities within existing market structures. There are already examples of controversy emerging in some contexts, e.g. Spain has recently enforced a "sun tax" which effectively removes many of the potential incentives for prosumption and distributed electricity production.[5]

Parag and Sovacool (2016, 2-3) discuss three potentially emerging models of prosumer markets, all with their distinct characteristics, potential upsides and potential downsides,

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[5] http://www.renewableenergyworld.com/articles/2015/10/spain-approves-sun-tax-discriminates-against-solar-pv.html

for different actors across the electricity system. Fig. 1 is a graphical representation of these potential models.

The first model is a *peer-to-peer model*, an organic and not very structured model, involving decentralized and relatively autonomous networks, developed bottom-up (fig 1, model a). Some have envisaged an Uber or Airbnb-inspired model, where a social platform of some sort allow consumers and producers of electricity to bid and sell services. This would entail a radical shift in market structures, the role of actors and involved technologies, and as such, it is likely that incumbent actors have diverging views on the model, and that new types of actors might push this development. In Norway, such models of energy sector "revolution" are promoted primarily by ICT actors. In 2015 a group of such actors joined forces with actors from the energy sector and sought funding for a centre of excellence from the Norwegian research council with the goal of "unlocking" this potential.[6]

The second model – termed *prosumer-to-grid models* – is more structured and involves prosumers linking up to local microgrids through brokerage systems. Parag and Sovacool point out that microgrids can be connected to a main grid, or that they can operate in an "island mode" (see fig. 1, models b and c). Connection to a main grid implies the possibility of selling to the grid, a potential incentive to produce as much as possible, while an "island mode" introduces many challenges of local optimization and balancing of the grid. While "island" in Parag and Sovacools instance is a metaphor, several potential cases in the MATCH project are located at actual islands, which we might hypothesize creates conditions favourable to "island mode" microgrids with a high penetration of local, small scale renewables.

The final model, an organized prosumer model, is a model where groups of prosumers organize in new ways to establish virtual power plants (fig. 1, model d). This is more organized than peer-to-peer models, but less so than prosumer-to-grid models. Parag and Sovacool foresee potential for such models in urban areas where local communities, neighbourhoods or organizations might collectively manage and pool their resources in new ways. This model poses interesting questions with respect to collective action and the management of common pool resources, where collective gains depend on individual decisions (e.g. Ostrom 1990, and Wolsink 2012 related to electricity).

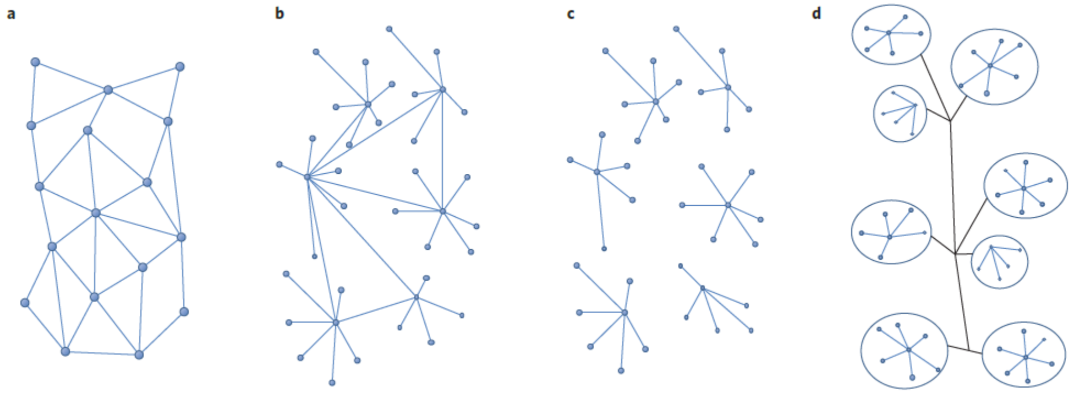

Figure 1 Potential structural attributes of prosumer markets. Parag & Sovacool 2016, p. 3

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[6] See: http://www.uis.no/research-and-phd-studies/research-areas/information-technology/energy-informatics/. The centre was not funded, but the research group pursues this agenda.

The introduction of micro generation and prosumption as a smart grid solution is highly interesting in the MATCH context as it has the potential to re-configure key parameters of how markets, actors and technologies interrelate in the energy system. Also for this reason, we will make it one of three key smart grid solutions to be studied in the project.

3.2.3 Integration of storage technologies

As the share of intermittent renewables increase, many energy systems are facing challenges of balance. Since wind and solar power production depends on the sun cycle and weather conditions, there is a question of how one should secure a reliable low-carbon base load or reserve capacity. One promising way of handling the issue is the installation of some sort of storage technology to decrease the dependence on fluctuating wind and sun. One option can be to install batteries in households, in the way that Tesla has proposed through its high profile Powerwall project.[7] In other sites, thermal storage is more likely to be implemented, or other kinds of building-to-grid technologies. Another type of storage that we might come across, particularly in the Norwegian case, is the aggregated use of batteries from electric vehicles (EVs). These can potentially play a dual role in future smart energy systems, because they on the one hand might generate new need for electricity production and increased power capacity, while on the other hand serve as a flexible load by ways of the batteries.

Introducing storage technologies could be a particularly promising strategy in contexts characterized by some sort of micro grid organization with a high penetration of intermittent renewables. As Wolsink (2012) wrote, with a specific focus on the potential of EVs:

> *"The flexibility in time-of-loading, inherent in the energy storage of a large electric vehicle fleet, offers opportunities to increase the feasibility of smart applications of renewable energy. Hence, options for reloading electric vehicles within the domain of microgrid community (e.g., at home) becomes a significant factor in advancing the deployment of renewable energy"* (p. 826)

Other storage technologies can play similar roles as a solution in reconfiguring the future smart energy system. Thus, storage integration will be one of the key MATCH solution focus areas.

3.3 From individual solutions to integrated hybrid configurations

As is emergent from the discussion above, the introduction of smart energy solutions entails reconfigurations of social and technical character. As a pragmatic choice, and to ease the burden both of writing and reading this report, the thematic description of the solution areas above has taken the introduction of new technology as a sort of starting point.

This, however, does not mean that we study technological solutions. As discussed in the section on theoretical considerations, our perspectives in different ways ask us to account for the social elements of any solution we study. This does not mean that we study how what many engineers would call "the human factor" are influencing technology performance. Rather, we are interested in the configuration of smart energy system solutions as a whole, meaning that we want to grasp the relationships between human and non-

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[7] see https://www.teslamotors.com/powerwall. There are, of course, many other actors working with batteries that we are more likely to come across in MATCH.

human actors in specific solution configurations or assemblages, and further, how these solutions interact with a broader contextual setting. Thus, we apply a symmetrical gaze, where neither humans nor technologies are privileged a priori. Their capacity to act, to do work, as well as the character and outcomes of this work needs to be accounted for on a case-to-case basis.

With this in mind, it should also be clear that we will seldom (though we might!) come across solutions that focus purely on one type of technology or one type of actor. One reason for this is that the world tends to be messier, and that any typology or classification implies some sort of reduction in complexity.

Another, more concrete reason can be found in the empirical field that we are interested in, which seems to have shifted away from a belief in individual solutions to more systems-oriented approaches. As an example, Norwegian policy makers had quite naïve ideas about what smart meters combined with feedback could achieve in terms of energy reduction and load shifting (Ballo 2015, Skjølsvold 2014). In the following years, however, studies of various individual solutions have provided sobering and somewhat disappointing results. As a response, many demonstration sites are now experimenting with much more hybrid, integrated solutions, where different components is expected to do different kinds of work. Arguably, we are currently seeing the exploration of second or even third[8] generation smart energy system solutions for small and medium consumers.

This would mean that a strict delineation of what we can study in MATCH based on the three categories of proposed solution areas would severely limit our possibilities both of being relevant and of producing meaningful, comprehensive analyses. It is the ambition of the MATCH project to move beyond individual solutions.

At this point it is difficult to practically say how a studied solution should be delineated, beyond stating that what the solutions consists of is an empirical question. As an example, it would make little sense to study exclusively a rooftop solar PV “solution”, if what is really installed is a combination of smart home technology, rooftop PV and battery capacity.

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[8] Solutions for prosumers involving batteries or EVs could be said to be the third generation.

4 Studying how solutions work

By now, we have a basic understanding of what we mean when we say “smart grids”. In fact, we have shifted our attention from the grid towards smart energy system solutions. We also have an idea of what we mean when we say that we want to study specific smart energy system “solutions”. In MATCH we will study smart energy solutions targeting small to medium customers. In the above we have discussed three types of solutions that we propose should form a sort of basis for the studies in the three countries. These are:

- Solutions aimed at changing demand side consumption patterns: Demand side management or Demand-response
- Micro generation
- Integration of storage

As discussed, this forms a relatively open-ended starting point for our studies, which also should allow us to study various combinations of integrated solutions and how they work. These will be compared in order to develop sound analysis of which kinds of solutions that are expected to work under which conditions, and further to formulate recommendations that feed into various discussions on how to best implement smart energy solutions. This section of the report will do two things. First, it will roughly outline the process of doing case studies, from research questions and selecting cases to writing up case study reports. In doing this, we will discuss some of the challenges we will come across. We will then proceed to discuss some analytical challenges related to comparatively assessing what it means that something works (see 4.7).

Issues to be discussed here include aspects such as how we define what it means that a smart energy solution “works”, how we move from cross-case comparative work to generalizations, and how we deal with issues such as “context”.

4.1 The research questions

As stated, the overall aim of MATCH is to study how complexities of factors influence the effectiveness of smart grid initiatives in order to contribute to better and more comprehensive smart grid (energy) solutions. More specifically, the case studies will analyse both the direct implications of smart energy solutions on the (everyday) practices of the users *as well as* how the solutions (and how they are used in practice) are integrated in a network of mutually dependent actors. The case studies will apply both analytical perspectives on the studied solutions, which are essentially closely related.

An example of the focus on the implications of the smart energy solutions for *social practices* could be, e.g., how the combined ownership of PVs and electric vehicles affects households’ (or other types of actors’) daily practices. For instance with regard to driving patterns, the timing of EV-charging or other electricity-consuming household practices etc.? In addition, an important question would be how this affects the energy consumption patterns of the users?

Similarly, an example of the focus on the *network* of the smart energy solutions could be how the PVs and electric vehicles are related to (dependent on), e.g., local actors (electricity suppliers, DSOs, the municipality etc.), national regulation of EVs, subscription schemes for prosumers, accessibility to local/national network of EV charging stations etc.

In carrying out the case studies, the earlier presented research questions (Section 2) will work as guidelines for the analysis.

4.2 Choosing cases

On a basic level, three case studies should be conducted in each country. These case studies should be examples of smart energy solutions, targeting small to medium consumers. These consumers could be ordinary households, but small-to-medium companies are also viable as users for our purpose. Smart energy solutions consist of a set of technologies, services, incentives, actor groups, users, practices, processes, meanings, etc. Thus, they are truly heterogeneous sociotechnical collectives. That said, the easiest point of entry, or the easiest way for the MATCH researchers to recognize them as new solutions, will most likely be through the identification of some sort of trial site where someone is engaged with testing new technology.

When such a trial (or trials) has been identified, the three solution focus areas give some pointers with respect to what to study. This means that a trial or a demonstration project might not necessarily be the same as a "solution", because it could in principle be testing dozens of solutions for different purposes. On the other hand, a smart energy demonstration project could easily be limited to the testing of one solution. Table 1 is a very simple matrix illustrating how three imagined cases might incorporate several different aspects from the proposed solution focus areas. If needed, such a matrix could be expanded and concretized in order to visualize and make comparisons between cases more tangible.

	DSM	Micro gen.	Storage
Case 1	x		
Case 2		x	x
Case 3	x	x	x

Table 1: Matrix illustrating different degrees of hybridity and integration in three imagined cases.

The three solution focus areas are broad enough to allow us to cover a broad range of the aspects of what is frequently discussed as "the smart grid", or the smart distributed energy system. It also allows us to look into both relatively mature types of solutions as well as less mature solutions and different types of experiments with integration of different solutions.

For the purpose of the MATCH project, it would be useful to choose cases where some experiences – positive or negative – have been gained from the solutions at hand. That said, there are likely lessons that can be learned also from projects that have been established more recently.

4.3 Doing case studies: some preliminary thoughts

Once cases have been identified, how do we study them? The focus of the project has originally emerged from engagement with the three-layer model as emphasized by the funding body for this project. This model proposes that there are basically three categories of elements involved in the development of the smart energy system. These are a) markets, b) actors and c) technologies.

As our discussion on potential solution focus areas indicate, it is quite clear that any smart energy solution entail some sort of re-configuration of these elements, and that a clear-cut differentiation between the three is not feasible. It will most likely be difficult at times to distinguish clearly between the categories. In the case of micro generation solutions, for example, small customers could potentially re-define market structures through the use of new technologies.

This brings some interesting questions for the MATCH consortium. In our proposal we have said that we want to study the relative "success" of such solutions. The very dynamic and shifting situation with respect to the smart energy system, however, suggests that a focus on success is too narrow. As an example, a solution could be a disaster for the business models of an incumbent industry actor, while at the same time being a raging success for a small consumer. In such a case – should we consider it as a success? Thus, we once again shift focus somewhat, and rather ask how the specific smart energy solutions work. This reflects our view on such solutions as hybrid collectives established by the relations between involved humans and technologies, and that what "works" is relational and contingent on the specific context of the solution. In practice, this means that it will also be useful to map how the solution in question works for different kinds of implicated actors.

However, while it is true, stating that "everything is complex" will not be very productive, at least not at this stage of the project. Hence, for the sake of making this report a more hands-on guide, let us begin with a brief and pragmatic discussion about what our key focus is when it comes to looking at the – admittedly simplistic – categories markets, actors and technologies.

4.4 Markets, actors, technologies

4.4.1 Markets

Market conditions are generally considered to be one of several framework conditions for smart energy solutions in the three countries. The countries have different taxation regimes, different market mechanisms for phasing in new renewables, different energy mixes, different levels of liberalization, integration with other countries, the EU, and most likely different public attitudes towards new regulations, new technologies, etc. Thus, one of the ways that we will incorporate markets in our studies is through doing a national study in each country. This study should be a descriptive and informative piece of text, which highlights the framework conditions in each country. This national study should be conducted before the actual empirical case study work begins (or in the very beginning of the case studies).

National study contents:

- A very brief description of the country.
- Information on current energy mix, and some broad historical lines on how this have developed over time.
- Information primarily on electricity use/consumption, and, if available, trends over time.

- A description of how the electricity system works together with/interacts with other parts of the energy system as well as some key statistics for the entire system.
- Information on the general state of the current electricity market – how is it regulated, how open is it, how does it relate to broader markets (EU, etc.),
- Information on general national policies, regulations, strategies for phasing in new renewables and/or other sustainable technologies (e.g. feed in tariffs, certificate schemes, subsidies, market liberalization, etc.)
- Information on specific policies, regulations, strategies, etc. targeting the development of the smart grid.
- Information on national smart grid initiatives, both research programmes and similar activities (players in the field, programmes, main projects, etc.) and industrial activities (networking activities, companies involved, etc.)

The production of the three national studies could provide interesting added value to our project. On the one hand, it opens for the possibility of doing some sort of comparative policy study. Further, we should also keep in mind that our empirical work on the smart energy solutions might shed new light on and create the need for elaborations on what we "know" about the three national energy contexts. Thus, while we should aim to have the documents on national context ready by the end of September 2016, we could consider keeping them "open" to be revisited at a later point in the project.

Related to the three case studies of smart energy solutions, MATCH researchers should also be sensitive to the business models built around the case solutions studied. What is done by whom in order to try to profit from the new solutions? What changes of the existing market rules would support the new solutions?

4.4.2 Actors

The key actors for MATCH are the small and medium consumers. Key questions to study are how they are involved and engaged in the smart energy solutions, and through this we should be able to give some recommendations on the potentials and limits to engagement. Typical modes of engagement could be as prosumers or as providers of "flexibility" when trying to balance the grid. We should also search for other (perhaps more innovative) ways that actors are engaged, e.g. through meetings, workshops, design exercises, empowerment mechanisms, etc.

However, actors are not only the small/medium customers. They could be the incumbent electricity generators, grid operators, ICT-companies, housing industry, heath care and welfare technology sector, entertainment industry, intermediaries of various types or others engaged in the development and testing of smart energy solutions. A key point here is that we should let the cases at hand direct us towards the actors. Who are involved, what are their roles, and what do they do? This also relates to matters such as organization of the solutions and the relationship between involved actors. Who formulates the solutions, and how do actors work to engage other types of actors in their proposed solutions? This could feed into related discussions about the ownership of various components in the "solution". As an example, Norwegian prosumers typically tend to purchase, and thus own, their PV panels, whereas similar solutions in other contexts have been based on home owners leasing PV panels, e.g. from DSOs.

For us, all of this might feed into discussions about what the organizational obstacles to making smart energy system solutions "work" are, and which modes of organization that helps. On a practical level, this can be operationalized by studying matters like rules, contracts, responsibilities and organizational practices, etc. We should also look for patterns of which actors are involved, as well as which roles different types of actors take on across cases and contexts.

4.4.3 Technology

Our discussion of the three proposed solution focus areas contains relatively rich descriptions of some of the potential technologies that we will come across in the MATCH-project. However, we are not studying technologies as such. Rather, our interest is how technologies work in interaction with people, households, organizations, markets, industry actors, "old" technologies, existing infrastructures, etc. Thus, technology is simply one of multiple elements that make up a "solution".

The gateways into studying technologies in a project like these are many. One potential way is through what we broadly can call technology development. It is quite likely that many of our studied solutions are parts of demonstration projects where such development is one of the goals. Technology development here should not be understood to be limited to the engineering exercises of producing new "gadgets", or to being limited to exercises of design. Instead, it could just as easily refer to combining existing technologies in new ways. An example could be technologies coming from different industrial realms, merging in the smart energy context. Combination of ideas about welfare technology with ideas from smart energy systems and the ICT-realm could be an example of this, combinations that in the past have resulted in the emergence of new and increased focus on matters like universal design and usability (Skjølsvold and Ryghaug 2015).

Thus, for us the technologies are not only interesting as carriers of certain technical qualities that can somehow be realized, e.g. through achieving "social acceptance" of the new technologies. Rather, the technologies are elements of any solution that comes with a set of expectations (including wider societal implications) with respect to future use, as well as with respect to the competences, and abilities of future users. The technologies stand in relation to other technologies, to users, to technology developers, policy maker, etc., and it is in relation to other actors that we might be able to say whether a technology "works" as part of a solution. A novelty in the MATCH project compared to many other projects on the smart grid and smart energy systems is that we will not only conduct studies of this type for individual technologies, but for integrated hybrid solutions, or solutions that in a much broader sense allows for discussions about what it might entail to upscale and disseminate solutions profoundly.

4.5 Doing case studies: a proposed five-step plan

In order to account for the market aspects, actors and technologies of each selected case (smart grid solution), we propose a five-step plan for the case studies at hand, which should ensure that all cases include a common basis of elements, which will enable the cross-case comparative analysis. This will cater for the production of descriptive case study reports from the countries, where we should strive to provide relatively descriptive accounts of the solutions.

The proposed procedure should not be read as a straight jacket, and where it is needed, the case studies should absolutely be tailored and adopted to the local conditions. It is an attempt to anticipate what we might come across and what might be expected, but as such it is also filled with the preconceived ideas of the authors, which might not correspond well to what we actually come across in the field. Another way to think of it is as a sort of baseline, which should ensure comparability.

In addition, the individual research partners might have individual research interests that they want to pursue, which is not covered in the following procedure. It should be stressed that this would provide obvious added value to the project and that it is encouraged.

With all these reservations in mind, the following has been written with the purpose of helping to generate a rich, comparable narrative for all cases, which can subsequently be analysed in different ways by different members of the consortium. The five steps are as follows:

4.5.1 Context

To add contextual depth from the national study, we should begin by mapping and describing relevant insights into the local context of the studied smart grid solution. This includes:

- Local/regional energy system characteristics (energy mix, status of the grid in the area, etc.)
- If applicable: a brief description of the broader demonstration project that the particular solution is a part of.
- Historical actor-constellations in the local energy system. E.g., ownership structures: cooperative, centralized, municipal, commercial, etc.

In most instances, this local insight can be obtained through desktop exercises. If necessary, local research teams can supplement with interviews, etc. as they see fit.

4.5.2 History

We should also have a brief "history" of the solution at hand. What was the original idea behind it? Who was involved in developing the idea, and what was their rationale? For how long has the solution it been tested? What has been learned so far – from the perspective of those testing the solution?

Has the solution been researched in relevant ways in the past, and if so – are there available results from such studies that might be relevant to the MATCH project? Questions concerning the history of the solution are important to gain insights into the visions and expectations of actors behind the solutions, and to gain a sense of the dynamics involved as smart grid solutions change over time. In many instances, this exercise can be done as a desktop exercise, supplemented with interviews of actors involved in the project start-up if needed.

4.5.3 Map

Once we have an overview of the context and the history of the solution, we can begin mapping the current state of the smart grid solution, its actor and technology constellations. This includes details on infra-technological relationships, e.g. on how the solution at hand have been involved with existing energy systems, technologies and actors.

- Who are the actors involved, and what are their goals/rationales?
- How do these actors interpret what it means that such a solution "works", or that they are successful?
- What are the technologies involved, including existing energy system infrastructures?
- What small scale/medium sized consumers are involved?
- What is expected from them in the project?

- How are they recruited – what incentives are they given to participate?
- How are the involved elements configured?

On one level, this mapping exercise can be considered purely descriptive. However, once we begin to understand how users were recruited and on which conditions they were recruited[9], the levels of technology subsidy funding, or other ways that technological solutions might be "shielded" from ordinary technology selection criteria in such trials, we can also begin to think about the relationship between the "trial conditions" and "real world conditions". At this stage, interviews with implicated actors are needed.

4.5.4 Experience

Based on these three steps, we should have a good understanding of the smart grid solutions, and we should be ready to study how the small/medium consumers act and interact with the technologies, incentives, organizations, etc. introduced as part of the smart grid solution. Given the largely qualitative character of the work, and the likelihood that cases will differ substantially, it is difficult to standardize this exercise too much. However, some pointers can be given:

- We should seek out small/medium consumers using the solutions with the goal of identifying their experiences (e.g. "negative" or "positive") with the technology. This should both include the users' own *interpretations* of their experiences (e.g. how the solutions have affected their everyday lives, etc.), but should also include descriptions of how practices are changed (if so).
- We should interview a broad sample of users and intermediaries, reflecting to the extent that this is possible the diversity of users involved in the smart grid solution trial. Thus, we should avoid the trap of interviewing only "Resource men" (Strengers 2013), but rather aim to include as many as possible of the actors that make up everyday-life (or work-life) situations for the users involved.
- We should probe for rich stories concerning technology use and related practices, patterns of use, how technologies have been integrated in everyday lives (or work life for SMEs), difficulties, understandings and interpretations of technologies etc.

The methods used will, as said, primarily be qualitative (interviews, observations, focus groups etc.), but might also, if relevant and possible, include some statistical data of existing data (for instance in order to analyse the energy implications of the studied solutions for the energy consumption patterns).

4.5.5 Product

Finally, we are ready to write up case study reports. To facilitate the cross-country and cross-case analysis, these should describe the cases, the actors involved, relevant market dynamics and technologies, implications for the practices of the users etc. They should also aim to provide as clear narratives as possible concerning how the studied solution works, and for whom it works.

Following the discussions in this report, this assessment needs some extra considerations. It is clear that something can work in multiple ways, and that it can work in different ways for different actors. It is also clear that what works for one set of actors, might

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[9] For instance: Did they invest in technologies, or did they lease/borrow them? Are they volunteers, or are everyone in a geographical location users? Are there other incentives for participating? Etc.

do the opposite for others. This also feeds into discussions about the relationship between the individual cases that we study and the wider energy systems and contexts that they are part of. The case study reports could be a good place to begin a preliminary analysis of such matters. This can be done in a two-step way, following the rich case description.

1) An evaluation of the case solution in hand. What was its core strengths and weaknesses? Why does it appear to work in the way that it does, or why does it not appear to work as intended? This step should include reflections on unintended consequences and wider implications of the introduction of the solution.
2) A first attempt at briefly exploring the consequences of upscaling the solution at hand. This would imply some sort of speculative scenario writing, where researchers contemplate potential consequences and pathways based on the information and knowledge available to them.

In the end, this will provide us with at least nine case study reports, three from each country. These will form the basis for the following comparative analytical work and should provide a rich and inspiring source to work further on.

4.6 A brief note on energy system models and scenarios

In addition to the qualitatively oriented work discussed above, MATCH will produce some energy system models and scenarios that might help producing narratives about the effects of certain types of solutions. It is currently somewhat unclear what types of data we need to be able to produce relevant model simulations. When and if such data are available, however, we should try to collect the following:

- Data on economics: the costs of installations and operation
- Data on how the solution in question influence the households power consumption. In practical terms this would be data indicating changes (or non-change) in load profiles for participant households.
- Data on savings per household (e.g. Kilowatt-hours per year per household)

As the case studies start, we should have an open dialogue within the consortium on the status of these issues, on what we need and what we can achieve through these and similar data collection exercises.

4.7 What does it mean that a solution “works”

A key outcome of the MATCH-project should be an increased knowledge about what smart energy solutions work under which circumstances. Thus, we should evaluate existing cases, and we should to a certain degree be able to harvest wider and applicable lessons from these evaluations. As the discussions throughout this report have indicated, this raises the question: what do we mean, when we say that something works? If we return to the earlier discussed peer-to-peer model of prosumer markets, it is clear that something like this could be said to work well for consumers, who in new ways become empowered and through this take control over the system in new ways. For incumbent actors, however, this would not necessarily constitute a success, because it undermines their business model and operation.

Thus, a “working solution” can be many things. Towards the end of this report we therefore find it fruitful to present a brief discussion of how to deal with the issue at later stages in the project. This section is mainly intended for reflection.

4.7.1 It works when the project goals are realized

MATCH is a project where researchers collaborate closely with industry/market actors. Several of these partners are owners of demonstration sites experimenting with the kinds of solutions that we aim to explore. For this reason, it might be argued that we should pay particular attention to what it would mean that a solution works for these actors.

One way to measure this is simply to look at the goals of the solution case in question, and to measure the performance of the trial in relation to this. E.g., some “solutions” might be implemented to “unlock” flexibility, or to reduce electricity demand. If data will be available, it would be relatively simple to determine if it works or not. If (sufficient) time shifting or electricity reduction has been achieved – it works. Thus, this way of identifying working solutions looks at performance output indicators before and after the trial started, and links this to the stated goal. The added value from MATCH compared to a more standard technical project would be to highlight that output in such instances is a result of the way that the socio-technical solution is configured, or the way that practices and elements of practices are bundled in the particular instance.

Through our interviews and studies of implicated actors we can get a sense of why and how the particular solution works for the particular actor groups, and through this be able to paint a richer picture of why the particular solution works to realize the industry actor goals. A concrete way to operationalize this in our studies would be to map the links between the expectations of the actors as they ventured into the smart energy system solution, and compare this to their actual experiences.

As an example, a study from Norway have indicated that when small consumers expect to save a lot of money, they have to re-interpret their participation in smart energy system trials, when they learn that they do not. For some small to medium consumers, this might lead to alienation from smart energy technologies as such, which leads to practices that do not cater for reaching the goals of the project operators. Other customers, however, are very happy to be part of a project where they mainly learn how cheap it is to spend electricity. This allows them to raise comfort levels. For such consumers, the solution has arguably “worked” in some way, in the sense that it resulted both in learning and the establishment of new practices, but obviously not for the benefit of the grid and the system in the way that the project owners would like.

4.7.2 Broadening the definition of a working solution

This indicates that it is probably wise to have a broader definition of what it could mean that a solution “works”, when we do our analysis. Through our mapping exercises we gain insights into the rationales and goals of many actors, and we will most likely also gain much knowledge about their experiences. Further, we will learn much about how the cases in question relate to their contexts, and the ways that external actors work to influence the solution in question. For instance, are there shielding mechanisms involved, such as subsidies, or other schemes meant to influence either the technology choices made or the usage patterns of these technologies?

A key point for us is that we are aware that solutions might have different implications for different implicated actor groups. If we take the users as an example, these might be a very diverse group. Single men, elderly couples and families with children might have very different ways of relating to energy, managing everyday lives and integrating new solutions into existing practices.

The realization that different actor groups might have different understandings, goals, aspirations and expectations does of course complicate things. However, for the MATCH consortium, it is arguably the strength that might give our recommendations more thrust than it would otherwise have.

This might also allow us to give advice with differing degrees of strength. The identification of a solution that is working, both in the sense that it fulfils the goals of the experimenters, and is integrated nicely into the everyday lives of various user groups, as well as works for other implicated actors, most likely indicate a relatively robust solution, with significant transfer value to other sites. Should the solution only work for some actors, however (e.g. grid operators and resource men), but leave other user groups (families, the elderly, teens, students, etc.) alienated or discouraged, this opens for recommendations on how to improve the performance. Table 2 is a crude idea for how we could begin to think about operationalizing this on a case-by-case basis. This rough sketch will have to be adopted to the situation for each specific case, and it is not certain that we actually end up using it in the end.

	Expectations			Experiences		
	Micro gen	DSM/DR	Storage	Micro gen	DSM/DR	Storage
Families w/childeren						
Single men						
Single woman						
Elderly						
Small company						
ICT company						
Construction company						
Energy producer						
PV supplier						
Description of solution «shielding mechanisms»:						

With nine case studies, it is likely that the degree of success for different implicated actors will differ across cases, and hopefully some patterns will emerge that we can exploit for the development of success criteria later in the MATCH-project.

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Case study report Austria

Findings from case studies of Model Village Köstendorf, HiT Housing Project and VLOTTE

Version 1.0

Michael Ornetzeder, Tanja Sinozic, Alicia Gutting, Steffen Bettin
Institute of Technology Assessment

23 November 2017

ERA-Net Smart Grids Plus | From local trials towards a European Knowledge Community

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About ERA-Net Smart Grids Plus

ERA-Net Smart Grids Plus is an initiative of 21 European countries and regions. The vision for Smart Grids in Europe is to create an electric power system that integrates renewable energies and enables flexible consumer and production technologies. This can help to shape an electricity grid with a high security of supply, coupled with low greenhouse gas emissions, at an affordable price. Our aim is to support the development of the technologies, market designs and customer adoptions that are necessary to reach this goal. The initiative is providing a hub for the collaboration of European member-states. It supports the coordination of funding partners, enabling joint funding of RDD projects. Beyond that ERA-Net SG+ builds up a knowledge community, involving key demo projects and experts from all over Europe, to organise the learning between projects and programs from the local level up to the European level.

www.eranet-smartgridsplus.eu

Preface

This report is the outcome of work package 2 *Detailed case studies* of the ERA-Net Smart Grids Plus project *Markets, Actors and Technologies: A comparative study of smart grid solutions* (MATCH), which involves partners from Austria, Norway and Denmark.

The aim of MATCH is to explore how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. This is studied on basis of detailed national case studies carried out in each of the three participating countries. This report (MATCH deliverable D2.1) presents the main findings from the Austrian case studies.

The national case studies establish the empirical foundation for the comparative analysis across cases and countries in work package 3 *Identifying determining factors for integrated and successful smart grid solutions* and for the later work package 5 *Recommendations for designers, planners and policy-makers*. The deliverables from these work packages will be published on the website of MATCH (http://www.match-project.eu/), which also includes further information about the project and its other publications. The latter includes coming scientific papers that are going to explore differences and similarities between cases in further detail in relation to specific research questions.

The empirical work in relation to the national case studies was guided by an analytical framework developed in the MATCH work package 1 *Design of overall analytical framework for case studies*. This deliverable (D1) can be downloaded from the MATCH website. The framework combined different theoretical perspectives in order to establish a shared understanding of how we should approach the cases and what kind of data to collect. This ensured a certain degree of empirical homogeneity between the national case studies.

In order to support the comparative analysis, the national case study reports (D2.1-D2.3) follow the same outline. Thus, in the following, we will first present the national context of the Austrian case studies (Chapter 1). This includes a brief introduction to the national profile of Austria in addition to a presentation of the Austrian energy system, policies & regulation, market structure & energy consumption and, finally, the smart grid landscape. Then follows the main part of the report (Chapter 2), which presents the outcome of the Austrian case studies. A brief description of the empirical work carried out introduces this chapter, and is followed by three sub-sections presenting the findings from the three national cases: Model Village Köstendorf (section 2.1), HiT Housing Project (section 2.2) and VLOTTE (section 2.3). Each of these case presentations is organised in three sub-sections: Background and project characteristics; Socio-technical configurations; Discussion of successes and outcomes.

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Vienna, 17th of November 2017

1 National Case Study Context: Austria

1.1 Country Profile of Austria

The Republic of Austria has a population of 8.77 million and an area of 83.879 km^2. It borders on Germany and the Czech Republic to the north, Switzerland and Liechtenstein to the west, Italy and Slovenia to the south, and Hungary and Slovakia to the east. Almost two-thirds of Austria's territory is mountainous with the Alps reaching its highest point with 3.798 m over sea level. The east of the country has lower lying plains of the Danube valley. 45 % of Austria is covered by forests (IEA 2014). Moreover, arable land amounts to around 16.1 % of the Austrian territory (Statistik Austria 2017).

Two climate regions are found in Austria. The eastern part shows hereby a Pannonian climate that is typical for Central Europe and consists of warm summers and cold winters. The west in the central Alpine region shows a typical alpine weather with more precipitation in summer and heavy snowfall during long winters (Ministry of Foreign Affairs 2017). Due to the topography, the temperature range is immense: highest measured temperature for 2016 are with 36.0 °C in Krems in July and lowest measured temperature was obtained with -28.2 °C in Tyrol in 3.437 m altitude and with -23.4 °C (1.442 m) in an inhabited area in Vorarlberg. Daylight ranges from 8.5 hours in winter up to 16 hours during summer (ZAMG 2017).

Austria's population is rising in the last decades up to 8.77 million inhabitants in January 2017. Of these inhabitants were 1.3 million without Austrian citizenship. While the strong population growth amid the 20th century resulted from baby boom, the latest increase in population is mainly due to immigration since the fall of the Iron Curtain around 1990. However, the birth surplus over deaths remains slightly positive. While all federal *Länder* experience population increase, those with larger cities (Vienna, Graz, Linz, Salzburg, and Bregenz) experienced a steeper increase than the others, again, due to net migration (Statistik Austria 2017).

In 2016, the average Austrian household consists of 2.22 persons and witnesses a trend to smaller households with single households having a share of 16.6 % of the population, while the majority (61 %) still resides in family households. In rented dwellings live 42 % of households. Ownership of these rented out dwellings was 18 % communal flats, 39 % were let by co-operatives and non-profit organizations, and the rest by private owners. Less than half of all Austrian households own the dwelling they live in (Statistik Austria 2017).

According to Esping-Andersen (1990), the Austrian welfare system can be classified as following the conservative-corporatist model. The system of social security in the Austrian welfare state consists of central elements such as the social insurance benefit issued by the federal government, while regional entities such as the Länder, and local municipalities organize healthcare, housing and most of the social services such as childcare (Social Affairs Ministry 2016).

In the Federal Republic of Austria, the nine *Bundesländer* (provinces) play an important role in designing and implementing energy policy. Their governments have responsibility for policy making, setting subsidy levels and implementing regulatory control of energy companies. Central to the Austrian opinion-forming and law-making processes are the "social partners" from labor and employer side. The labor stakeholders are the Austrian Chamber of Labour and the Austrian Trade Union Federation, while the employer stakeholders are represented through the Economic Chamber, the Chamber of Agriculture, and the Austrian Federation of Industry (IEA 2014, Social Affairs Ministry 2016). As in any EU member state, Austria's energy policy is heavily influenced by EU regulations. Crucial and important EU legislation on energy issues are the Energy and Climate package, with its 20-20-20 goals, and the Third Package for the Internal Energy market. Further central EU-directives are on energy services and end-use efficiency, on the energy performance of buildings, on the ecodesign of energy-related products, and on the regulation on security of natural gas supply. These directives found their way into Austrian law as, the Climate Protection Law (2011), the Buildings Initiative (2010), the Electricity Act (2010), and the Gas Act (2011) (IEA 2014, Austrian Environmental Agency 2016).

Austria has an open and relatively robust economy. Its gross domestic product (GDP) grew by 1.6 % in 2015 and by 2.3 % in 2016 in nominal terms, reaching EUR 350 billion in 2016. GDP per person is relatively high, at EUR 39.970 in 2016. The unemployment rate according to the ILO concept at 6 % in 2016, has been the highest for Austria since 1995. As in all developed economies, services are the largest sector, accounting for 70.4 % of GDP in 2016. Industry accounted for 28.3 % and the primary sector (agriculture, forestry and mining) for 1.3 %. In industry, the largest subsectors by turnover are machinery, basic metals, foodstuffs and chemicals (IEA 2014, Statistik Austria 2017).

1.2 The Austrian Energy System

The Austrian power transmission network (Figure 1) has a grid-length over 6.970 km and is composed of the three different voltage levels 110 kV, 220 kV, and 380 kV. Hereby, the extra high voltage level (380 kV) is used as a standard for transporting high transmission load over long distances. Transformation of high to lower voltage levels to supply households happens in over 58 switching stations with close proximity to residential and industrial areas. The high-power grid covers all of Austria and is divided into two operating regions North & West and South & East (APG 2017).

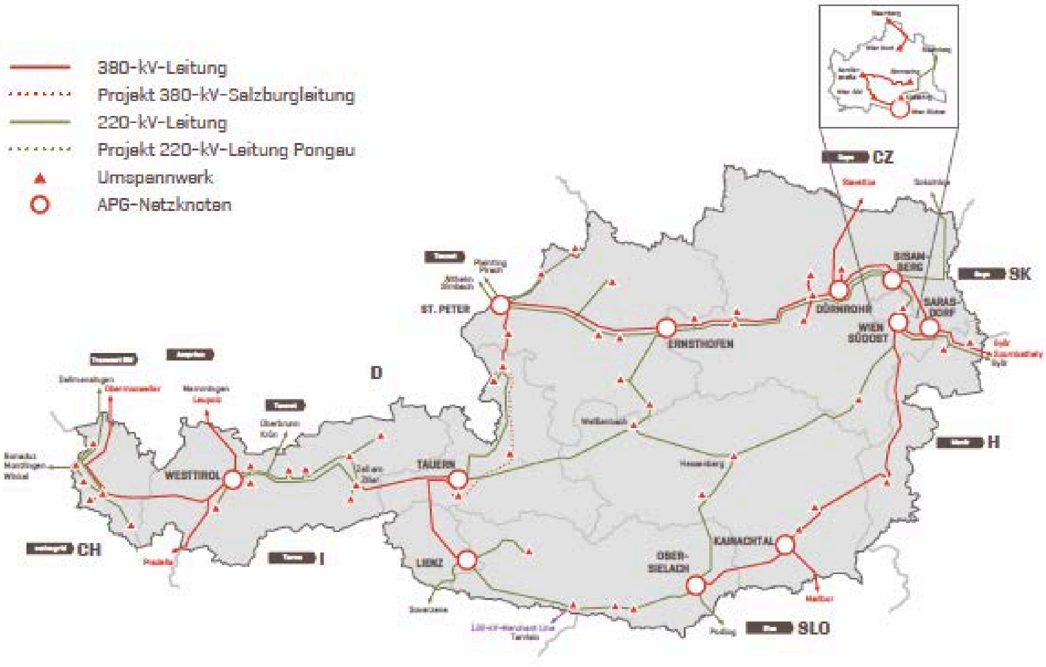

Figure 1: Austrian electricity grid of 380kV (red) and 220kV (green) (E-Control retrieved 22 June 2017)

Austria, through its central continental position, is deeply integrated in the emerging European electricity grids with AC interconnection to the Czech Republic, Hungary, Italy, Slovenia, and Switzerland. Congestion management is necessary between all these countries. This is organized through implicit auctions according to the European day ahead market couplings in the Austria-Italy border and through explicit auctions for the other border grids. Slovakia is the only neighboring country without any direct grid connection to Austria. Now, Germany and Austria form one price zone and both enjoy grid connections that do not require congestion management as capacity is sufficient (E-Control 2016b). However, congestion management of 4.900 MWh will be re-introduced that will likely lead to a small increase in Austrian electricity prices, but will be gradually increased to 7.000 MWh. Further, Austrian thermal power plants will provide from autumn 2017 onwards 1 GW of production capacity to German TSOs (E-Control 2017, Bundesnetzagentur 2017, WKO 2017). Thus, while the re-introduction of congestion management is a step back for market integration, the announced measurements between Germany and Austria can be judged as small dents in the process to full integration.

Austria is part of the Central Eastern Europe (CEE) region with Czech Republic, Germany, Hungary, Slovakia and Slovenia where Austria’s energy regulator (E-Control) assumes the role of lead regulator. Further, Austria participates as an observer country in the Central Southern Europe (CSE) region with France, Germany, Italy Greece, and Slovenia where day-ahead market coupling was introduced at almost all Italian borders in 2015. Through its current strong interconnection with the German market through the single price zone Austria is also linked through the Central Western Europe (CWE) region of Belgium, France, Luxembourg, and the Netherlands (E-Control 2017).

According to the World Economic Forum, Austria has a very high energy security and is accredited with having a quite reliable electric system (WEF 2014) (WEF retrieved 2017-june-22). Outages and disturbances in the Austrian grid remain minimal. In 2015, the Austrian grid had an average outage for every customer served (SAIDI) of 42.31 minutes, which shows high reliability (E-Control 2016a).

By 2014, renewable energy (wind power, biomass and renewable waste, solar power, and hydro power) had a share of 82 % of the Austrian electricity while other waste incineration made 1 % and fossil fuels 17 %. Figure 2 shows how the distribution of the electricity production by energy sources developed from 1994 to 2014. This development shows the historic importance of hydro power for the Austrian electricity production and the slight increase of biomass use and wind power while decreasing use of solid fuels such as coal and of gas.

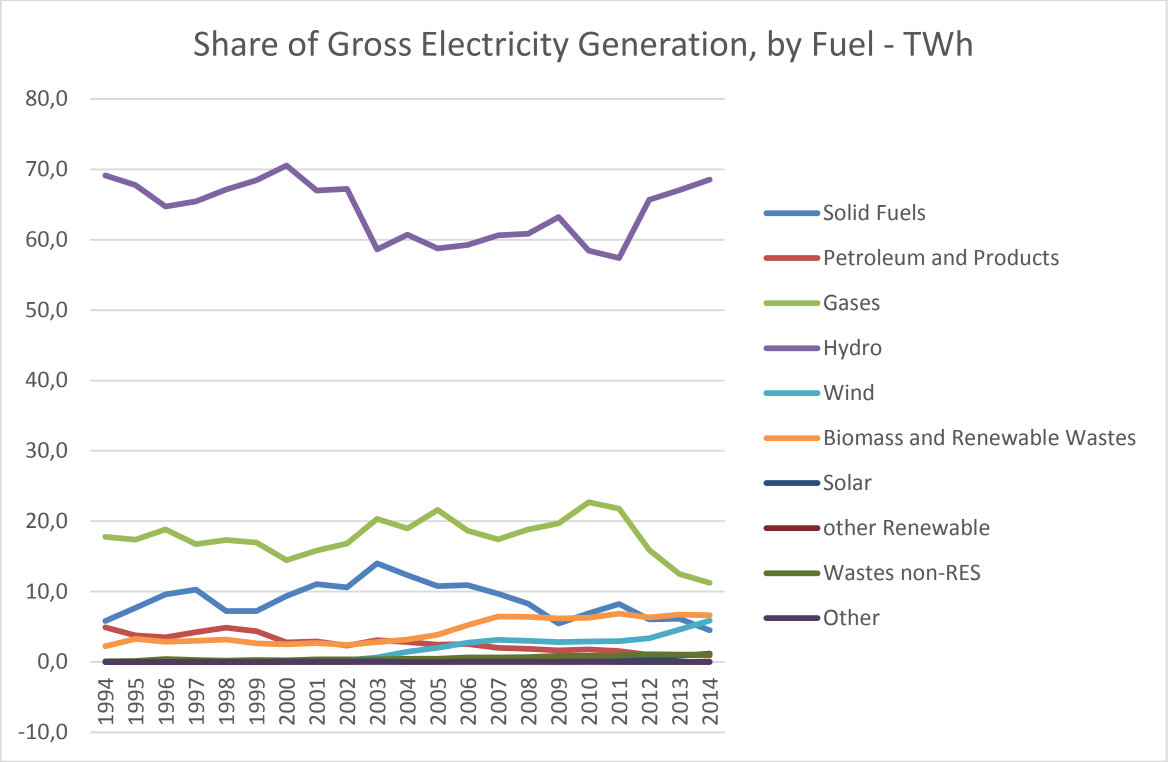

Figure 2: Share of gross electricity generation in Austria (Source: EU Commission, DG ENERGY, Unit A4)

The strong share of hydro power for Austrian electricity generation must be taken with care since hydro power in pumped hydro energy storage (PHES) facilities includes partially hidden non-renewable sources in energy accounting. Electricity imports from nuclear and fossil fuels heavy energy mixes (e.g. Germany) will end up being transformed into renewable hydro power. However, since 2015 according to the Austrian regulatory agency, energy of unknown origin (grey energy) is impossible to deliver anymore and subsequently no nuclear energy was permissioned to enter the system (E-Control 2017).

In 2016, around 62 % of households have central and floor heating. The second largest share with around 28 % received district heating as main form of heating. Other forms of heating such as electric heating (4 %) play a minor role for Austrian households. Regarding the source of heat generation, the largest share in 2014 has with 36 PJ renewable energies, which entail almost exclusively the use of biomass. While firewood consumption has remained relatively constant since the 1980s modern biofuels (wood chips, sawmill by-products, pellets, etc.) experienced a steep increase especially in the last ten years. The second largest source of heat generation are gases with 31 PJ in 2014 (Figure 3). The most important driver of the increase in natural gas consumption is the industrial sector. On average, industrial energy consumption rose by 2 % per year between 1995 and 2014 (BMWFW 2016b).

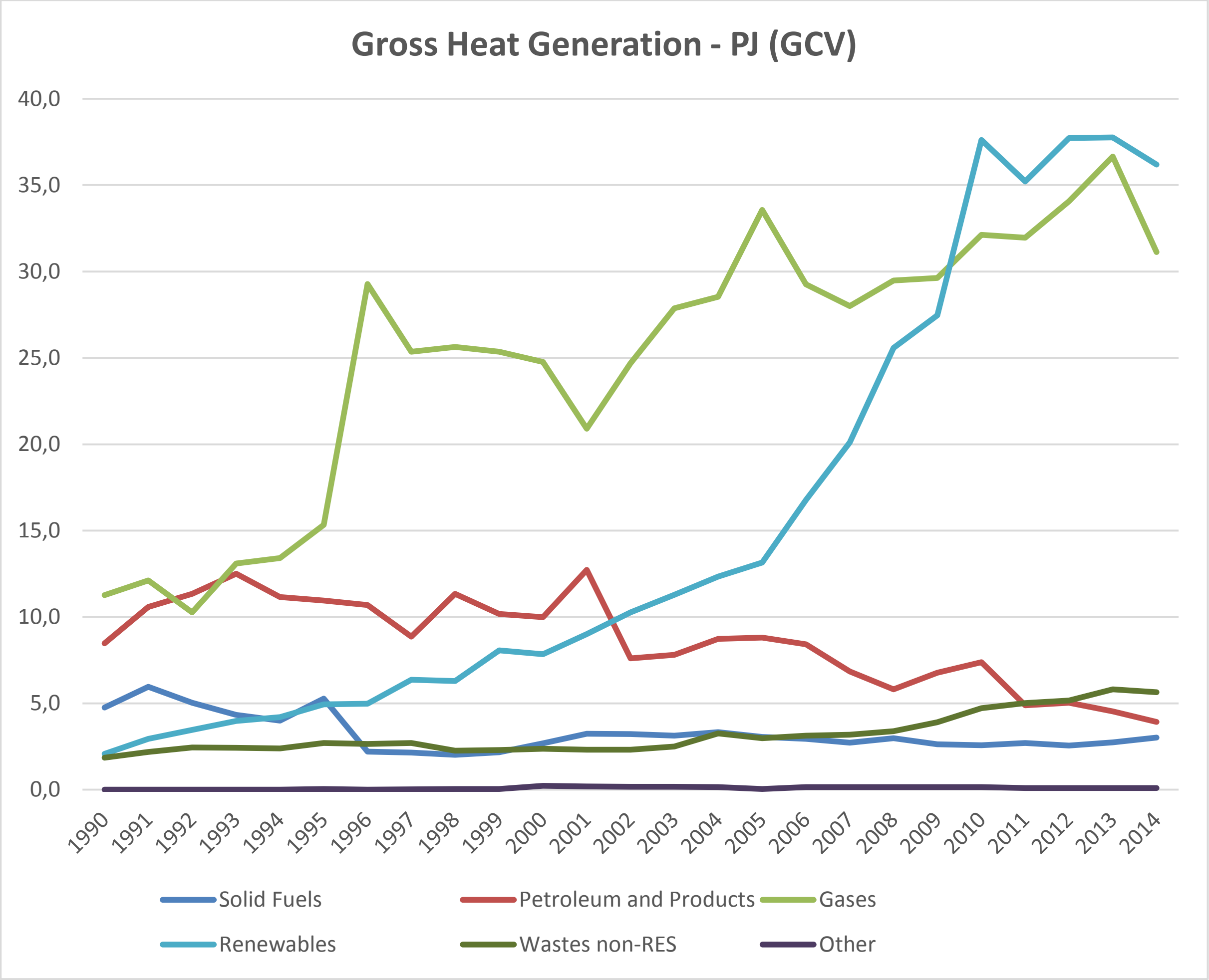

Figure 3: Gross heat generation in Austria (Source: EU Commission, DG ENERGY, Unit A4)

In 2016, with newly registered 3.826 battery electric vehicles (BEV) and 1.237 plug-in hybrid vehicles (PHEV) Austria saw a stark increase in the use of personal electric vehicles and had the highest share of newly registered vehicles in the European Union (VCO 2017). The overall market penetration in 2016 had a share of 1.54 % (EAFO 2017). Within Austria, the *Bundesland* of Vorarlberg, which is in the west next to neighboring Liechtenstein, Switzerland, and Germany, showed the highest share of newly registered electric vehicles. This was also achieved through incentives to municipalities to procure electric vehicles (VCO 2017).

Austria's overall gross energy consumption is significantly higher than its production as Figure 4 illustrates. Thus, Austria is highly import dependent. The largest share of import stems from different forms of fossil fuels such as coal, gas, and petroleum products (Figure 5). These products are alien to Austria (Figures 5 and 6), but nonetheless essential for its current functioning as an import dependency of around 100 % for hard coal, 92 % for petroleum, and 97 % for gases shows (DG Energy 2017). However, the last coal fire plant is announced to be shut down in 2025 (Environment Agency Austria 2016).

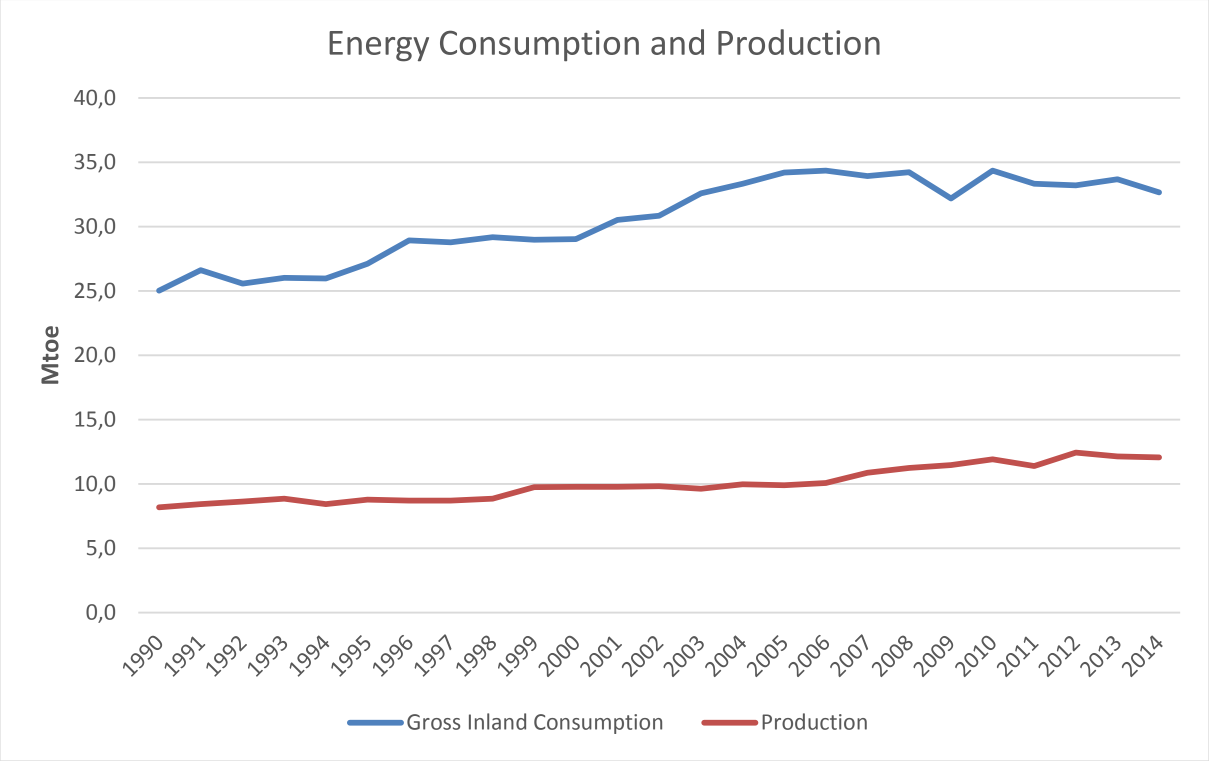

Figure 4: Energy consumption and production in Austria (Source: EU Commission, DG ENERGY, Unit A4)

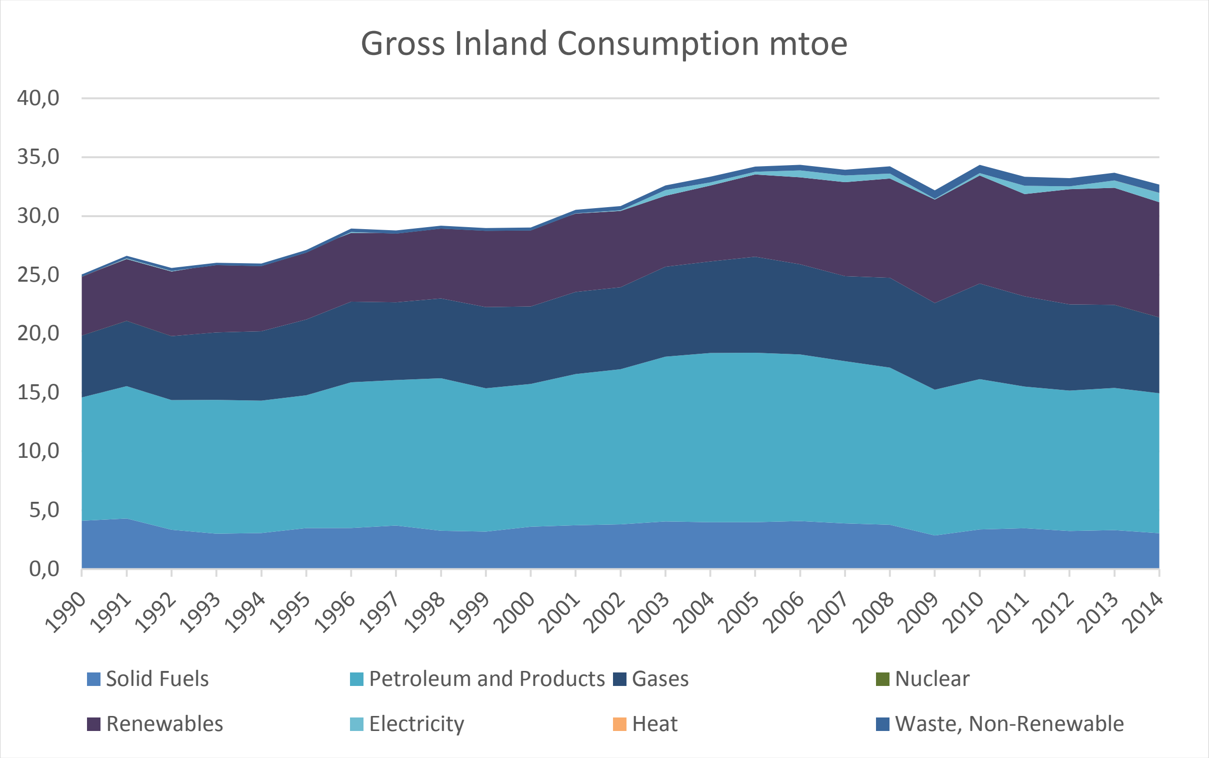

Figure 5: Gross inland consumption in Austria (Source: EU Commission, DG ENERGY, Unit A4

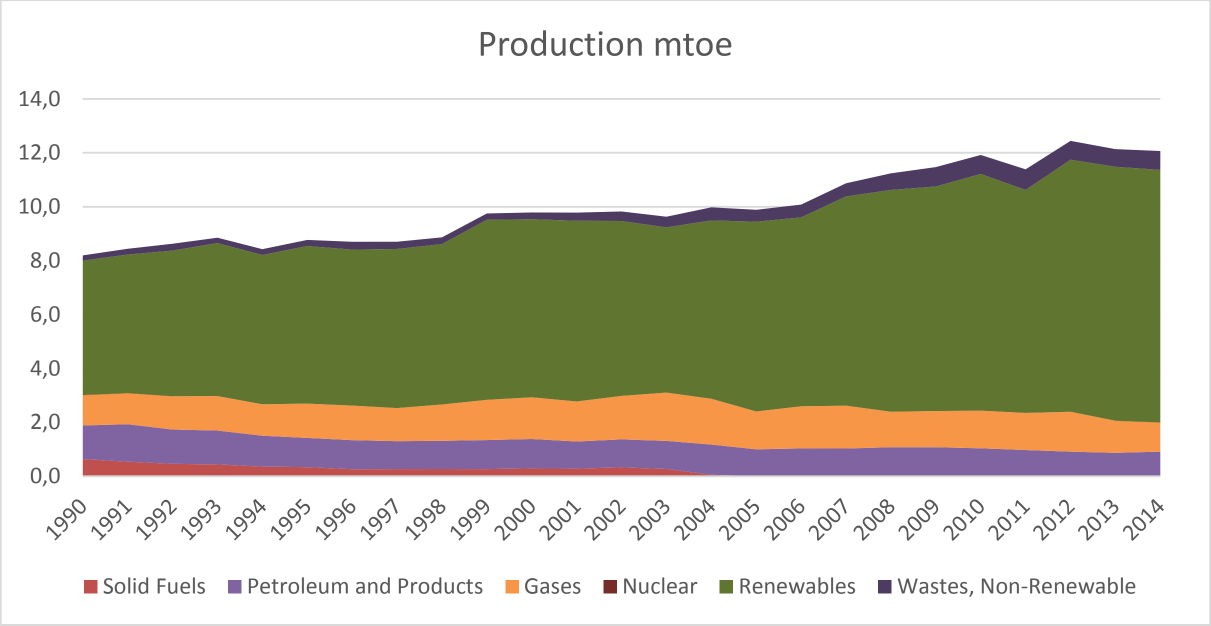

Figure 6: Inland production in Austria (Source: EU Commission, DG ENERGY, Unit A4)

The production and consumption of the renewable energy hydro power and biomass and renewable waste has always been considerable large, and saw a slight increase over the years (Figure 7). Renewables such as solar and wind power saw a dramatic increase particularly in the last 15 years, while their overall importance to the energy systems remains currently low.

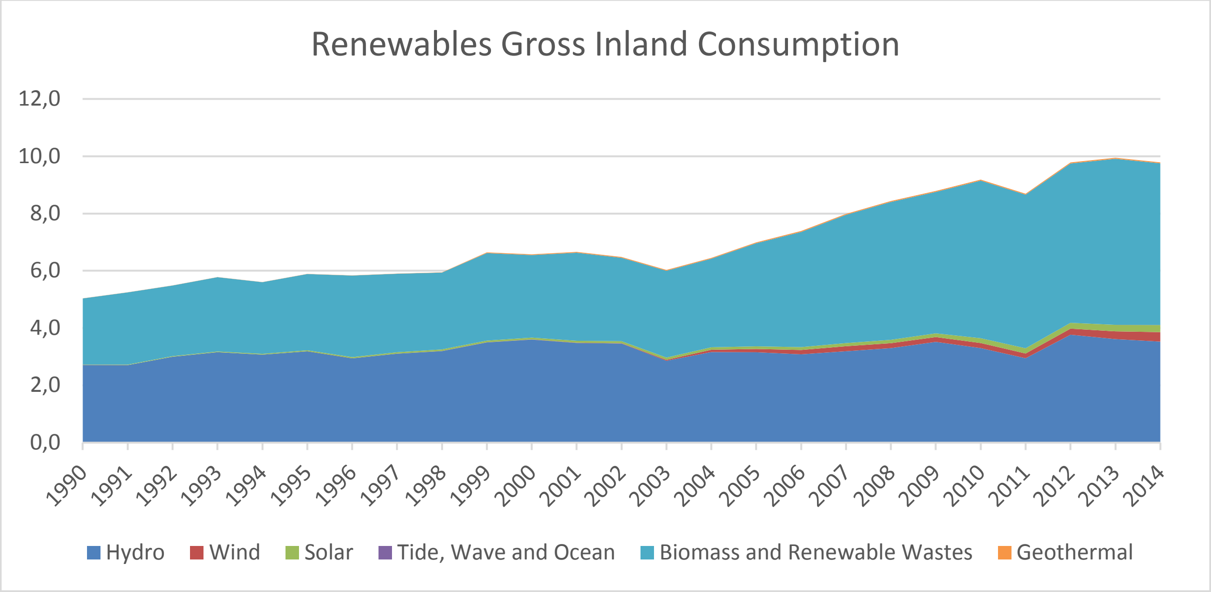

Figure 7: Renewables gross inland consumption in Austria (Source: EU Commission, DG ENERGY, Unit A4

In 2013, the Austrian production based CO_2 emissions per capita were 7.4 tons/year and range in the middle of Norway (11.7 tons/year) and Denmark (6.7 tons/year). Biggest contributors are the sectors energy, industry, transportation, agriculture, and buildings (BMWFW 2016).

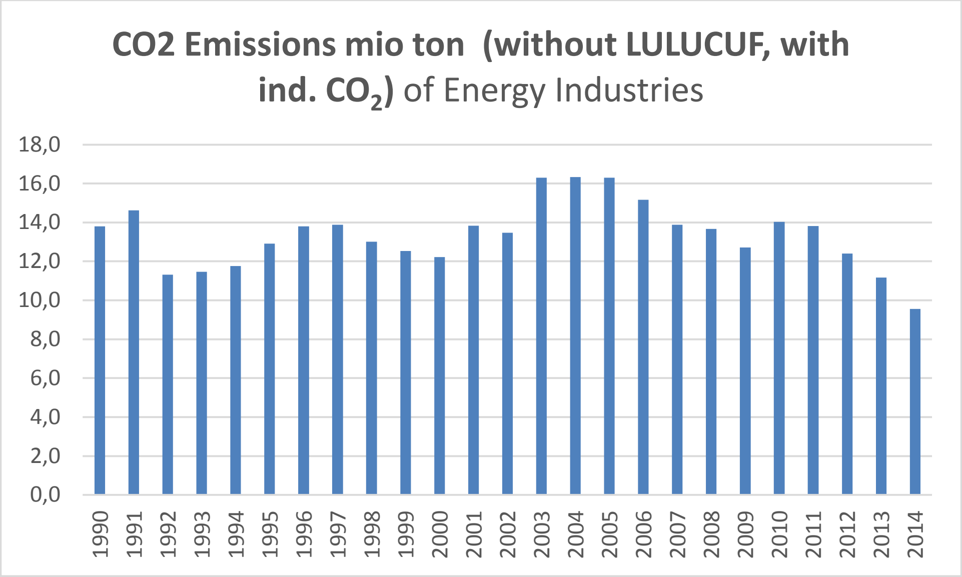

Figure 8: CO2 emissions of energy industries in Austria (Source: EU Commission, DG ENERGY, Unit A4

CO_2 emissions of the Austrian energy industry saw a slow but steady decline since 2005 from 16.3 million tons to 9.6 million tons in 2014 with a clear dent in the trend during the financial crisis (Figure 8). This trend can be explained with the continuous substitution of coal with natural gas and fossil fuels with renewable forms of energy (BMWFW 2016).

According to the *Climate Change Performance Index 2017*, prepared by the German NGO *Germanwatch* and the European *Climate Action Network Europe*, which is an index that evaluates and compares the climate protection performance of countries, Austria ranks as number 41, in comparison to Denmark 13 and Norway 38 (Germanwatch 2016).

1.3 Policy and Regulation of the Energy Market

Austria's long term energy policy goal is to solely rely on renewable energies by 2050. The Austrian energy strategy that was established in 2009 based on EU's 2020 process and submitted to the Commission in 2010 rests on three substantial pillars: security of supply, energy efficiency and renewable energy resources (IEA 2014, BMWFW 2010). Energy efficiency includes a fixed target of 1.100 PJ of final energy consumption in 2020 – this target corresponds approximately to the value of the base year 2005 (BMWFW 2010) with a cumulative energy efficiency goal of 200 PJ since 2005. From 2014 to 2020 energy producers must show energy efficiency measurements of 0.6 % per year of their production. In addition, according to the latest buildings directive[1], all new public owned or used buildings from 2018 and all newly constructed buildings from 2020 must be built as low-energy houses. Renewable energy resources include the increase of water power, wind power, biomass and -gas, and photovoltaic (Environment Agency Austria 2016).[2]

Based on the EU goal to substantially decarbonize the energy system by 2050 several steps are established to reach this goal through EU (targets for Austria: 36 % emissions reduction until 2030 to the base 2005[3]) and Austrian regulation.[4]

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[1] Buildings Directive (RL 2010/31/EG).

[2] Green Electricity Acts 2012 (BGBl. I Nr. 75/2011).

[3] RL 2009/28/EG

The EU's Energy and Climate Package translates the European to Austrian targets with: a 34 % renewable energy target, an overall indicative 20 % energy efficiency, and a 20 % reduction of GHG emissions. According to the IEA, Austria is on track regarding the renewable energy target and shows significant progress regarding energy efficiency (IEA 2014). In its National Energy Efficiency Action Plan (NEEAP) Austria established even more ambitious renewable energy targets of 50 % renewable energy in 2020 (BMWFW 2017). Currently, quantitative (Table 1) and qualitative targets can be distinguished.

Table 1: Quantitative political goals for the transition of the Austrian energy system

100 % renewable energy in 2050	20 % reduction of GHG emissions (2020)
179.9 PJ electricity from renewables	396.5 PJ or 35.48% energy from renewable energy (2020)
143.4 PJ heating from renewables in 2020	district heating from renewables 38.2 PJ in 2020

Sources: (BMWFW 2010, Environment Agency Austria 2016)

Table 2: Qualitative political goals for the transition of the Austrian energy system

Goal	Description
Energy efficiency	This includes all stages of provision and use of energy such as building, mobility, implementation of energy management systems, and spatial planning.
Renewable energy	Hereby, the focus is on hydro power, wind power, biomass, and photovoltaic.
Security of supply	The security is aimed at the highest possible degree of cost effectiveness through district heating and cooling, new transmission networks, diversification of sources and routes, gas storage, smart grids, and smart metering.
Stabilizing the final energy consumption	The stabilizing will be achieved through the above mentioned fix target of 1.100 PJ final energy consumption in 2020.

Source: (BMWFW 2010)

In the current (July 2017) program of the Federal Government, four initiatives are explicitly mentioned that will change the energy sector:

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[4] Austrian Climate Protection Law KSG BGBI. I. Nr. 106/2011

- The first small eco-electricity amendment (*kleine Ökostromnovelle*) simplifies the installation and using of PV-panels on multiple family dwellings and provides more governmental funding for small scale hydro plants.
- The larger eco-electricity amendment (*große Ökostromnovelle*) aims at extending the use of renewable energy sources through re-organization of the eco-electricity subsidies to achieve EU-climate and energy goals and establish 100% net-balance coverage of Austrian electricity in 2030. The planned measures follow a market liberalization logic and focus cost-efficient, competition based founding system such as transparent tender and auctioning of investment subsidies and premiums. To achieve affordable electricity, there will be a cost cap on eco-electricity subsidies.
- To avoid higher electricity prices through the separation of the Austrian-German price zone, Austria will actively advocate for continuing the current trade.
- The White Paper on energy and climate strategy aims to build the cornerstone for the new energy strategy and has economic growth and new employment opportunities as central goals. Hereby, it focuses on renewable energy, energy efficiency, infrastructure, as well as innovation and research of environmental and energy technologies. Building on intensive consultation processes that include the previous energy strategy that was also build on simulation runs, public consultations, and EU and national targets, the White Paper will establish the definitive climate and energy strategy of the Federal Government until 2030. (Federal Government of Austria 2016, 2017)

1.4 Market Structure and Energy Consumption

Prices at the Austrian spot market fluctuate. In rare cases of electricity excess they reach even negative prices. End user electricity prices for households are considerably larger than for companies with 0.2 €/kWh instead of 0.07 €/kWh in 2016 (Figure 9).

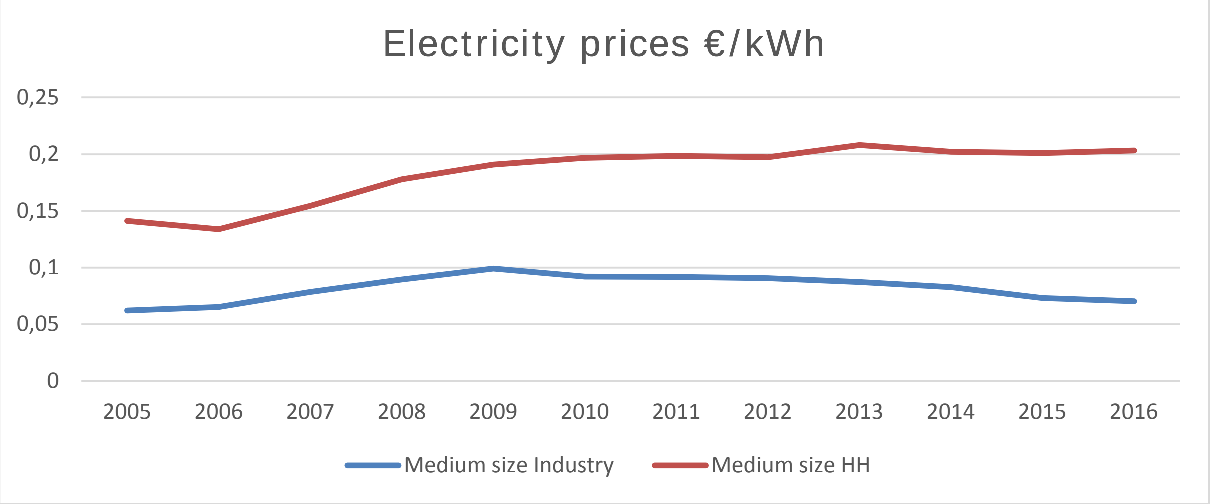

Figure 9: Electricity prices in Austria (Eurostat 2017)

The energy prices for medium size households[5] consists to 32.3 % of the actual energy prices, 40.1 % taxes and charges, and 27.7 % grid charges (Figure 10).

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[5] 3500 kWh electricity/ year

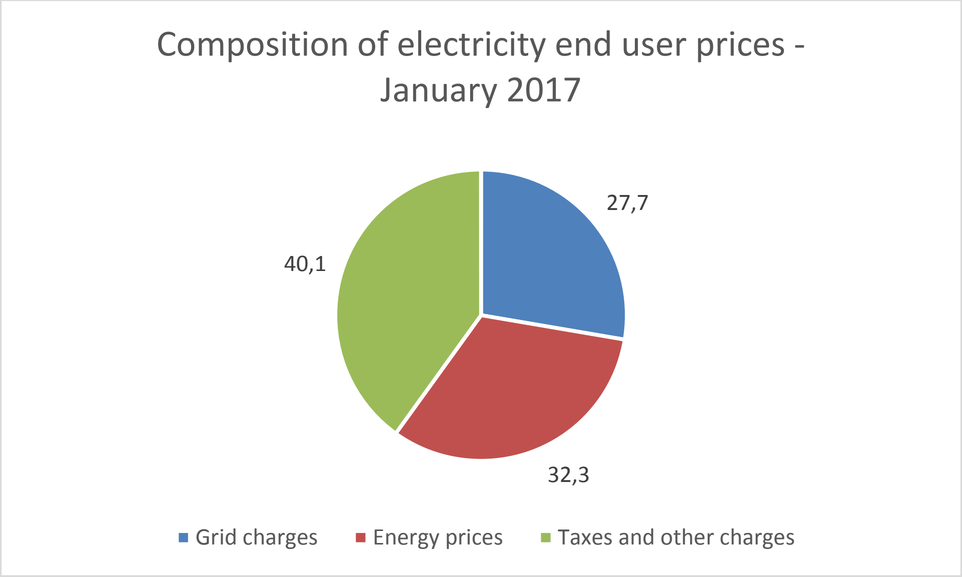

Figure 10: Composition of electricity end user prices in Austria (Source: E-control retrieved 2017-june-30)

Austria has implemented the Third Package for the Internal Energy Market to follow the EU-way to more market liberalization with specific legislation in 2010, which includes the creation of an independent energy regulator (E-Control). As mentioned above, the directives on electricity and gas markets have been implemented through the Elektrizitätswirtschafts- und Organisations-Gesetz 2010 (Electricity Act) and the Gaswirtschafts-Gesetz 2011 (Gas Act) (IEA 2014, Austrian Environmental Agency 2016).

In Austria, the one nation-wide *transmission system operator* (TSO) is the Austrian Power Grid (APG), which is an independent enterprise that belongs to VERBUND AG and was separated from it due to market liberalization of the third EU energy packet. VERBUND AG, in turn, is majorly owned by the Republic of Austria. APG regulates all of Austria except a small corridor in Vorarlberg, which is part of the German regulatory block (APG 2017).

In Austria, a variety of primary power producing companies is active. There are over 140 electricity producing companies in Austria, as well as over 30 gas providing companies: all with varying prices between companies and differing regional reach. Some provide power only in few municipalities or *Länder*, while others provide power across *Länder*-borders (E-Control 2017). The biggest 10 electricity producing companies, however, supply 70 % of all industrial customers and 80 % of all households (PWC 2016). The biggest electricity producer VERBUND AG provides 40 % of all Austrian electricity and is majorly owned by the Republic of Austria. The second biggest provider, Energie Allianz Austria GmbH, is an alliance of several other *Länder*-provider such as Wien Energie, EVN, and Burgenland AG (E-Control 2017).

The distribution system operators (DSOs) task of transporting electricity between producers and withdrawers, while maintaining network stability is currently undertaken by several different DSOs in Austria. In June 2017, 21 DSOs where registered in Austria that differ in size and shape. Many of these DSOs are owned by municipalities or as joint companies by a combination of Austrian *Bundesländer*, other Austrian energy providers and publicly owned bank and insurance groups. Further, they must meter consumption and attribute it to the balance groups and transmit consumption data to the clearing and settlement agent (a public company owned by the Austrian energy industry: APCS Power Clearing and Settlement AG) (E-Control 2017; APCS 2017).

Especially for new customers, those that switch suppliers, prices are considerably lower than for long-term customers. In 2016, the lowest price was 3 cent/kWh without any deductibles. In contrast, new customers had prices of 1.06 cent/kWh in their first year. This is clearly below the market price of 3.27 cent/kWh.[6]

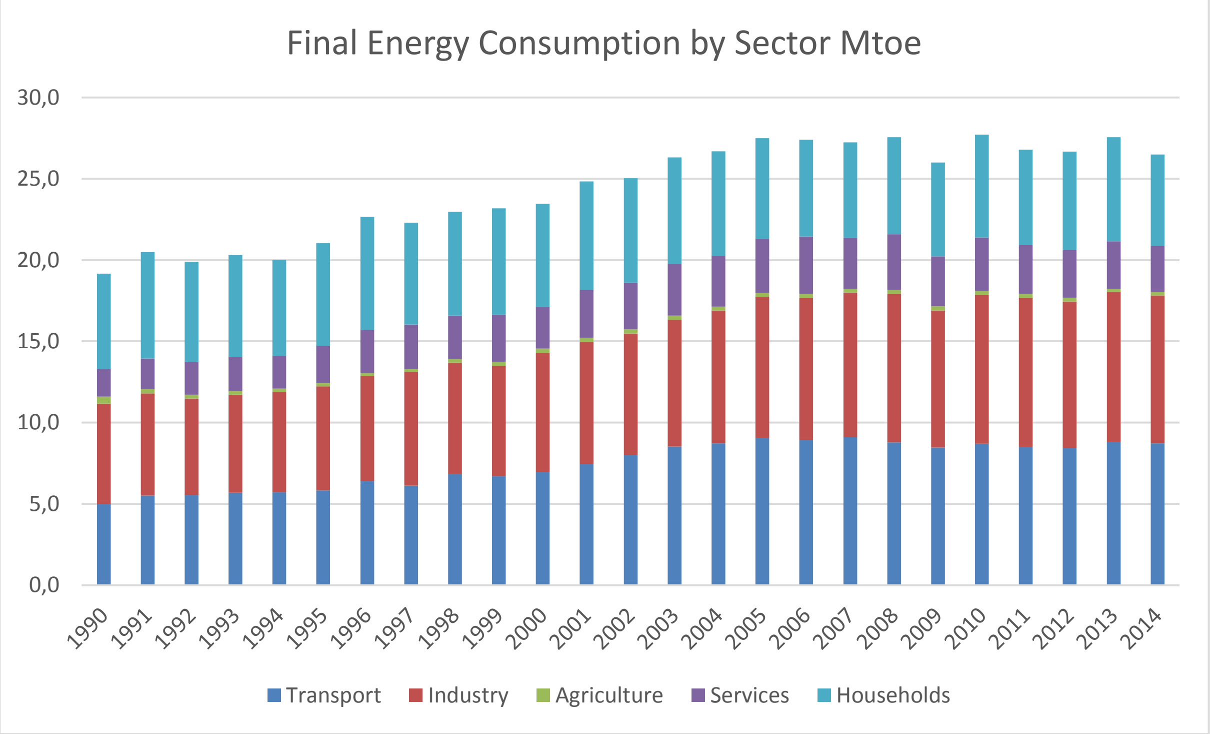

Figure 11: Final energy consumption by sector in Austria (Source: EU Commission, DG ENERGY, Unit A4)

Figure 11 shows the development in the Austrian final energy consumption from 1990-2014 (distributed by sectors). Overall, the energy consumption of the transport sectors has been steadily increasing, as well as for the industrial sector and services. Energy consumption by households, however, remains fairly constant over the time from 5.9 mtoe in 1990 to 5.6 mtoe in 2014.

1.5 The Smart Grid Landscape in Austria

There are a lot of smart grid activities in Austria, from governmental initiatives, subsidies and consultations, and conversely a strong push by ICT industry. Normalized per capita, Austria invests heavily in smart grids and is close to the investment per capita of Norway (Figure 12).

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[6] December 2016 (EEX/EPEX spot market Year-ahead 80% Base/20% Peak, monthly average)

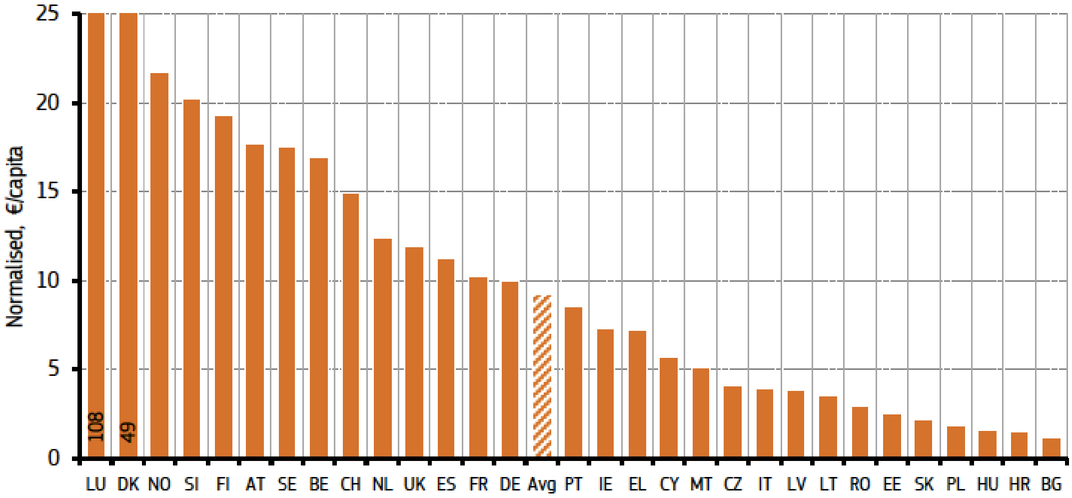

Figure 12 Total Investment in Smart Grids normalized per capita (Source: JRC 2017)

While Austria's capacity of large-scale storage through pumped hydro is considerably large due to mountainous areas of the alps, the maximum amount of storable electricity is 450 GWh (Environment Agency Austria 2016). Thus, large hydro pumped storage provides substantial storage capacity, but can and need to be expanded for about five times, if the entire electricity supply is to be provided from renewable sources (Maier 2013). Incentives to invest in these technologies, however, remain quite low, due to low electricity prices (Environment Agency Austria 2016).

Austria's governmental smart grid strategy, subsumed under "Strategy Process Smart Grids 2.0", currently attempts to establish a multi-facetted process that involves technology companies, utilities, and regulatory agencies (BMVIT 2016). Further, the process is accompanied by several scientific programs to assess and assist the development of R&D projects and accompanying regulation. Central elements are the following:

- Decentralizing and participation through an interactive energy system that allows for citizen engagement.
- Achieve equal distribution of cost and benefits of smart energy solutions.
- Create economic opportunities from existing flexibility options for dynamic energy systems.
- Enable the use of data created through smart services by use of data processing.
- Security of supply, resilience, and data privacy protection have highest priority and must be central for designing smart grids.
- Strengthening Austrian engineering capacities.

Two recent strategies where hereby created, a long-term "strategic research agenda" to support the transition of the Austrian energy sector until 2050, and a second short-term strategy to accompany this process until 2020. The latter, first published in 2013 by Austria's Ministry for Transport, Innovation and Technology published a substantial technology roadmap on smart grids (BMVIT 2015), as part of this strategic process, in cooperation with the actors of Austrian ICT companies, energy agencies, universities, and industry organizations (BMVIT 2015). The key objectives of this strategy include: in addition to conventional grid extension, smart-grid solutions to enable decentral and regional matching of supply and demand. This is achieved through communicative connection between single components such as production facilitates, decentral energy storage, flexible consumers, and intelligent buildings. The plan is hereby to build an environment that allows Austria’s ICT companies to increase competitive advantage and to establish their regulatory and technological standards. The technology roadmap has three short range targets until 2020:

- Finding scalable ICT solutions, based on the current system’s ICT architecture.
- Validate projects that assess practicality of systemic grid solutions, which are applied to larger scale real-world cases.
- Developing a working market as a show-case for the leadership of Austrian technology companies.

(BMVIT 2017)

Austria’s long term strategy consists of four central themes that will be initiated with different stakeholders of research institutes, companies and through participatory processes that involve a larger public (BMVIT 2017):

- Infrastructure development across different kind of energy sources and geographies.
- Governance of energy transition.
- Electricity system, heat- and cold supply, as well as ICT and storage technologies.
- Issues of energy efficiency that show relevancy for the grid and for developing new business models.

A third strategy is a large and substantial consultation process with different stakeholders in the Austrian public (BMVIT 2016).

Austria’s industry is heavily pushing for initiating smart grid projects, lobbying for government support, and actively connecting companies from the ICT and traditional energy sectors. One incubator for these activities provides the smart grid platform. This platform aims at coordinating within industry and with national and supranational agencies to initiate pilot projects and to establish new industry standards. In Austria, the platform is also engaged in the pilot projects of model regions which include rural and urban projects (Figure 13).

The hereby created roadmap tries to connect these activities within a coherent process until 2020. In addition to the mentioned cornerstones of shared projects, model regions, etc., another focus is on cyber security of smart grids and their surrounding architecture (Smartgrid Austria 2017).

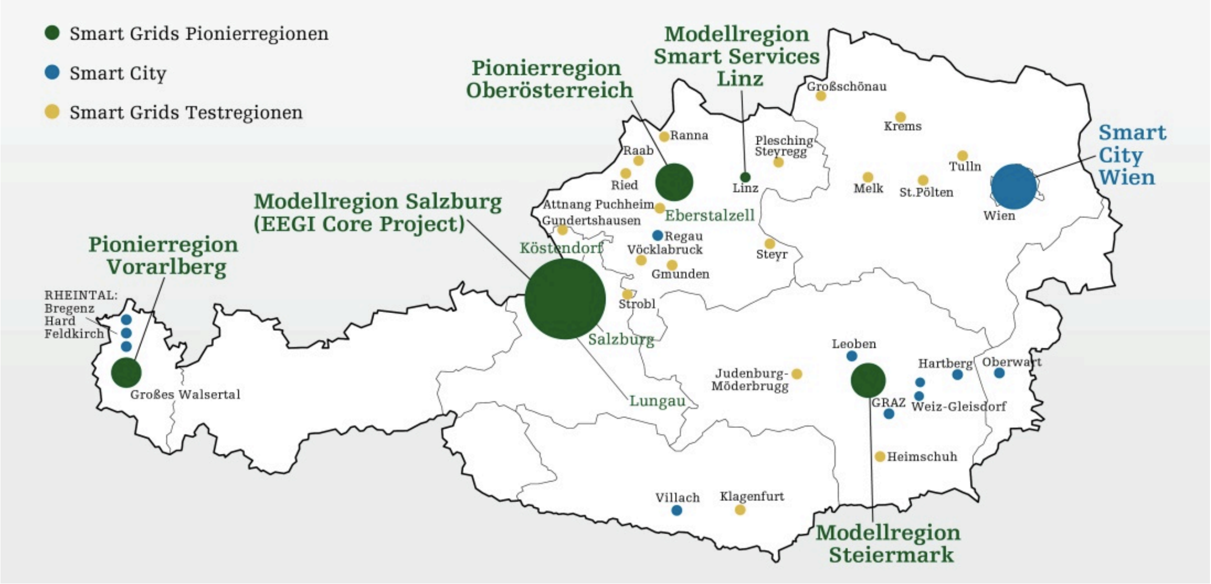

Figure 13: *Model Regions in Austria* (Smartgrid Austria 2017)

The Austrian demo-projects work next to the integration of smart grid systems in households on behavior and user acceptance of its inhabitants. This is attempted through interactive use-displays, and mobile devices that allow for more monitoring (even remotely) over energy consumption, humidity, and air quality in these homes (BMVIT 2015). Other pilot projects focus on identifying different user profiles regarding their energy consumption using smart meters and further sensors. With these information, tailored incentive systems to reduce energy use, while achieving satisfied users, are developed. This variety of approaches of the Austrian projects, which focus on both technical and non-technical aspects is further exemplified in the two case studies *Köstendorf* and *Rosa Zukunft*, which are located in the model region of Salzburg.

2 Austrian Case Studies

The selected Austrian cases represent three different aspects of a future smart energy system. The main focus of the first case – the model village Köstendorf – is to experiment with smart distribution networks involving private households with PV, EVs and stationary battery systems. The second case – called Rosa Zukunft – is located in an urban setting and it represents a comprehensive building-to-grid solution. The third case – called VLOTTE – focuses on e-mobility, distributed generation and load-management. The first two cases (Köstendorf and Rosa Zukunft), are located in the region of Salzburg and the third case (VLOTTE) is located in Vorarlberg, the most western region of Austria. In addition to their main thematic foci (see Table 3 below) all cases involve a number of additional aspects of smart energy solutions. They target small to medium consumers, run for several years and show a variety of 'working' solutions. Moreover, in all three cases local actors agreed to support the MATCH project. In the case model village Köstendorf the project MATCH cooperates with the on-going ERA-NET project ReFlex[7].

Table 3. Austrian cases in comparison

	Case 1	Case 2	Case 3
Name	Model village Köstendorf	Rosa Zukunft	VLOTTE
Main focus	Smart distribution grid field test	Building-to-grid solution DSM field test	E-mobility model region
Type of consumers	Households, SMEs, public buildings	Private households (apartments)	Own use (employees), private customers, SMEs
DSM	Demand response	Energy efficiency Demand response Dynamic demand	Demand response (load management)
Micro generation	Rooftop PV systems	Rooftop PV systems CHP unit (biogas)	Rooftop PV systems
Storage	Car batteries Stationary batteries	Large heat storage	Car batteries Stationary battery

Austria has a strong environmental technology sector and the selected cases must be viewed against this background. In the last 20 years innovation-specific funding for small and medium sized companies have played an important role in this field. In 2003, the Austrian government started to fund research in smart grid technologies with the program "Energy Systems of Tomorrow" that applied a broad approach with a focus on basic studies and concepts. The total funding sum was EUR 16 Mio. over a time of four

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[7] In order to coordinate this cooperation occasional meetings were agreed. A first meeting took place in June 2016, a second meeting took place in October 2016.

years and different demonstration and pilot regions could be established (BMVIT 2017). In 2008, stakeholders from industry, research and public bodies founded a national technology platform for smart grids to represent interests and coordinate the activities in this field.

The first region in Austria that has been the focus of large-scale funding for smart grids research was the federal state of Salzburg. The Smart Grids Model Region Salzburg (SGMS) was an initiative launched by the Ministry for Transport, Innovation and Technology and is led by different stakeholders of the energy sector (Salzburg AG, Salzburg Netz GmbH), the housing industry (Salzburg Wohnbau), the industry (Siemens), consulting (Fichtner) and partners from research institutions (Austrian Institute of Technology, TU Wien, CURE).[8] Different funding programs helped to develop the region. Starting in 2008 with the program New Energies 2020 (Neue Energien 2020) of the Climate and Energy Fund. This program was followed by the program e!MISSION.at - Energy Mission Austria, which is still active today. The SGMS received about EUR 3.1 million in 2009 for pilot and demonstration projects in the area of smart grid research and development.[9] Between 2009 and 2013 the municipality of Köstendorf was selected as a site for a smart grid demo project as part of the model region programme, and has since been further developing and investing in smart grid solutions with the support of the local grid operator (Salzburg Netz GmbH). The second case study project, Rosa Zukunft, was also implemented as part of the smart grid model region Salzburg.

The third case study project, VLOTTE, started in 2008. It was the first e-mobility field test in Austria. Similarly to the other two cases, national funding played an important role to stimulate regional activities. However, as we will show later, the project also profited from a number of supportive local conditions. Today, Vorarlberg is one of the leading e-mobility regions in Europe.

For the selection of the Austrian case study projects we applied a multi-step process. First, based on desk research and informal expert interviews a long-list of possible case study sites was prepared. This list included 15 possible cases. Based on this long-list the project team selected a smaller number of case study candidates for further investigation. Important criteria for the final selection of cases were of theoretical (variety of thematic focus, technological options, implementation of solutions) as well as of practical nature (accessibility, willingness of main local actors to cooperate with the project team).

Based on the MATCH research framework, an interview guideline for stakeholders, experts and end-users was drawn up. The questions cover the history of the case, its context, the role of main stakeholders and/or users, elements of the socio-technical configurations applied, experiences made in the project, success criteria, and a short outlook section.

In November 2016 the project team made a first round of field trips to the three case study sites. On November 22 we visited the project VLOTTE in Bregenz. On November 28 we were in Salzburg to visit both projects. During the site visits seven interviews were carried out. Several additional interviews with experts in Vienna followed. The second round of field trips took part in May 2017. Overall, 31 interviews have been conducted. Interviews lasted between one and two hours. All interviews were transcribed and coded using the programme MAXQDA and prepared for analysis. In addition, existing studies and other written documents were also used for the case studies.

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[8] http://www.smartgridssalzburg.at/content/dam/websites/smartgrids/Downloads/SGMS-Ergebnisse-2013.pdf, last accessed 18 October 2017.

[9] http://www.smartgridssalzburg.at/content/website_smartgrids/de_at/modellregion-salzburg/foerderungen.html, last accessed 18 October 2017.

2.1 Case 1: Modell Village Köstendorf

2.1.1 Background and Project Characteristics

Köstendorf is a small village in the Austrian Bundesland Salzburg. As of 1 January 2016 it had 2.555 inhabitants[10]. In 2011 Köstendorf was selected as the location for the testing of smart grid energy technology solutions as part of the research project DG[11] DemoNet Smart Low Voltage Grid (Kupzog et al., 2013)[12]. The project ran between 2011 and 2013. DG DemoNet is part of the federal government's strategic research and testing initiative Smart Grid Model Region Salzburg (SGMS). About 23 projects were funded under this programme, the funds for which were provided by the Austrian Climate and Energy Fund (KLIEN)[13], and the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT). The relatively large research programmes Energy for the Future, New Energies 2020 and e!mission are precursors of the SMGS initiative. All programmes broadly focus on the testing of smart grid technologies in practice at the level of buildings, communities and regions, with the aim of solving technological problems of energy technologies and their integration with existing energy systems, and other sectors such as transportation and increasing tourism by attracting people to the region for reasons such as energy innovation.

The federate state of Salzburg has adopted specific policy targets pertaining to the reduction of CO^2 emissions and increase in the use of renewable energy, as set out in Agenda 2020[14], Agenda 2050[15] and policies at the EU level (the binding targets are those defined at the EU level). Formulated in 2013, Salzburg's Agenda 2050 aims for state-wide climate neutrality and autonomy in its energy production. These goals refer to all primary energy systems such as heating, transportation and electricity.

The SGMS funded research projects, such as DG DemoNet Smart Low Voltage Grid and its predecessor DG DemoNet, aim at testing and technological problem-solving in the integration of renewables and ICTs in existing energy technology systems in real-world settings in the state of Salzburg. DG DemoNet and its follow-on project DG DemoNet Smart Low Voltage Grid focused on understanding the planning investments required to solve the problems of fluctuating energy demand on the one hand (high in the early morning and evenings) and changes in the supply of solar energy on the other (high at daytime and during the summer, low at other times). The goal is to gain knowledge on how to balance out these changes with limited investments in infrastructure, devices and systems, and minimising discomfort to consumers.

The main actors in the DG DemoNet Smart Low Voltage Grid project implemented in Köstendorf are the Austrian government, the regional energy sector, industry, and universities and research institutes. The initial team behind the project was composed of the local government of Salzburg, the regional energy provider Salzburg AG, the regional grid operator Salzburg Netze GmbH, the firm Siemens, the Vienna University of Technology (TU Wien), the Austrian Institute of Technology (AIT), and the grid provider Netz Oberösterreich GmbH. These actors had collaborated in projects in the past, although not necessarily all in exactly the same consortia. The call for projects on the topic of smart grids was launched by the Austrian Climate and Energy Fund (KLIEN) in 2010 and at this time the project idea was made concrete.

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[10] http://www.koestendorf.at/.

[11] DG is short for distribution grid.

[12] https://www.ait.ac.at/en/research-fields/smart-grids/projects/dg-demonet-smart-lv-grid/.

[13] https://www.klimafonds.gv.at.

[14] https://www.salzburg.gv.at/umweltnaturwasser_/Seiten/salzburg2050.aspx.

[15] https://www.ait.ac.at/en/research-fields/smart-grids/projects/dg-demonet-smart-lv-grid/.

As previously stated, the project DG DemoNet, which was the predecessor to the project DG DemoNet Smart Low Voltage Grid which was implemented in Köstendorf, focused on medium voltage and had been carried out in Vorarlberg. After this first project, the research focus shifted to low voltage. Low-voltage was then addressed in the follow-on project, and this time in a different region of Austria. The consortium of both projects was quite similar, except that in the second project the partners from Vorarlberg no longer participated, and the state of Upper Austria was added to the regions in which products and systems were tested. The field-test was carried out in the municipality Eberstallzell in Upper Austria. The goal of the follow-on project was to explore low voltage smart grid technologies. The criteria were to test out the possibilities of having a penetration share of about 50% PV energy production and 30% electric vehicles (EVs) share of total vehicles in a local community, and the interactions this would have with the existing grid. In this first stage of the project formulation, it was still unclear which local community would be the testbed.

The criteria for site selection were to find a low voltage grid that resembles what a smart grid might look like in the next 20 to 30 years, which specific cabling features, demographic characteristics, sufficient length of the existing low-voltage cable, and suitability of the building hosting the existing transformer station and whether it needs to be rebuilt to host a second (smart) transformer. Ten local communities in Salzburg including Köstendorf had these desired features. Köstendorf was the first locality approached to take part in the project and they quickly accepted. Some of the reasons for the quick acceptance are some pre-existing local affinity towards energy conservation and own production (for example, installation of PVs at own cost), as well as the close personal ties between one community member (who later on in the project became the local mayor) and the local energy provider Salzburg AG. The local affinity towards renewable form of energy and environmental conservation in general has a long history in Austria. Indeed, together with Germany, Austria has been a pioneer in promoting public awareness of environmental concerns and what people can do about it. Furthermore, these projects are always accompanied by subsidies and investments either directly from the government or indirectly through research funds. Pilot and demonstration projects are known to be accompanied with this and local communities are often keen on both the money that comes to the community through these projects, as well as the technological upgrading that is a result of R&D performed locally (e.g. knowledge spillovers). It is impossible to separate the direct effects of each of these factors but they are often stated as supporting factors in the literature on strategic niche management (for example, Schot and Geels, 2008) on the development of niches.

From the beginning of the project, many households and small companies supported the project. At the village level, investments had already been made in the past, for example through the installation of biomass heating plants. Overall, the local community had an affinity towards sustainable energy production and consumption, which was an important factor for choosing it as the research site. Following site selection at the beginning of the project in 2011, different funds were raised to install the necessary equipment such as solar panels and the controllable transformer. The federate state of Salzburg provided the subsidies to supply the participating households with PV solar panels. In total 43 buildings (private houses, the municipal office, the school, and some small companies) were chosen to participate in the research. The households agreed to have the following devices and systems installed: PV panels, building energy agent (BEA) and smart meter. Some households also received electric vehicles and wall boxes installed on site (for free during the project, later at a price of 29 Euros per month per e-vehicle). At a later stage, as part of the next pilot and demonstration project on the site (the LEAFS[16] project), the

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[16] https://www.ait.ac.at/en/research-fields/smart-grids/projects/leafs-lv-loads-and-storage-integration/

households got batteries installed. The households bought the following themselves (at heavily subsidised prices): PV panels and smart inverter. All other components, specifically the Building Energy Agent (BEA), the smart meter, and all technologies supporting the smart meter were bought and remain in ownership of Salzburg AG. The local community of Köstendorf also received funding from the Bundesland Salzburg designed for small projects in small communities. Because of financial restrictions not all interested households could have been selected to take part in the project, there were some negative sentiments raised in the non-participating households, some of which had only previously bought solar panels and electric vehicles using much smaller subsidies than were offered as part of the project. These households had not purchased this equipment because they would be more eligible to participate (they did not know about it when they bought the equipment), but rather because they had a keen personal interest in self-generation and energy autonomy. As these households are located in other parts of the village, they were not considered as participants of the filed test in principle.

One of the background goals of the pilot projects was to manage the intermittent supply of renewable solar energy with changes in demand. The testing phase of the technical elements involved finding out how well the controllable transformer[17] can be controlled in the context of decentralised electricity production in private households through PVs, the charging of electric vehicles in the households, and the controllable transformer. The controllable transformer costs about twice as much as a regular transformer, and even though it would work, its high price is a barrier to widespread implementation. The field-test also should explore whether such a transformer is actually necessary under the given circumstances or not. A further aim was to test whether the low voltage grid is sufficient if there is an expansion of PVs, or whether it is necessary to extend the grid. The project had the following research question: How can a high share of photovoltaic systems and electric vehicles be optimally integrated in low voltage networks using intelligent planning, real-time monitoring and active network management?[18]

Today, the installed devices and systems are still being used, and the subsidy for the electric vehicles has been changed to a monthly fee of 29 Euros per vehicle per month (the vehicles are the Nissan Leaf or the Renault ZOE). Both the expansion of the test region is planned for the future, as well as the kinds of technologies that are to be tested. For example, a follow-on project in which Power2Heat technologies are tested is already being planned. The Power2Heat devices are already available on site (biomass), and the installation is dependent upon funding, which if it comes before December 2017 will be put in use in 2018, and is aimed at substituting the amount of heating oil used with the use of a heat pump (the oil burner will be replaced by a heat pump). Planning of a further project is underway, focusing on the development of a building project featuring open internal exchange of electricity from on-site PV systems. The realization of the project is however highly dependent upon the new Austrian economic and organisational regulation for the electricity industry (Elektrizitaetswirtschafts- und -organisationsgesetz (EIWOG))[19].

2.1.2 Socio-Technical Configurations

In the model village Köstendorf we can identify three different socio-technical configurations that are of interest from a smart energy perspective (see Table 4): There is a smart distribution grid with an extraordinary high share of PV generation, there are single households with PV systems, EVs and stationary batteries, and there is a 100% renewable energy household.

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[17] For an explanation of how a transformer works, please see: https://en.wikipedia.org/wiki/Transformer

[18] Kupzog et al., (2013, p.17).

[19] https://www.e-control.at/recht/bundesrecht/strom/gesetze.

Smart distribution grid with vast PV generation

The first configuration covers the part of the field-test that focuses on the integration of a large number of small PV-systems and electric vehicles (EVs) to the local grid (within one single string of the local distribution grid). In this case, the main interest of the field-test was to learn more about effects that appear when local electricity generation is based on solar energy to a large extent and at the same time the local grid has to deal with significant higher levels of electricity consumption due to a local concentration of EVs. The main technical elements of this configuration consist of a controllable low voltage transformer, an ICT-infrastructure and a control unit. Data on the voltage level in the local grid from the smart meters is used to stabilize the load situation in the local distribution grid. In addition, single households are equipped with smart inverters that allow for phase shifting which alternatively can be used to balance the distribution grid. The high density of PV systems and EVs was essential to create real-world conditions for testing the behaviour of the local distribution grid over a longer period of time. The willingness of local homeowners to participate in the field-test was backed by attractive subsidies, awareness for energy issues stimulated by previous activities in the village and a strong personal and political commitment of the municipality. In addition to 40 private households and some small companies, three larger PV systems are run by the municipality as part of the field-test. Technically, the field-test revealed that the grid can be stabilized using phase shifting only. The controllable transformer did work properly but was not necessary to stabilize the local grid. As a result, the responsible grid operator decided to use smart PV inverters at the household level (which allow for phase shifting) as the standard solution in the future. The participants identify strongly with the objectives of the project. They are proud to play an active part in the energy transitions. Some participants reported that they tried to shift electricity consumption patterns and others showed some interest to increase their self-consumption. The main focus of the researchers in this project was not to find out the implications of time shifting, but to identify the technical impacts of an increase in the share of PVs and EVs on the local grid. It was about investigating options for grid management in the context of proliferation of these two solutions. Time shifting was a very minor side-effect which had a small influence on the households themselves, but not on the grid, which was the real focus. However, the most important experience of the households as part of the field-test related to electric mobility. In most cases the electric vehicles from the field-test are still in use and became an integral part of the household's mobility practices. All households interviewed reported to using the EVs more than their regular ICE cars although the EVs did not replace the original car.

Figure 13: PVs on house rooftops in Koestendorf

Figure 14: Smart grid monitoring equipment in Koestendorf households

Table 4: Socio-technical configurations in the model village Köstendorf (Smart energy system field-test)

	Smart distribution grid with vast PV generation	Generation & storage household (field-test)	100% renewable household
Technical elements	Low voltage grid (covering 90 buildings) Controllable transformer 43 distributed PV units (192 kWp), smart meters, IT control units, smart inverters, stationary batteries (in some households) 36 E-vehicles, wall boxes ICT-infrastructure	Rooftop PV (3,5 kWp) Smart inverter (phase shifting), web interface Grid connection Smart meters, IT control units Stationary battery (in some households) Wall box E-vehicle	Thermal solar system, large storage tank Wood stove Heat pump Rooftop and free-standing PV systems (6,3 kWp) Inverter, web interface Grid connection Stationary battery Wall box E-vehicle
Social elements	40 households participate in the field test 3 PV units are run by the municipality Households/municipality own and operate the equipment in the homes Field-test households belong to the same neighbourhood (“Vogltenn”) No economic connection between participants, households ‘sell’ surplus electricity to the grid Mayor of Köstendorf works at Salzburg AG Active energy group at the municipal level (e5) High subsidies for private households (PV, batteries) and EVs for free On-going demo project and showcase	Household owns the equipment and ‘sells’ surplus electricity to the grid EVs are owned by Salzburg AG and rented by household High subsidies for private household On-going demo project (optimisation of self-consumption) Agreement between household and Salzburg AG Household in close contact with field-test project manager who cares for the technology	Homeowner is investor and system operator Highly motivated ‘resource man’ and active member of local energy group (e5) Household buys green electricity but is otherwise a normal customer of Salzburg AG Household is not part of the field-test

Generation and storage household

The second interesting configuration is represented by the single field-test households, usually equipped with rooftop PV, stationary battery and EV (the same households as in the smart grid field-test but with a different research focus). Here, the main focus is on user acceptance and experiences with the provided technology. In households with stationary battery systems on-going research is about the optimization of self-consumption, which referred to for example using electric appliances when either solar energy was available directly or with the battery, as well as moving towards energy autonomy. A locally installed IT control unit make sure that self-produced electricity is first of all used in the household (for direct consumption or to charge the battery) only then electricity is fed into the grid. Although the households own most of the technical equipment (only the EV is rented from the Salzburg AG in the same 29 Euro per month deal) responsible staff from the Salzburg AG play an important role regarding the operation and optimization of the technology. The cooperation between the project leader (Salzburg AG) and the households is regulated by an agreement that guarantees unrestricted access to data and to the technical equipment in the homes. Homeowners and project staff jointly take care of the technology. Over the years close personal relationships have been developed. Although the local grid operator (Salzburg AG) is the main actor in this configuration, participants with battery systems stated that the technology will help them to become more independent from the local utility and be self-sufficient in the future. The grid operator, however, again is interested to use local batteries as elements to stabilize the local grid and learn more about the systemic implications of prosumer-households.

Figure 15: EVs and charging stations in a household in Koestendorf

100% renewable household

The third configuration is realized in only one household and developed much earlier independently of the field-test. However, there are plans that also this household will become part of the household battery research project. This configuration can be characterized as a full renewable household. In this case, almost the entire energy needs of the two-person household is covered by renewable energy sources. The detached building is heated with wood, solar thermal, and geothermal energy. Electricity is produced by three PV systems and, apart from normal electricity needs, the own generation is used to run a heat pump and to charge two EVs. The system is connected to the grid but the household consumes a large share of the own self-generated electricity by itself. Additional electricity needs in the winter season are covered by the grid using green electricity. Mastermind and operator of the quite complex technical system is the male householder. Already in the early 1990s he joined one of the at that time very popular thermal solar panel DIY groups. Since then the whole technical system of the private home has gradually been developed towards renewable energies. The male household member perfectly fits the 'resource man' typology. He not only designed the whole system by himself and actively cares for the technology, he also has a lot of knowledge, and regularly checks the measured data. Over the years the household has invested a lot of money in this system, even the owner itself sees these high financial investments as problematic.

2.1.3 Discussion: Success and Outcomes

The solutions tested in the project can be considered as successful in several respects from different stakeholder perspectives. In particular, the project has succeeded in its R&D objectives, the planning objectives of the utilities provider Salzburg AG, the local community has profited both from direct subsidies and the technological momentum that has been created from the implementation, testing and management of the solutions. In terms of R&D, the project set out to address the specific problem of integration of PVs and electric vehicles without disruption to the existing energy system and at a feasible cost. A successful planning aspect was arriving at the finding that with local regulation and an integrated approach it is possible to achieve 100% increase in local grid capacity and reduce the additional costs by 50% (interview MR Salzburg AG p. 14). Furthermore, one of the technical solutions (phase shifting) that was tested in Köstendorf and which proved to be suitable will be rolled out to the Salzburg region.

A further success feature is that the community interactions led by the utilities provider Salzburg AG and the local mayor, and the project's publicity brought benefits to Köstendorf that were not directly intended. For example, the only local pub was reopened because of the large numbers of visitors coming to the village to learn about the local energy project. The satisfied customers in Köstendorf have told others about their experiences and supported the diffusion of the technologies amongst the village and to other villages as well. It was reported that over 70 different country delegations came to visit the village, creating a type of "energy tourism" which had not existed there before. Through the active engagement from the utilities provider, who are also the equipment owners, the customers gained more awareness of the challenges facing sustainable energy supply, the role they can play in energy production. A positive image was created of the utilities providers, which had not been as positive prior to the project. The project participants who were fortunate enough to receive one or two free electric vehicles for the duration of the project (and heavily subsidised thereafter) got much more confident in driving electric vehicles, and some households even started to plan their holidays around where they will be able to charge their car throughout the journey.

The main preliminary findings with regards to the MATCH framework dimensions of markets, actors and technologies, are:

Markets

- In the first two configurations, the subsidies dimension (both the quantity of resources and who administers them) are very important. Households that have received them are shielded from real-world economic conditions. Most of these solutions are not economically viable, at least in the short to medium term. The households that are not put off by economic inefficiency of the solutions are few and far between (in our survey we found only one such household, described in the third configuration, who maintains the investments with no significant near-term pay-off andbut out of conviction and as a role model as a kind of hobby).
- The interest in either keeping up existing subsidies (through Salzburg AG) remains, with new demonstration projects currently taking place and others planned for the near-term future. The region is a protected niche and test bed for both research and industry. These and other features of the project (for example,

the research and industry driver) means that market formation in this regional context is highly mediated and controlled. The main player, Salzburg AG, has a clear interest in maintaining its gatekeeper position in the overall market and is exploring options to do so, in this case in a rural setting.

- The project boosted the regular sale of PV systems in Köstendorf and made it one of the leading villages in this respect in all of Austria. These conditions have created a fruitful ground for spin-off projects as well as further developments of the energy technology field in Köstendorf.
- The households favour the solutions also because they would like to move towards self-sufficiency and autonomy in energy production and consumption. This is despite the involvement of the big player Salzburg AG, and the associated subsidies. This creates an interesting contradicting dynamic in the process for the longer term, but makes sense at present because both parties perceive a benefit in the current set-up.
- An important insight gained for the EVs market is the good experience that households had with them after they had the opportunity to test them out at almost no cost. This is in line with the current literature on EVs, which states that consumers tend to be quite sceptical at first, but given the opportunity to own and charge the vehicles they are lose their scepticism and become regular users (add source).

Actors

- The project consortium was highly competent in engineering, and management know-how, as well as well-networked with the local and regional government which was important for obtaining resources and lowering transaction costs. All parties learned in the process.
- Users were involved from the very beginning, and treated as ‘partners on a level playing field’. There was and remains good communication between the project leader and the local citizens. The involvement of local installers for the equipment worked well by helping to improve their installation skills for PVs as well as improving local support for the field-test.
- Users enjoyed using the electric vehicles and highly appreciate being able to have an active part in the ‘Energiewende’ in Austria. They are proud to produce green electricity, and endeavour to further improve their energy autonomy and optimize the consumption of their self-generated electricity (with or without a battery).
- The 100% RE household is run by a typical ‘resource man’ who is driven by a desire “to show the world that it is possible to rely almost exclusively on renewable sources” (direct quote). For this household, the last 25 years have been a period of repeated experimentation and learning with the installing and re-installing of different bits of equipment, and although he was unable to participate in the project because his house did not meet the infrastructural requirements (which he, together with exchanges with Salzburg AG, is trying to improve, so that he increases his chances in taking part in initiatives in the future), he has benefited in other ways from it by being able to discuss and learn from the project consortium.
- The project could be viewed as a strategy to create local market niches because individual decisions have sustained the momentum but rather there has been a very successful group dynamic (similar to the famous DIY thermal solar panel groups in Austria) created by the field-test. This was based, however, on pre-existing social resources such as the “e5 Group”, which meets on a regular basis in self-organised events to develop plans for the expansion of renewable energy production and consumption in the village. The group is made up of private households (mostly male retirees) and the local mayor. In contrast, the single

100% renewable energy household is an example that shows that it is even possible to achieve this with much fewer subsidies under existing market conditions.

- As previously stated, the solutions are a success from the perspective of the local community. The solutions have full local support, evident from the included and not included local households, their support of the continued involvement of Salzburg AG, the formation of an interest group to gather and exchange information and push change along in terms of energy self-sufficiency in the village, the re-opening of the local pub, and other spillovers such as more awareness of the existence of these products and systems which speeds up diffusion both locally and in the neighbouring villages.
- The project and the solutions improved the local economy by attracting energy tourists and other visitors to the village.
- The participating households are very satisfied with their involvement in the project. They are happy with the solutions that have been implemented in their households (smart PVs and EVs and charging stations, batteries). For the households, the most important part of the field-test were the EVs. As stated previously, during the field-test the free provision of the EVs allowed the households to experience them at virtually no economic risk, and they had all changed their opinions about EVs as a result, becoming passionate users of them although the provided vehicles were very early models.

Technologies

- In terms of technology research outcomes technical change, it can be saidsaid it was found out that even a high share of PV generation can function in the existing grid without a controllable transformer (a smart inverters with phase shifting will do the job). EVs and PVs partly work together, but even when the EVs are charged in the evenings and at night no problems are caused for the grid. These results indicate that, given the same configuration, the solution is most likely transferable to other adopting contexts.
- Research on batteries is ongoing, for example optimization and the consumption of electricity generated from one's own PV system could be beneficial for the grid, but the extent and degree of this is unclear. In comparison, the motivation for consuming the energy generated by own PVs and stored in own battery systems in Denmark was motivated by regulation.
- The 100% renewable household case shows that the solutions are also useful for upgrading existing systems that were implemented before the start of the project.
- An understanding of the regional requirements and differences in regional conditions was built during the research. For example, the solutions work in Salzburg and in Upper Austria, but not in Lower Austria because in the latter the reactive power in the households does not exist, so they do not have the capacity to do the stress optimization (Spannungsbandoptimierung, MR page 24 bottom). Salzburg has a high degree of cabling which means that the grid has a high capacity so the inductive idle power/reactive power is very useful.

2.2 Case 2: HiT Housing Project

2.2.1 Background and Project Characteristics

The city of Salzburg is the fourth largest city of Austria. The city has a surface area of 65.68 km^2 and a population of 150,887[20]. It is located about 300 km to the west of

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[20] As of January 2016, see https://en.wikipedia.org/wiki/Salzburg.

Vienna and about 140 km to the east of Munich. The city is divided by the Salzach river, with medieval and baroque buildings of the *Altstadt* (old town) on the left bank, and the 19th century *Neustadt* (new city) on the right. The city is internationally famous for being the birthplace of the composer Wolfgang Amadeus Mozart. The *Altstadt* of the city is very well preserved, and has been listed as a UNESCO World Heritage Site since 1997. The city is a tourist favourite, with the number of tourists outnumbering locals by a large share in peak season. Salzburg is part of the temperate zone, also classified as either oceanic climate or humid continental, with four distinct seasons. The temperature averages 0 degrees Celsius in the winter months (December to March) and 20 degrees Celsius in the summer months (June to September). Due to its location at the northern boundary of the Alps, the amount of rain is relatively high, especially in the summer months. Salzburg is a centre of education and hosts three universities, as well as several polytechnics (*Fachhochschulen*) and high schools (*Gymnasien*). The city is served by comprehensive rail and air transport connections. There are frequent trains to Vienna, Munich, Innsbruck and Zurich. The city acts as a hub for southbound trains to Italy. Salzburg Airport is the second busiest airport in Austria, after Vienna Airport. Due to its relatively small size, it is fairly common that people working in the larger public and private organisations know each other and are used to networking with each other. Such conditions make it feasible to get projects off the ground, especially those that correspond to the state's strategic policy goals of climate neutrality, resource efficiency and innovation.

The Salzburg region has been hosting pilot and demonstration projects in the field of smart grid technologies since the early 2000s. Between 2003 and 2013 the region was a focus of 23 projects funded under the remit of the large scale research programme (relative to other topics in Austria these programmes secure quite a large amount of funds for smart grids research) known as the Smart Grids Model Region Salzburg (SGMS)[21]. The primary actors driving the programme are private actors, as in the previous case (Köstendorf), namely the regional distribution system operator (DSO) Salzburg AG, the regional building developer Salzburg Wohnbau and Siemens Austria. Project funding comes from the Austrian Climate and Energy Fund (KLIEN) specially created for innovation towards a decarbonized economy. At the core of the SGMS programme lies the specialised testing and development of technologies for a better integration of renewables, upgrading of electricity distribution networks, diffusion of electric mobility, integration of residential and commercial buildings in the smart grid, and advancements in load management (AIT et al., 2013). Depending on the project, the private actors are supported in their research by public research institutions in Austria such as the Austrian Institute of Technology (AIT) and the Vienna Technical University (TU Wien).

The "HiT – houses as interactive participant in the smart grid" project

The HiT Rosa Zukunft[22] project, the focus of our case study, is one of 23 projects under the remit of the SGMS programme and focused on the testing and implementation of residential energy and mobility solutions. The research part of the project ran between 2011 and 2013. It was a partnership between the private firms Salzburg Wohnbau,

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[21] http://www.smartgridssalzburg.at/content/website_smartgrids/de_at.html. Smart energy technologies have been a strategic R&D and innovation focus of the Austrian government, scientific and research organisations, and firms for at least two decades (Kletzan-Slamanig and Koeppl, 2009). Some larger research funding programmes which are predecessors to SGMS are Energy for the Future, New Energies 2020 and e!mission.

[22] The HiT Rosa Zukunft development project is named after its location on the Rosa Hoffmann Street in Salzburg Maxglan, where Rosa Hoffman, an Austrian resistance fighter, grew up. On 9 March 1943 she was murdered by the Nazis in Berlin.

Salzburg AG, and Siemens Austria, with support from an interdisciplinary research team from the public research institutes AIT, CURE and Fichtner, and the Vienna Technical University (TU Wien). The development and construction of the eight residential buildings (129 dwelling units) in the HiT project was carried out by the housing corporation “die salzburg”, Salzburger Siedlungswerk/Salzburg Wohnbau, the evangelical charity Diakoniewerk Salzburg (organising the social and community events such as information evenings and support groups, for example), the building firm Baumeister Steiner, and the SGMS organisation. The start of construction was 2012 and the first residents moved in in late 2013. The city of Salzburg, although not a direct partner in the energy aspects of the project, played a significant role in paving the way for the project through the creation of favourable framework conditions. Salzburg state directly supported the project by adjusting housing support to include partial public funding for the installation of photovoltaic (PV) panels. Furthermore, disability access and the building of living spaces to meet special social and healthcare needs of residents were ensured through cooperation between the developer and the builders.

The aim of the HiT project was to test the incorporation of smart grid technologies (demand response) in residential buildings, and lead the way for change in these areas for future housing developments in Salzburg (AIT et al., 2013:11). At the basis of the project were two innovative energy concepts, one mobility concept, and a broad overarching social concept. The energy and mobility concepts were developed by the core team of the firms Salzburg AG, Siemens and the research institutions AIT and TU Wien, who mainly focused on the highly technical and modelling aspects of the project. Several supporting individuals from Salzburg Wohnbau and the Diakoniewerk Salzburg managed the active involvement of the users, by providing information evenings, and acting as a one-stop-shop for any questions, concerns and complaints the residents had about energy use in the buildings. These information evenings were well attended at first, but over time the residents lost interest in taking part. It was said that only a few “usual suspects” were regularly present at all the meetings, for whom it was important to be there and get informed. Briefly here, the first energy concept focused on decentralised energy generation (CHP unit with biogas fuel and PVs), and automated load transfer (controlled thermal heat pump, controlled EV charging and home automation). The second energy concept focused on energy feedback with user interaction (using smartphone and tablet) as well as special monitoring apartments that were equipped with technology to monitor the use of energy, heating and water, as well as room temperature, humidity and CO_2 levels in the rooms. The goal of this concept was both load shifting and the corresponding reduction of energy costs. The mobility concept involved a shared fleet of EVs and an EV charging station. The idea was that residents could freely use the EVs for a small monthly fee, but car-sharing concepts never really took off. The energy and mobility concepts are explained in more detail in the section on socio-technical configurations.

The social concept was the main focus of Salzburg Wohnbau and the Diakoniewerk Salzburg. The underlying idea behind this part of the project was to have a housing complex in which different generations and income groups live together. The aim was that a local community develops and that there is social cohesion between the residents. The role of the Diakoniewerk Salzburg was to participate in the selection of residents (young persons, seniors, singles and families, persons needing assistance), to coordinate the living arrangements, and to manage the common room (or recreation room) as a central meeting point for all the residents (SMGS et al., 2013). There is support for the creation of neighbourhood support networks and a continuous chaperonage and living coordination (ibid.). The living coordinator Diakoniewerk is present on site 30 hours per week and financed through a monthly fee from each resident. It organises social events and activities of a secular nature in which residents can participate in, managing the different interests of the residents, and organises assistance to elderly residents. It also manages the use of the Diakonie app which also aims to support community building processes in the housing complex.

Throughout the duration of the research project, all concepts were very closely monitored by the actors responsible for them, specifically Salzburg AG, the research consortium, Salzburg Wohnbau for the energy concepts, and Diakonie and die Salzburg for the social and daily living aspects. A lot of effort was put in making them work. Over time however, it became clear that the first energy concept (building-to-grid - decentralised energy generation & automated load transfer) worked best of all because it was automatic and involved very little effort and no changes in user behaviour. This is also the part of the project that later became internationally famous and currently has a kind of pioneering reputation in the scientific and building communities. The in-home monitoring displays, the demand side management (DSM) concept, was much less successful, as users reported that the time-shifting changes that they had to implement did not pay off. Similarly, there was very little user interest in the shared EVs, because of reasons such as wanting to have an own car at disposal at all times, and not trusting that the battery would last for the trips that the residents wanted to make. The social housing concept continues to work well (social housing has a very long history in Austria and this concept builds on this long and successful tradition) and residents report being generally satisfied with the living arrangements.

In the case study, we focused on collecting expert views and user experiences on the two energy concepts and the mobility concept. We carried out expert interviews with engineers, managers and scientists from Salzburg AG, Salzburg Netze and AIT. Our user interviews were carried out with residents living in the regular as well as the special home monitoring apartments. The following section describes the three socio-technical configurations studied.

2.2.2 Socio-technical Configurations

The three configurations we analysed in this case study are building-to-grid, in-home monitoring, and EV sharing. The first configuration focused on energy management of the entire housing complex with micro generation (PVs and CHP), energy storage (heat, 90 m^3 water tank), and smart metering. The second configuration closely connected to the first, involved in-home smart monitoring with feedback communication between the consumers, the main heating system, and Salzburg AG. EV sharing is our third configuration, involving a planned car sharing system with two EVs per four to six apartments, an on-site charging station, a booking system, and electric bicycles. As previously stated the first configuration remains fully operational and in use today, whereas the second and the third configurations dissolved when the project ended, as it became clear that users were not interested in continuing the use of these technologies (except for one exception). The main socio-technical dimensions in each configuration are presented in Table 5 below.

Table 5: Socio-technical configurations in the HiT Rosa Zukunft (building-to-grid) project

	Building-to-grid	Energy feedback & DR	EV sharing
Technical elements	8 buildings with a total of 129 apartment units Combined heat and power (CHP) unit (biogas) Heat pump Energy storage tank (hot water, 90 m3) Rooftop PV (72 kWp) Central heating system in the settlement, District heating as backup IT control unit, smart meters	33 monitoring apartment units In-home display (tablet) Bus system, eco-button and smart meter in the apartment Sensors to measure humidity, CO2-level, temperature in the apartment Central hard and software and web portal IT control unit	On-site charging station EV
Social elements	Local (energy) utility owns technical equipment and provides heat and electricity Contract between utility and the housing company Variable tariff (calculated on a daily basis) Surplus electricity is fed into the power grid (domestic production) Occupants are passive consumers (but obliged to buy heat from Salzburg AG) Biogas virtual (offset)	Demand response field test (one year) Consumption measuring at 15 minutes intervals Agreement to take part at the field test Variable tariff (calculated on a 12 hours basis, special approval by regulator) Traffic light system Technical equipment sponsored by Siemens and research funds	Closed e-car sharing system (4 households share 1 EV) Provided by the housing company

Figure 16: Residential building complex HiT Rosa Zukunft

Building-to-grid configuration

At the heart of this configuration are questions on how load peaks in the grid can be reduced through the connection of intelligent residential buildings into the smart grid (AIT et al., 2013). In this configuration, the technical elements include the equipping of the eight residential buildings (129 apartment units) with a centralised heating system consisting of a micro cogeneration unit (which runs on biogas), a heat pump, and a large energy storage tank to store surplus energy. When the energy production in the building complex that was generated through the on-site heating system (micro cogeneration and heat pump) does not meet the housing energy demand, then district central heating is used as a backup.

The central communications system is located in one of the apartment blocks (known as the “HiT Energiezentrale” or “HiT energy centre”, see figure XXX). The main communications device of this technical set-up is a development of the company Siemens called Building Energy Agent (BEA). The BEA communicates between the smart meter, user interface, the weather predictions, the building automation system, the electric vehicle charging station and the electricity grid. The planning and building of this configuration was highly computer and electrical engineering intensive, mainly because of the nature of the equipment and the sophisticated modelling and programming that is involved in making such a system work well. For example, one of our expert interviewees from AIT stated that it takes much effort to calculate how much energy such a complex needs, at what times, and to design the corresponding size of the energy production and storage units. It was even said that the slow diffusion of these specific building-to-grid technologies, is in part due to the highly advanced modelling skills that are required to build them, which are currently in very short supply both in Austria and globally.

A key social aspect of this configuration is that all of the technical equipment is owned and operated by the local energy utility firm Salzburg AG. This includes the generated data. Salzburg AG shares the data with the AIT, who use it for their research and optimisation of the individual products, several of which have already been patented as a result of the research carried out in this project. The housing company Salzburg Wohnbau has a contract with Salzburg AG for this equipment. The user residents cannot tell whether they are consuming electricity from solar or any other source, and the PV surplus is fed back into the power grid. Indeed, in this configuration, there are no conditions created for an active role for users in which they are involved in the design, rule-setting, functionality, or in defining the boundaries of the configuration. Rather the advantages and disadvantages are experienced at the level of the local energy utility provider and spread out over the energy system.

Figure 17: Central energy station of the residential building complex

Energy feedback and DR

In contrast to the first configuration where users had a passive role, in the second configuration they are given a very active (albeit scripted) role. The main interest of this configuration is to find out if users can be integrated in the smart grid if they are provided with information on network load and their own individual electricity consumption. Out of the total 129 apartments, 33 were chosen as monitoring apartments in which special displays, gauges and switches were installed. And there was similar large control group… Upon registering for the apartments the residents could specify whether they wanted to be part of the field-test or not. A criterion for narrowing the sample even further, was to include different households with different compositions (singles, couples, families, and the elderly). These apartments were provided with a tablet PC that showed their use of energy, heat and water. Each apartment had a smart meter, and an “ECO-button” which, if pressed, switches off all appliances except the refrigerator with just one switch. It was also possible to control the heating system via the internet or smartphone, as well as to monitor room temperature, humidity and CO_2 levels.

A function that was introduced to complement the information provided by BEA and to transfer it to the users is a “traffic light model” (“*Ampelmodell*”) which is based on the principle of the traffic lights, red indicates the network load is critically high, yellow indicates a medium level, and green shows that the load is low and thus a “good” time to consume electricity. Users could observe the colour on the traffic light model to organise their use of household appliances, and thereby directly adjust their behaviour to what is going on in the grid.

The in-home monitoring field-test lasted one year, after which the devices (which had been funded by Siemens) were dismantled and removed. The households were required to indicate their acceptance to take part in the field test as soon as they registered their interest for an apartment in the housing complex. According to one of our interviewees who participated, they had agreed to take part in the field test because they feared that otherwise they would not be considered for an apartment. It was said that three times as many people expressed interest for the apartments than were available, so the competition for them was high.

During the field-test (2012-2013), the consumption of electricity, heat and water was measured at 15 minute intervals. A variable tariff was introduced under special approval by the regulator. The variability in pricing was communicated to the users via the in-home displays. The residents reported to have tried to adjust their cooking, dish-washing and laundering based on the information obtained, but were generally disappointed with the overall result. Cooking at different times proved to be impossible because people were used to eating at other times than when the electricity price and the network load were low. Laundering was difficult to do at the cheaper times because that was usually after 10 pm in the evening, after which time people in Austria are legally required to make as little noise as possible (the police can be called and will normally come to your house if a neighbour reports that your washing machine is working loudly in the night). Indeed, some neighbours did complain to the residents in the monitoring households and they therefore stopped laundering at night. Furthermore, at the end of the one-year period when the residents of the monitoring apartments made their calculations, the amount that they had saved was much lower than they had expected and in their view not worth the effort[23]. Energy monitoring is still in use in a couple of apartments. However, the vast majority of the participants decided against taking over the monitoring equipment although this would have been free of charge. Only one out of 33 households decided to keep all of the monitoring equipment, and a second household decided to keep a part of it, namely the CO_2 monitoring display. The male in the first household continues to read all the available information from the equipment. The male in the second household, who kept the CO_2 monitor, also continues to use it and has learned how and when the windows and balcony door need to be opened to let enough fresh air in to balance out CO_2 level in the flat. It has to be said here that keeping the monitoring equipment is motivated more by a passion and keen interest in energy saving than economic reasoning. The bus system based equipment is very expensive to maintain and repair: each of the monitors/sensors can cost up to 200 Euros, and then if they break it can cost between 100 and 400 Euros to repair them. This is of course much more than the 15 Euros per year that could be saved if DSM routines are followed in the household.

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[23] From a systems perspective even a small degree of savings (such as 15 Euros per year as the households reported) is a relatively large amount scaled up to the entire population, even if it would only occur perhaps once at the end of one specific year.

Figure 18: Model of the monitoring equipment switches installed in the monitoring apartments during the field-test

EV sharing configuration

The third configuration involved the provision (by Salzburg AG) of EVs, an on-site charging station, as well as an electric bike and a charging station for the electric bicycles. The idea behind this configuration was to understand the barriers and supports to the promotion of green mobility, to see how this approach can help contribute to load balancing, and to test a sharing approach to electrical mobility in a residential setting (AIT et al., 2013). The funding for this was provided by the housing firm Salzburg Wohnbau. The plan for this configuration was as follows: The EVs could be rented for a highly favourable rate of 90 Euros per month, which included unlimited charging, insurance, repairs, and any other aspects of regular car use costs. The EVs could be charged and shared by the residents using an online booking system. Two EVs were to be made available for sharing between four and six apartments. A further two EVs were to be shared between the housing coordinator and the facility manager. There was reserved underground parking for all EVs, which is also where the charging station was located. However, this plan was never realised because none of the residents wanted to take part in the sharing scheme (they were unwilling to share the car between two or more people). It was said in the interviews that they were apprehensive about using the EVs because they did not have confidence in how long the battery would last, where they would be able to charge the car, and how they would be able to integrate that with the trips they needed to make during the day. Furthermore, it was said that for people who needed their cars to go to and from work on a daily basis, the sharing option was not reliable enough as they could not risk that a car was not available exactly when they needed it.

2.2.3 Discussion: Success and Outcomes

Overall, the project is viewed as a success from a research perspective. The most successful configuration in the project is the building-to-grid solution, which is still operative today, and is financially viable. In fact, it was said that even if the solution had to be built without external funding it would still be feasible to do so (with some modification such as having a smaller storage tank which is currently oversized for the building complex). Another important research success is the finding is that even though district heating is being used as a back-up in this configuration, it could still function without it (the CHP and the heat pump are sufficient). Currently, a second project is underway in Austria that follows on from these findings, and it is the same configuration without the use of district heating as back-up.

The stakeholders and experts interviewed are very pleased with the research outcomes, and that the solution works so well in practice, and have reported that it has been an internationally significant success that has kept the attention of Siemens, and led to patents and a potential license. From the point of view of the users, the building-to-grid configuration is considered as a success only after the initial problems in the first few months (lack of hot water in some apartments, problems with heating) had been solved. After these early problems were solved, the residents were not really able to see or feel a real difference neither in the comfort in their home (which was already quite high in international comparison – Austria has the highest standards in subsidised housing in the world) nor in the energy bills they pay from the regular buildings they lived in previously.

The monitoring configuration has been relatively less successful from the perspective of the researchers and stakeholders, and almost completely unsuccessful from the perspective of the users. Nevertheless, a lot was learned from both parties. The researchers learned that many aspects of daily routines that were the focus of the ‘traffic light model’ feedback system, such as washing, laundry and cooking, are highly sticky, especially if children live in the household as well as if the financial incentive is so extremely low (about 15 Euros per year). Furthermore, the times at which the indicator was red (high load and price), yellow or green was not predictable during the day, so it was difficult to plan the chores. Users reported to be quite annoyed by this, and one user said that she was disturbed by the sensor lights in the rooms and she taped over them so she could no longer see them, and was happy when it was all removed. A further unpredictability was the energy bill at the end of the month. Users said that the bills did not always correspond to their expectations, some larger households had lower bills than smaller ones, despite some changes in energy saving behaviour. Users who later reported on what changes they had made in their behaviour were under the impression that they were changing a lot (35% said that they changed the time at which they did the laundry, and 22% reported to changing the time at which they put on the dishwasher) (source: interview with research from the AIT). However, when the calculations were made by the researchers, the share of energy usage during the “green” times were almost the same in the monitoring households as they were in the control group. The researchers were surprised by this, and the users grew frustrated because the researchers could not explain to them why their efforts did not show up as lower energy bills. The researchers had suggested big impacts of the technologies which were later not realized. Thus, overall, the expectations of the users were quite high, but ended in disappointment. One interviewee said that if he had to do the same again, he would appreciate being told a more accurate story of what he could expect.

Stickiness of daily routines was known from previous projects and this project further confirmed this finding. Throughout the duration of the field-test, only about half of the monitoring households had a look at the information on their energy consumption provided in the tablet, and this also varied a lot during the project (higher at the beginning and at the end). One criticism from the users was that it was not possible to see on the tablet what kind of energy source was currently being used to produce the energy. So they could not adjust their consumption to solar energy or other clean energy for example, but only to the price and the load information provided, which was not as satisfactory. The majority of users put more effort in complying with the project demands when they knew that a meeting with the project leaders was coming up and they would be asked questions. Only one household was passionate about the monitoring equipment and decided to keep it, even though it currently does not pay off.

A lot was also learned in the closed EV sharing configuration, especially about the differences in perception between researchers and users. From a research point of view this part of the project failed in getting people to use the shared EVs. It also showed what was wrong with the concept and what needed to be changed. The residents were very positive about the concept when they first heard about the plan, but reluctant to use it when it was made available to them. Some users thought that a move towards emissions free vehicles are generally a good idea, but they are not confident enough to rely on them for their daily needs. It might be too early a stage to expect this shift in this context, and trust still needs to be built over time. In addition to the insecurities involved in how long the car battery will last, and where they will be able to charge it, users placed a lot of importance on always having a car available, which was not believed to be possible in this haring configuration which was 'closed' or limited to a small number of cars for a small pre-defined group of people. Rather, it was learned that an open car sharing service may have been more successful, also because there is a comparable open car sharing project in Salzburg (called EMIL) which currently does work very well. The use of the electric bicycle was also not as frequent as expected, mainly because the elderly residents who live in the housing complex found it too difficult to cycle with. There were also problems with the charging point for the bicycle (it was too sensitive and stopped charging when the bicycle was accidentally moved only by a little bit) and it was sent back to the producing firm to be improved further.

The main preliminary findings with regards to the MATCH framework dimensions of markets, actors and technologies, are:

Markets:

- The configuration that worked best of all was one in which people did not have to change their day to day behaviour for it to work, but rather it worked 'in the background'.
- No loss of comfort to the user was very important for the solution to be considered 'workable'. If different energy sources are being used in the background this is not considered a loss of comfort, although users would like to be informed about the source. A loss of comfort is caused by having to perform daily chores at different times every day. The enthusiasm of making daily modifications to behaviour can be quite high at the beginning when everything is new, but peters off after some time and people tend to lose interest if they are not pressed to do so and no (or minimal) short to medium term benefit is experienced.
- The building-to-grid solution works but it creates a "natural" monopoly, restricting users' freedom of choice. The solution only works because all customers receive the heat (warm water and heating) from one supplier (Salzburg AG).
- The building-to-grid solution works on the flexibility market. It is able to generate power (CHP) when there is a demand from the grid and is able consume electricity (heat pump) at times when there is a surplus supply (renewable production) in the grid.
- EVs are, in this market context studied (apartment buildings, high proportion of elderly residents) still a product that is met with a lot of scepticism. People do not trust that the car batteries will last and that they will be able to charge the cars easily and conveniently.
- The closed sharing concept for cars does not work in this context. People do not trust that a car will be available as and when they need it.
- Even though people were sometimes unhappy with what the solutions may have required of them, they were happy that their apartment buildings got so media and public attention and that they were part of that.

Actors:

- The actors consider the project to be a success for both research purposes and for gaining an understanding of how solutions work in practice. Foremost the DSO

Salzburg AG and the research institute AIT find that their objectives were met in the building-to-grid configuration.

- The involvement in such projects increases user awareness of energy generation and usage (due to direct energy advice), and how they themselves can play a role in this system by changing their household usage. This awareness alone can be very powerful in leading users to try to buy energy efficient devices and save electricity, even if the overall economic outcome for them is quite minimal.
- The project partners maintained a good working relationship during the project and continue to work together on the sharing of data and licensing of patents.
- The households are happy with their apartments, but they were not generally positive about having participated in the energy feedback and DR configuration. They had invested in energy saving equipment when they moved in (state-of-the-art ovens, dishwashers and washing machines) which made energy saving through time-shifting even more difficult. They had expected a greater economic return on their time-shifting efforts, and wished that they had been properly informed about what kinds of savings they could reasonably expect at the start of the project.
- The DSO (Salzburg AG) on the other hand learned from the users about what kinds of energy efficient household devices are on the market today.

Technologies:

- Technically all configurations and solutions can function in practice, but only the building-to-grid configuration can be said to match the current market and actor conditions in this context.
- The building-to-grid solution can even function without district heating as a back-up and it is also economically viable. It of course helps to have a national government subsidy for solar panels, but it is likely that the DSO would build it even without the subsidy.
- The functioning of these technologies in practice is heavily dependent upon diverse actors (for example, DSO, building authority, users) working together. For the technical and business aspects to better fit the market, greater alignment is needed between what users need and want in their day to day lives and what solutions the project actors want to experiment with.

2.3 Case 3: VLOTTE

2.3.1 Background and Project Characteristics

The federal state of Vorarlberg is the most western state of Austria and borders the countries Germany, Switzerland and Liechtenstein. It covers 2.601 km^2 from the river Rhine to Lake Constance to the Arlberg and the Silvretta Alps. Only 69 km of the 321 km long border connect Vorarlberg with the rest of Austria. Two thirds of the state is at an altitude higher than 1.000 m above sea level, 35.9 % is covered by forest and the Alps make 23.3 %. Compared with the rest of Austria, it is situated in the drainage area of the Rhine and not the Danube. From its area and population, it is the second smallest state in Austria and has a population of 383.094 (2015). In the last thirty years, it had the highest demographic growth in Austria with 22 %. It is also the state with the highest share of young persons (16 % are less than 15 years old).[24] Vorarlberg has a GDP per capita of 41.500 € and an unemployment rate of 3.4 % (2014) which is low compared to the Austrian average of 5.6 %.[25]

Vorarlberg's industry underwent a substantial transformation in the past 40 years. It changed from textile production as the main driver to the production of machines and metal making, which now make up around 50 % of the industry. Vorarlberg exports 60 % of its goods to foreign countries. In comparison, foreign exports for the rest of Austria are 40 %. The energy sector is growing due to the expansion of hydropower and favourable natural conditions. Renewable energy roughly covers the energy demand in the state and surplus is exported to neighbouring countries such as Germany. Further, the tourism industry is an important part of Vorarlberg's economy and it is an attractive tourist destination throughout the entire year. The majority of people are employed in the services followed by industry and trade (cf. Landespressestelle 2015).

What makes Vorarlberg unique in Austria is not only its geographic position, but also the dialect. It is the only state with Alemannic dialects[26], which are spoken equally in private as well as in public. Dialect is an essential part of the people's identity in Vorarlberg. In the rest of Austria Bavarian dialects are prevalent.

Vorarlberg is constituted of the four districts Bregenz, Dornbirn, Feldkirch and Bludenz and has 96 municipalities, 5 cities and 11 market towns. Since the beginning of the Second Republic (1945) Vorarlberg has been dominated by the conservative party (*ÖVP*) and since the last election 16 of 36 seats are held by them. Federalism is traditionally emphasised in Vorarlberg and there is also a tradition of being fundamentally oppositional to the Federal Government in Vienna in some cases.

In 2009, all parties agreed on the strategic goal of Vorarlberg becoming energy autonomous by 2050.[27] The energy autonomy goal is understood as a process for development and design of a sustainable energy supply. Therefore, it aims at producing as much energy from renewable resources as is demanded. The strategy is based on four pillars: saving energy, energy efficiency, renewable energy as well as research, development and education. To reach this goal, the federal government initiated several steps that have already been taken and further steps that are currently in the process of development. Some of the preferential measures are a program for mobility planning for

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[24] https://www.vorarlberg.at/pdf/vorarlbergkompaktb11153_1.pdf, accessed 29 August 2017.

[25] https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/Vorarlberg, accessed 29 August 2017.

[26] There are also small regions in Tyrol where Alemannic dialects are spoken, but not as extensively as in Vorarlberg (https://de.wikipedia.org/wiki/Alemannische_Dialekte, accessed 20 August 2017).

[27] https://www.energieautonomie-vorarlberg.at/de/, accessed 27 August 2017.

municipalities, expansion of the cycle path network, energy monitoring of public buildings and expansion of hydropower. A visionary process was the basis for reaching the climate goals and therefore working groups for the topics renewable energy, buildings, trade and industry as well as mobility and spatial planning have been built. These working groups wrote frameworks where the steps for each topic are formulated. Currently, it has been agreed on steps to be taken until 2020, which is seen as the first stage of the plan to reach energy autonomy by 2050. This stage is based on the European Union's 2020 goals. The 1990 level is taken as the initial point and for Vorarlberg this means that the energy consumption has to be reduced by 15 % in comparison to 2005, CO_2 emissions by 18 % and the share of renewable energy has to be expanded by 13 % in comparison to 2009. More precisely, 101 measures need to be adopted. They are called the *101 enkeltaugliche Maßnahmen* (measures fit for grandchildren) (Energieautonomie Vorarlberg 2011). As the name already suggests, the measures are meant to preserve the world as a liveable place for the grandchildren who are yet to come.

illwerke vkw is a group of companies composed of Vorarlberger Illwerke AG (peak and control energy and tourism), Vorarlberger Kraftwerke AG (energy supply, energy services and energy trading) and Vorarlberger Energienetze GmbH (electricity and gas network). The group is 95.5 % state-owned (Vorarlberg) and the remaining 5 % are owned by an asset company in property of the state Vorarlberg as well as in diversified holdings (Vorarlberger Illwerke AG 2016). As a state-owned company, illwerke vkw supports Vorarlberg in reaching its aim to become energy autonomous by 2050. Different measures are necessary to achieve this goal, one of which is the diffusion of electric mobility. Vorarlberg is the electric mobility pioneer region in Austria and the leading state in new registrations of e-vehicles. There are several reasons behind the region's successful implementation of e-mobility. In general, different tax benefits, low maintenance costs and an increasing driving range bring more and more private persons as well as businesses to buying an e-vehicle. Short distances, a pro-active federal government, a general eco-friendly mentality of the people and illwerke vkw's dedication to e-mobility are supporting factors. Furthermore, illwerke vkw has established a mobility centre (*Mobilitätszentrale*) where counsel is offered free of charge and different kinds of e-vehicles can be tested. However, the origin of the success of e-mobility in Vorarlberg lies in the project VLOTTE.

VLOTTE started as a project initiated by the e-mobility model region funding program (*Modellregionen der Elektromobilität*) of the Climate and Energy Fund (*Klima- und Energiefonds – KLIEN*) and the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (*BMLFUW*) in late 2008. E-mobility model regions were not common in Austria at that time and the Climate and Energy Fund was one of the groundbreakers for the establishment of electric mobility. Today, there are 7 model regions in the whole of Austria: Vorarlberg (*VLOTTE*, call 2008 and 2009), Salzburg (*ElectroDrive Salzburg*, call 2009), Vienna (*e-mobility on demand*, call 2010), Graz (*e-mobility Graz*, call 2010), Lower Austria (*e-pendler in niederösterreich* (e-commuters in Lower Austria) call 2011), Carinthia (*E-LOG Klagenfurt*, call 2011) and Vienna (*E-Mobility Post*, call 2011). Except the *E-Mobility Post* project which runs in all of Austria, all the other projects are limited to a geographic region. The general idea behind the e-mobility model region programme was to test different e-mobility systems and to pave the way for e-mobility technology for everyday life. The different actions in the projects on vehicles, infrastructure, business and distribution models made it possible to bring around 2000 e-vehicles on the streets and to install about 3000 charging points between 2009 and 2011. The funding programme included three stages: 1. test of electric mobility in different regions und building up of different systems; 2. funding of networking and consolidating projects in cooperation with the different model regions; 3. spreading of experiences and gained knowledge in whole Austria (Klima- und Energiefonds 2017). The last call of the funding program was in 2014.

The project VLOTTE (2009-2011) was initiated by the independent non-profit organisation Kairos in Bregenz. illwerke vkw then submitted the proposal to the first e-mobility model region call in late 2008 also due to support from the federal government. It was the only accepted project during that time. According to the person responsible at KLIEN only one project was funded because of the limited financial resources. One condition of the call was that an operating company was handing in an application, so the risk would not be on the side of the customers. At that time, the development of e-vehicles was in an early phase and there was only a very limited amount of charging points available. Also, the proposition had to lay out a plan for an overall mobility concept for a larger region. The idea of VLOTTE was to establish an e-mobility model region and therefore prove the suitability for daily use of e-vehicles. In the early days, VLOTTE did not have a specific focus, but a broader approach: new plants for renewable energy were built, charging infrastructure was established and early e-vehicles were brought to Vorarlberg. Then, e-vehicles were not common and electric mass-production vehicles did not exist. Therefore, experimental e-vehicles and conversion vehicles had to be sought, the early cars were four Th!nk City of the Norwegian company Think Global. Potential customers had to accept these cars and pay a comparably high price to be able to drive an electric car. The first batteries in use were ZEBRA-batteries, which today cost around 12.000 € for 2 kWh.[28] These early batteries were not only very expensive, but also highly inconvenient. When not in use, they had to be kept at a temperature of 260 °C to stay operative (VLOTTE 2016). Therefore, energy was not only used during operating times, but it was also wasted when the vehicle was not in use. The target group was composed of 40 % public administration, 40 % businesses and 20 % private customers. Especially public administration institutions and businesses were of interest due to the risks and the high costs in the beginning. They were seen as forerunners in the e-mobility innovation process. After the launch of serial models like Mitsubishi i-MiEV more private persons were targeted. ZEBRA-batteries were in use until late 2010. In 2011, 631 e-vehicles were newly registered in Austria. 279 e-vehicles within the project VLOTTE, which amounts to 44 % of new registrations. Then, 272 of the 279 e-vehicles were equipped with lithium-ion batteries (ibid.).

After the publicly funded project phase, illwerke vkw turned VLOTTE into a business model, which is still operative today. The early business model of VLOTTE was built around a mobility card (*Mobilitätskarte*), which cost around 500 €/month. It covered the lease of an e-vehicle, maintenance costs, a ticket for public transport in Vorarlberg, unlimited access to charging stations and membership in the Austrian automobile club with roadside assistance (*ÖAMTC*). After four years of use, the customers could buy the e-vehicle for 25 % of the original price. From 2011, it was possible for business and public administration customers to return the car to the Raiffeisen Leasing GmbH (financing institution of the e-vehicles) after five years of use.

Throughout the project duration, 113 public charging points were established. In spring 2012, 29 further charging stations and three fast charging stations were built. The stations are situated at well accessible and convenient places like supermarkets car parks.

In 2010, the second phase of VLOTTE started, called *VLOTTE II*. It aimed at making electric mobility more accessible. Therefore, so called *e-stationen* (e-stations) were implemented, where e-vehicles, e-scooters and e-bicycles could be rented. The idea was to make e-mobility accessible for every third person in Vorarlberg. After two years this stage of the project showed that the offer was not accepted by the public.

VLOTTE III or *VLOTTE EMOTIONS* (start 2012) was the stage of VLOTTE where the *E-Mobilitätszentrale* (e-mobility centre) was established, positive awareness in the public was actively spread and impact studies were conducted to substantiate efforts at persuasion in politics and in business. The *E-Mobilitätszentrale* is a measure to develop a comprehensive range of consulting and technical services for e-mobility. It is also a

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[28] https://sedl.at/Elektroauto/Akkus, last accessed 6 September 2017.

platform for automakers to present their models and their companies. Potential customers can consult the *E-Mobilitätszentrale* online, via phone as well as physically at the location of the illwerke vkw in Bregenz. As of 2014 the service is free of charge after the purchase of the *VLOTTE Mobilitätskarte*[29] (VLOTTE mobility card, 5€). There is no bias to a specific brand of car and it is possible to go on test rides. This project ended in late 2015, but is still operative.

Even though VLOTTE evolved from a demo project to a business, most of the technology is still in an experimental phase. Therefore, small demo projects are also carried out on the site of illwerke vkw. A business-oriented demo project is the EV car park at the head office in Bregenz, internally called *Hochgarage* (multi-storey car park), which started in 2015. A smaller scale and private-oriented demo project is the smart energy trial household, which started in 2011. Both projects are still running and the *Hochgarage* is today well-implemented in the day to day business. These projects are not only carried out due to testing purposes, but they also substantiate the credibility of illwerke vkw internally as well as externally in the public.

In *VLOTTE IV* or *VLOTTE MEET&CHARGE* e-mobility was further spread in Vorarlberg. In addition to the already established public charging points, e-parking at restaurants was built (*e-Gastro*). This phase of the project builds on experiences made in the former phases. Smart wall boxes with at least 11 kWh delivery rate fuel by green electricity were installed. It is financed by *Ökostrom für E-Mobile* (green electricity for e-vehicles) and a structure fee of the restaurant. The restaurant in return can charge their customers for the use of the e-charging stations. The first site was opened in September 2014. One year later already 13 sites have been opened. Further sites are already being planned (November 2016). Hotels and restaurants are generally of interest as e-mobility is gaining more and more significance in tourism. However, potential business partners are still not convinced and are under the impression of not being well informed enough of conditions and possibilities. Therefore, VLOTTE cooperated with the *Wirtschaftskammer Vorarlberg* (Economic Chamber Vorarlberg) and contacted 800 hotels as well as restaurants. Of the 800 potential customers, 38 decided to test one of the three packages illwerke vkw has on offer. For illwerke vkw hotels and restaurants are a future market opportunity. In October 2017, it was announced that VLOTTE is expanding to Salzburg. Here, charging infrastructure for hotels and restaurants is offered. The key products are customised solutions so hotels and restaurants can meet the e-mobility needs of customers and employees (Vorarlberger Kraftwerke AG 2015).

VLOTTE 2.00 is the most recent initiative. In this initiative commuters are the target audience. 125 e-vehicles for commuters were subsidised with EUR 4000 each. EUR 500.000 was the whole funding sum and it is a product of illwerke vkw. Until November 2016, 113 subsidies were handed out and 85 commuters have already received the funding. To simplify the communication between car dealers and illwerke vkw a new platform was programmed, where all relevant data is gathered.

The current and last phase VLOTTE is in shifted from a project-oriented to product-oriented program. When the first phase was primarily about testing the technology and finding interested customers, and the second phase was about the distribution and dissemination of e-mobility itself, the third phase is more business- and user-oriented. This means that illwerke vkw reacts to customers' needs and develops products induced by customers' demands. One example is the configuration company e-fleet. In this configuration, a business owner approached illwerke vkw with the demand to build public charging infrastructure on the company's car park, which is also the car park of a shopping centre. Hence, the installed fast charger belongs to illwerke vkw, can be used by customers that own a *vkw Mobilitätskarte*, but it is also in front of the company's office and therefore easily accessible by the employees.

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[29] Not to be mistaken with the first *Mobilitätskarte*, that offered a whole e-mobility package. The second *Mobilitätskarte* only covers the information service as well as test drives.

2.3.2 Socio-technical Configurations

In our case study, we analysed the three configurations EV car-park, company e-fleet and smart energy trial household, which were all realised within the frame of the project VLOTTE.

The first configuration is a car park of illwerke vkw, where the company’s e-fleet is charged. The second configuration is the e-fleet of an external company with a contracting fast charging point from illwerke vkw. The third configuration is a demo project and operates on the household level. All three configurations are still operational today and in the process of being further developed. The main socio-technical dimensions in each configuration are presented in Table 6 below.

Table 6. Socio-technical configurations in the VLOTTE (E-Mobility) project

	EV car park	Company e-fleet	Smart energy trial household
Technical elements	Car park with rooftop PV (60 kW peak) Converter Stationary battery (reused care batteries) Smart (interconnected) wall boxes Standard grid connection Company e-fleet with approximately 40 EVs Online reservation system	Company e-fleet with 15 EVs Fast charging point Strong grid connection Two wall boxes	Rooftop PV (5,2 kW peak) Converter and control unit Stationary battery (10 kWh) 2 Conventional chargers E-vehicle (16 kWh battery) Monitoring equipment and online tools (for the battery and the converter)
Social elements	Owned, operated, and used by the energy service company (ESCO) No contracts with external partners Demo project (now in regular use)	Contracting model (between the ESCO and the fleet owner) The fast charging station is open for the public Smaller wall boxes for internal use only Commercial solution	Private household (3 adults) Technical equipment owned by the ESCO (except PV) Subsidised feed-in tariff (till 2016) Contact person is employed by regional ESCO Company-internal research Informal agreement

EV car park

The first configuration is an internal project of illwerke vkw. The Hochgarage (high-storey car park) started as a demo project and is now in regular use. It is owned, operated and used by the company and continuously further developed. The technological elements are a car park with rooftop PV, a converter, a stationary battery (reused car ZEBRA-batteries), smart wall boxes and a standard grid connection. It all started in the year 2015 when illwerke vkw did a review of the efficiency of the company's own fleet of vehicles (how often cars are actually used, how many kilometres they are driven etc.). Today, every employee can book a car online, they have to type in where they are going and then the system assigns them a vehicle (both types of vehicles). Today, short distances are usually driven with e-vehicles. In the beginning, the fleet department had to monitor when which car was booked and for what distance. If a combustion car was booked for a short distance, the employee was contacted by the fleet department with the offer to change the selection from combustion to e-vehicle. This way, educational work was carried out as the employees were a little hesitant to choose an e-vehicle over a combustion car in the beginning. The introduction of e-vehicles and the smart booking system happened simultaneously but are not connected. However, the booking system eases the management of the e-vehicles for the fleet department. At the moment, the automakers have not shared the interface of the state of charge of the battery yet, so the battery cannot communicate with the system. Therefore, the user has to tell the system the battery status when returning the e-vehicle and the system automatically blocks the car for roughly one hour to ensure that the next user will find a fully loaded battery. The whole fleet at the car park site has roughly 60 cars, about 18 of them are e-vehicles (Renault ZOE). There are many more e-vehicles throughout the entire fleet, but these are assigned to specific employees. In total illwerke vkw has 35-40 e-vehicles available at different sites. Load management is the other challenge that needs to be tackled. The supply cable of the Hochgarage is quite generous, but not sufficient for the need of all 20 e-vehicles. As an expansion of the grid connection would require high investments, a smart load management strategy is implemented. The rooftop PV with 60 kW peak is also contributing to the power that is needed, but is not a key element of the configuration. The PV energy is stored in a stationary battery, which consists of two Zebra batteries of discarded Th!nk City e-vehicles. The vision is that the battery will be contributing to the load management, but it is still in an experimental phase of the project and not fully applied. The controller of the load management communicates with the wall boxes. There are two master wall boxes that communicate with the client wall boxes. A crucial aspect of the configuration is the smart, fair und grid-friendly distribution of power as the whole facility has a limited grid connection (it was decided at the beginning to avoid costly investments for a stronger grid connection in order to “simulate” real-world conditions). If several e-vehicles are charging at the same time, they are also all being charged at the same speed. Prioritising one vehicle over another is not implemented yet, but it is one of the next goals. Prioritising in this case would mean charging vehicles according to the immediate requirements (reservation ranking and planned routes). The automatic blocking of returned e-vehicles is just a temporary solution. However, the system tells the e-vehicle that it does not necessarily need to load with 22 kW when the battery is still half full and 11 kW would be sufficient. Generally speaking, the configuration works very well and the *Hochgarage* is also an ideal test site and will be continuously used as such.

Figure 19: Renault Zoes charging at the EV car park of illwerke vkw.

Company e-fleet

The company e-fleet is the most recent configuration, started in May 2016 and can be counted as one of VLOTTE's products. The company, which is a customer of illwerke vkw, has two sites in smaller municipalities in Vorarlberg and the fleet is based in the primary location of the business. The business owner decided that he wanted to transform the company's combustion fleet to an electric one. Several reasons supported this decision, such as his desire to boist the overall image of the company, tax reasons for both the employer as well as the employees, funding by the government and also environmental factors as the company has been active in several eco-projects in the past. The entry point into e-mobility and renewable energy was the installation of a rooftop PV two years before the transformation of the fleet. This rooftop PV has an output of around 1 MWh per year and started a transformation process towards green energy. The technical elements of the configuration are 15 EVs, a fast charging point and a strong grid connection. The EVs are leased from a car dealer the business has a partnership with and the fast charging point is part of the contracting model with illwerke vkw. There are also two wall boxes in the underground parking facility of the company. The reason why the e-cars are leased is that the technology is quickly evolving and buying such a technology is not of interest to them. In 2011, illwerke vkw contacted the company in the early days of the VLOTTE project and provided a Mitsubishi i-MIEV for a monthly lease, so this was not the first time the company had an e-vehicle in their fleet. The e-car was only used randomly as the employees were not happy with the model itself. During that time a charging point was also installed close by at the car park. Today, the e-fleet consists of ten VW e-Golfs and five Renault ZOEs. Both vehicles usually take between six and eight hours to load using the standard wall box. As it is a building company and therefore frequent travel is happening during the day, six to eight hours are not practicable in any case. Therefore, the business owner contacted illwerke vkw and asked them to build a fast charging point with 50-60 kW. The cost for a fast charging point is approximately around 30.000 €, which the business owner did not want to invest. Based on these aspects the contracting model evolved: illwerke vkw planned and built the fast charging point, the company provided the building ground and pays a monthly fee (between 600-700 €/month) that covers unlimited charging. The fast charging point is also open to public use. Overall, the business owner as well as the employees are satisfied with the transformation and did not make any negative experiences. Especially the employees who use the EVs on a daily basis are content and were surprised how well everything works. Key is a Good communication, coordination, and mutual help between the employees are key, as well as knowledge about when their colleagues need to use the fast charging point. A major concern they had in the beginning was about the range of the e-vehicles, but as the construction sites are mostly close by, and a construction manager roughly commutes around 160 km/day, the range of the current models is sufficient. However, they would not mind if they had to charge the vehicle less frequently.

Figure 20: Public charging station at the car park of the company e-fleet.

Smart energy trial household

The third configuration is a technical trial arrangement located in a private two family house in Vorarlberg. The trial was initiated and implemented by the regional ESCO (illwerke) as a spin-off activity of the VLOTTE project. The main focus of this trial was to gain practical experience with PV system, stationary battery systems and electric vehicles in a realistic use environment. The trial household has been selected from among the employees. The selected test site has been already equipped with a PV rooftop system (5,2 kW peak) at that time and the employee (contact person) was highly motivated to run the trial. The trial started in 2011 with the e-vehicle (Citroen C-Zero), and in 2014 the battery system was added. The local contact person still uses and monitors the technical equipment, main findings, however, have already been collected in the first two years. The technical elements of this configuration involve the rooftop PV system, a converter and a control unit, a large stationary battery system (10 kWh), monitoring and metering technology, a conventional charging device, and the e-vehicle. All equipment except the PV system is (still) owned by the regional ESCO. The homeowner did not have to pay any costs except for a very cheap rental of the e-vehicle. The trial household can use the devices without restriction and benefit financially from it. In return, the homeowner provides all data, actively participates in the project and guarantees the project owner unrestricted access to the facilities. These rules only are set out in an informal agreement. First and foremost, this arrangement led to a significant increase in the share of own electricity consumption. Before the battery had been installed, the household was able to consume 15% of the electricity from the own PV system on an annual basis. With the battery system this number rose to 40% (in the summer half-year, the household is almost self-sufficient at 98%). Within the trial period the household could not profit from this higher share of self-consumption due to an existing subsidized feed-in tariff. However, this situation has changed in the meantime, now only the first 3000 kWh per year are being purchased by the energy supplier at a high tariff (15 Cents per kWh) but it is too early to assess the economic impact of this change in the tariff system. The PV system, the stationary battery and the e-vehicle the technology work reliably with one exception – in the beginning of the trial an installation error caused an overvoltage that destroyed the inverter and the charger. The users did not have to adapt their daily routines to the technology at all as load shifting never was part of the trial. The e-vehicle worked well, but due to the very small capacity of battery and charger and because it was only used as a second car it had no considerable impact on the energy consumption pattern of the household. The project owner learnt a lot about the proper dimensioning of this technology and the knowledge which was gained has been incorporated into the consulting activities of the ESCO.

2.3.3 Discussion: Success and Outcomes

Seen from the perspective of the stakeholders the project is very successful. Starting with the organisation Kairos, which wanted to promote e-mobility in Vorarlberg to the federal government with their climate goals to illwerke vkw, who want to support the federal government in their sustainable development goals but also expanded their product line. The Climate and Energy Fund as a federal project funder wanted to pave the way for alternative modes of driving with the funding program e-mobility model region (*Modellregionen der Elektromobilität*) and has expanded their e-mobility region funding program. In terms of technology the project was very experimental in the beginning and therefore risky for both stakeholders as well as users. However, taking the risk has paid off and VLOTTE made the transition from an experimental project to a business model. At the moment, the range of e-vehicles is still controversially discussed and might be one of the reasons why some potential customers are still not convinced enough to purchase them. The company with an e-fleet solved this problem by leasing e-vehicles, which was also part of the early VLOTTE concept. Important aspects are the strong ties between the company and the regional government and the dedication of illwerke vkw to the topics renewable energy and e-mobility. New technologies are not only tested, but there is awareness within the company that trials should be run in the first place with participation of the employees instead of regular users. Therefore, the company can build up credibility and it is more likely to get support from the public. This is the case with the smart energy trial household. Here, not only the technology, but also different tariff models could be tested. These findings helped with the setup of new projects and business ideas. A concrete example in the trial household case is the development of the product “virtual storage”. In order to meet the customer's desire for more autonomy and at the same time to take into account the currently still very high costs of battery systems, customers can store their surplus solar power in a pumped storage power plant and purchase it later at no additional cost. Also, the company e-fleet is a successful business case. It was a direct spin-off of the VLOTTE project and the contracting has now been in use in other businesses as well. The business partner was an early adopter, but is still satisfied with the solution and is currently cooperating with illwerke vkw at one of the company's other locations. Furthermore, the internal project *Hochgarage* can be seen as being on the threshold from an experimental to a potential product. Subsidies were always beneficial as these motivated the customers to take part in the project. Financial incentives have been mentioned throughout the case as key factors.

The VLOTTE project and its implementation have shown that communication and interaction are crucial in this still experimental field. Businesses like car dealers are still very sceptical of EVs, but are important partners and need to be motivated. Furthermore, customers and potential users need to be approached. illwerke vkw did so by hosting events and offering communication platforms like the *Mobilitätszentrale*, where interested parties had the opportunity to discuss their concerns. The involvement of people is of general importance as they are usually more cooperative and supportive if they feel heard. These events also strengthened the social cohesion of EV drivers to organise their own events, drive in convoys to events and are generally very positive in their attitude towards e-mobility. This is not necessarily the case when the EV is a company car.

The regional aspect of the success of the project should not be underestimated. Even though the goal to become energy autonomous by 2050 is based on the EU's 2020 goals and Austria in general pursues similar goals, the federal government of Vorarlberg has been very supportive of experimental demo projects. Another aspect are the short driving distances in Vorarlberg on account of its spatial small size, that probably reduced some of the prejudices towards the range of e-vehicles and the progressive attitude of illwerke vkw as a state-owned company. It is questionable that a similar project in Lower Austria would be as successful as in Vorarlberg.

Overall, the success of VLOTTE can be summarised as follows:

Markets

- EVs have transformed from converting vehicles to serial models, which of course is not directly related to the project.
- However, in parallel to these developments, VLOTTE prepared a favourable and well-working environment for e-mobility including charging infrastructure expansion (e.g. region with the highest number of charging points per capita in Austria), a broad range of consulting services (e.g. tailor-made energy solutions), new business models (e.g. public-private charging station) and products (e.g. virtual electricity storage).
- The expansion of VLOTTE to Salzburg is also due to the successful implementation of e-mobility in Vorarlberg.

Actors

- A significant part of the success lies in the strong connection between illwerke vkw and the federal government. As a consequence, political visions directly influence the strategic orientation of the company (and vice versa).
- Furthermore, the ESCO usually runs trials internally before reaching out to the public, which fosters the credibility; this was the case with the trial household as well as the *Hochgarage*.
- Moreover, the cooperation with customers and the meeting of customers' demands also works very well; as seen in the tailor-made company e-fleet solution. The project owner is still enthusiastic about the topic and is constantly working on new related projects and products. They are working together with other

actors like funders and potential customers to adapt their products to the existing needs and demands.

Technology

- The technology has proven that it works.
- In case of the EVs the range is still a limiting factor, but the technological progress in this area is rapidly advancing.
- Load management in the *Hochgarage* works well and helps to charge a larger number EVs in an efficient way. E-vehicles are charged when needed and at the same time additional financial investments in network infrastructure could be avoided.
- Based on the practical experience, a series of new ideas for further improvements of the tested solutions have been developed, some of which have already been taken up, such as the prioritised charging in the car park or the integration of the second life battery.
- The main focus in this case is on the integration of existing technological options to well-working solutions.

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Case study report Denmark

Findings from case studies of ProjectZero, Renewable Energy Island Samsø and Innovation Fur (GreenCom)

Version 1.0

Toke Haunstrup Christensen & Freja Friis

Danish Building Research Institute, Aalborg University

23 November 2017

ERA-Net Smart Grids Plus | From local trials towards a European Knowledge Community

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About ERA-Net Smart Grids Plus

ERA-Net Smart Grids Plus is an initiative of 21 European countries and regions. The vision for Smart Grids in Europe is to create an electric power system that integrates renewable energies and enables flexible consumer and production technologies. This can help to shape an electricity grid with a high security of supply, coupled with low greenhouse gas emissions, at an affordable price. Our aim is to support the development of the technologies, market designs and customer adoptions that are necessary to reach this goal. The initiative is providing a hub for the collaboration of European member-states. It supports the coordination of funding partners, enabling joint funding of RDD projects. Beyond that ERA-Net SG+ builds up a knowledge community, involving key demo projects and experts from all over Europe, to organise the learning between projects and programs from the local level up to the European level.

www.eranet-smartgridsplus.eu

Preface

This report is the outcome of work package 2 *Detailed case studies* of the ERA-Net Smart Grids Plus project *Markets, Actors and Technologies: A comparative study of smart grid solutions* (MATCH), which involves partners from Austria, Norway and Denmark.

The aim of MATCH is to explore how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. This is studied on basis of detailed national case studies carried out in each of the three participating countries. This report (MATCH deliverable D2.2) presents the main findings from the Danish case studies.

The national case studies establish the empirical foundation for the comparative analysis across cases and countries in work package 3 *Identifying determining factors for integrated and successful smart grid solutions* and for the later work package 5 *Recommendations for designers, planners and policy-makers*. The deliverables from these work packages will be published on the website of MATCH (http://www.match-project.eu/), which also includes further information about the project and its other publications. The latter includes coming scientific papers that are going to explore differences and similarities between cases in further detail in relation to specific research questions.

The empirical work in relation to the national case studies was guided by an analytical framework developed in the MATCH work package 1 *Design of overall analytical framework for case studies*. This deliverable (D1) can be downloaded from the MATCH website. The framework combined different theoretical perspectives in order to establish a shared understanding of how we should approach the cases and what kind of data to collect. This ensured a certain degree of empirical homogeneity between the national case studies.

In order to support the comparative analysis, the national case study reports (D2.1-D2.3) follow the same outline. Thus, in the following, we will first present the national context of the Danish case studies (Chapter 1). This includes a brief introduction to the national profile of Denmark in addition to a presentation of the Danish energy system, policies & regulation, market structure & energy consumption and, finally, the smart grid landscape. Then follows the main part of the report (Chapter 2), which presents the outcome of the Danish case studies. A brief description of the empirical work carried out introduces this chapter, and is followed by three sub-sections presenting the findings from the three national cases: Innovation Fur (GreenCom) on the island of Fur (section 2.1), ProjectZero in Sønderborg (section 2.2) and Renewable Energy Island Samsø (section 2.3). Each of these case presentations is organised in three sub-sections: Background and project characteristics; socio-technical configurations; Discussion of successes and outcomes.

Toke Haunstrup Christensen
Freja Friis

Copenhagen, 17th of November 2017

1 National context factors

1.1 Country profile of Denmark

The kingdom of Denmark (excluding Greenland and the Faroe Islands) has a total area of about 43,000 km². The main part measured by land area is the peninsula Jutland and the rest of the country consists of 406 islands, 78 of which are inhabited, with the largest being Zealand, the Northern part of Jutland and Funen. Denmark also exercises sovereignty over the Faroe Islands and Greenland, but both enjoy autonomous self-government. Compared to the small size of the country, Denmark has an extraordinary extensive coastline of more than 7,300 km, which corresponds to almost 1.5 metres of coast per inhabitant. Denmark's topography is relatively flat with few hills and the highest point being no more than 173 metres above sea level. The flat topography partly explains why Denmark has a long history of farming and the fact that two-thirds of the landscape is agriculture areas (Statistics Denmark, 2016a; IEA, 2011).

The position between a continent and an ocean means that the Danish weather often changes. The average temperature ranges from -1 °C in February to 17 °C in July. Further, because of Denmark's northern location, there are large seasonal variations in daylight with short days during the winter (7 hours of daylight) and long summer days (17 ½ hours).[1]

By January 2016, the population was 5.7 million people. The country has witnessed decreasing birth rates and a general ageing of the population, but due to immigration the Danish population has still increased slightly. Overall, Denmark has about 2.7 million households, which results in an average household size of 2.2 persons (Statistics Denmark, 2017). Reflecting the global trend of urbanization, the populations of the largest cities (including Copenhagen, Aarhus, Odense and Aalborg) are increasing, while the population size in the peripheral regions decreases. Hence, municipalities covering the peripheral areas are in particular struggling with a variety of strategies to retain and attract citizens to their region (Local Government Denmark, 2014).

Over half of the population (58%) live in owner-occupied dwellings with an average area per person that has increased continuously during the years, which is partly explained by more people living alone, partly by a general increase in the size of new-built owner-occupied dwellings. In particular, 70% of people aged 50-70 years live currently in owner-occupied dwellings, while there is a greater share of 20-33-year-olds and persons aged around 80 years living in rented dwellings (Statistics Denmark, 2016a).

Based on a liberal capitalist economy, the Danish welfare state regime follows the Scandinavian social democratic welfare model, with principles of universalism and social rights extended to both the working and the middle classes. With one of the world's highest personal income tax rates, this entails the pursuit of high equality and high-quality service provision for all (Esping-Andersen, 1990). For example, almost all citizens in Denmark receive social services at shorter or longer periods in their lives, e.g. children families are offered day-care institutions (with a limited user charge) and child benefits, and a major part of the elderly receive pensions, nursing care, nursing homes (with a limited user charge), help in their homes etc. (Statistics Denmark, 2016a)

Ageing of the population in combination with low birth rates and difficulty in keeping labour market participation high have resulted in the emergence of a policy discourse, which emphasises the future pressure on public budgets being a major challenge to the Danish welfare state. Accordingly, the policy response has recently been to limit access to early retirement and to implement cuts in social security and unemployment benefits (Larsen et al., 2017). Recently, the number of retired persons has passed 1 million (Statistics Denmark, 2016a).

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[1] www.dmi.dk

Although the five regions are responsible for the provision of hospitals, the State and local government level (98 municipalities in total) take care of almost every other matter such as housing policy, urban and regional planning, environmental issues etc. Most of the social welfare (e.g. home help of elderly, unemployment benefit and programmes, schools etc.) is provided at the municipality level. The four largest municipalities are also covering the four largest Danish cities: Copenhagen (602,500 inhabitants by 2017), Aarhus (335,700 inhabitants), Aalborg (212,000 inhabitants) and Odense (200,600 inhabitants). The remaining 94 municipalities have an average size of 46,800 inhabitants; hereof, 79 have more than 23,000 inhabitants and only 15 less (the smallest five being islands like Samsø). (Statistics Denmark, 2017)

Since Denmark in 1972 joined the European Community (EU in 1993), the national policy within financial affairs, foreign policies, justice, social dimensions and energy and climate etc. has been influenced by the current EU-regulation on many areas.

The national growth in GDP in 2016 counted for 1.6%, and the average GDP per inhabitant is about 41,000 EUR[2]. The disposable income differs according to the municipality of residence as e.g. the metropolitan areas and large cities account for the greatest incomes. In 2014, the unemployment rate was 6.4% of the total workforce, which is among the lowest in Europe[3]. Based on a Eurostat survey, Denmark accounts for the highest consumer prices in the EU. Regarding this, in particular consumption and money spent on dwelling (including rent and heating) have increased, while expenses on food and beverages have decreased (Statistics Denmark, 2016a).

1.2 The Danish energy system

The Danish power transmission network is divided into two separate grids; the Western transmission grid (Jutland and Funen) is connected to the European continental grid, while the Eastern grid (Zealand and islands south of Zealand) is connected to the Nordic grid via connections to Sweden. Since 2010, the Eastern and Western areas have been connected via a 600 MW DC connection across the Great Belt (between Funen and Zealand). The East grid includes four AC interconnections with a total transmission capacity of 1,900 MW to Sweden and a 600 MW DC connection to Germany. The West AC transmission connection to Germany is determined by congestion in the surrounding grids and has a normal capacity of 1,500 MW in the southbound direction and 950 MW in the northbound direction. Further, West Denmark is connected with DC connections of 740 MW to Sweden and 1,040 MW to Norway. (Sorknæs et al., 2013)

Denmark is part of the Nordic power trading market Nord Pool, which is a platform for day-ahead and intraday trading. The day-ahead Nord Pool spot market operates in the Nordic countries, the Baltic countries and the UK.[4] Because the Danish grid is separated into two different areas, and as a result of bottlenecks in the electrical grid in the Nord Pool Spot area, the Danish electricity market is divided into two price areas; West Denmark and East Denmark.

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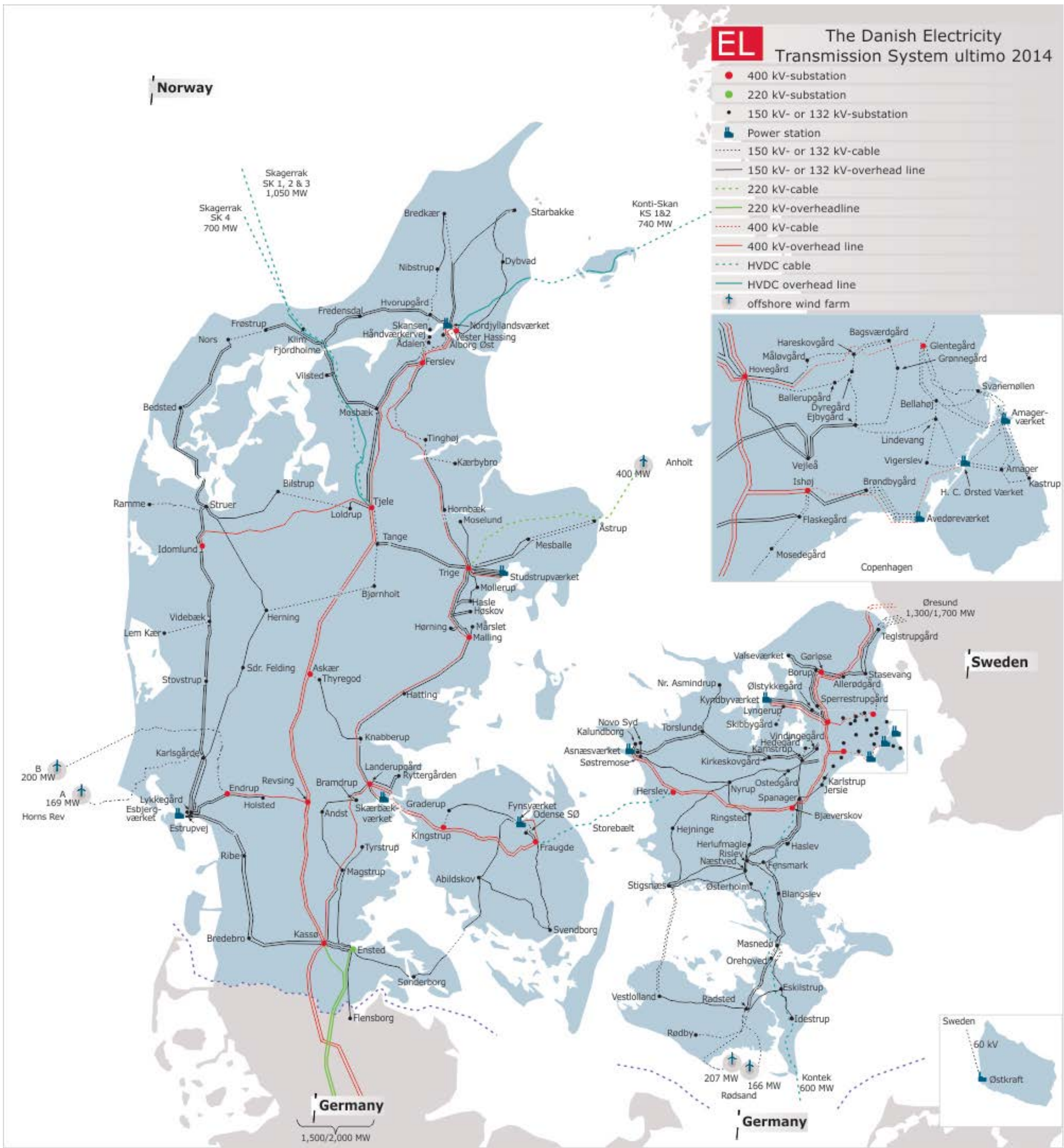
[2] www.geotema.dk

[3] https://data.oecd.org/unemp/unemployment-rate.htm

[4] http://www.nordpoolspot.com/TAS/Day-ahead-market-Elspot/

Figure 1: Overview of the Danish Electricity Transmission Network



Reproduced from: www.energinet.dk

According to the World Economic Forum, Denmark has one of the highest energy securities and reliable electricity systems in Europe.[5]

By 2015, renewable energy (wind power, biomass and solar power) represented about 62% of the Danish electricity production, while waste incineration and fossil fuels (coal and oil) represented 6% and 32%, respectively. Figure 2 shows how the distribution of the electricity production by energy sources has developed from 1994 to 2015. This shows how the Danish electricity system has changed from being primarily based on power production in centralised condensing power plants based on fossil fuels (partly as combined heat and power plants, CHPs) to a system with a much greater mix of different sources, with wind power being the main source. Following this transition, the electricity production is much less based on condensing power plants, and the integration of renewables have re-delegated many of the condensing power plants (centralised as well as

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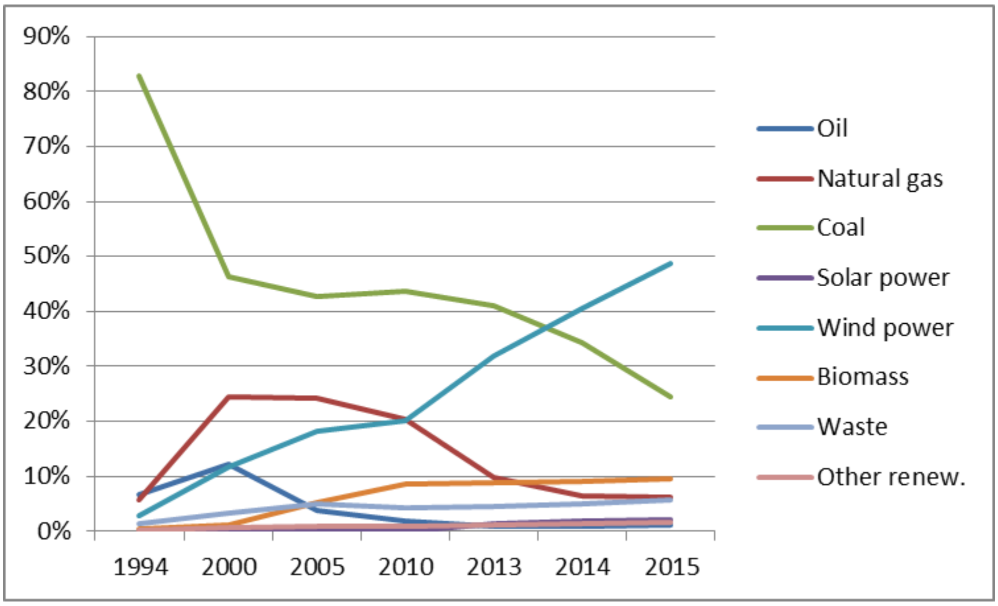
[5] http://reports.weforum.org/global-energy-architecture-performance-index-2014/global-rankings/#view/fn-10 Accessed: 04.11.2016.

decentralised) to primarily playing the role of power back up for the energy system (typically on windless days) and suppliers of heat for district heating.

The intermittency of especially wind power has become a major concern in Danish energy planning and policy-making. Today, this is partly handled through international trading (e.g. selling surplus electricity to Norway on windy days and buying hydro power-based electricity from Norway on windless days) and using condensing power plants a reserve capacity.

Figure 2: Distribution of electricy production by energy sources (1994-2015)



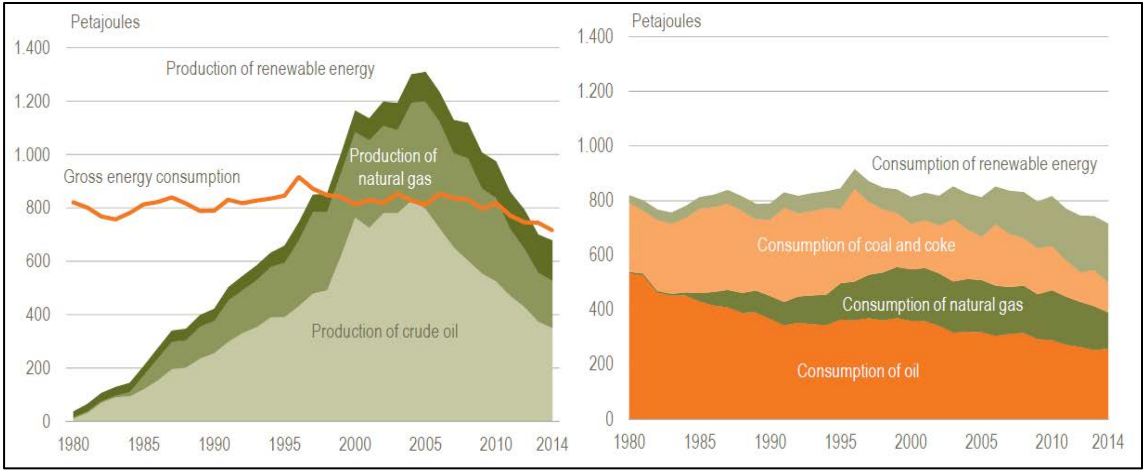
Source: Danish Energy Agency, 2017

Space heating is to a high degree based on district heating. Almost two-thirds (64%) of the Danish homes are heated by district heating, while 25% of the homes are heated by oil or natural gas burners (this is typically homes outside larger towns/cities), 5% have direct electric heating and 2% have heat pumps (Statistics Denmark, 2017). District heating is often based on biomass (wood and straw) as energy source, which represents 35% of the fuel consumption for district heating in 2015. Other major sources are natural gas (24%), coal (15%) and waste incineration (20%). Central CHP plants represents 40% of the total heat energy production, typically supplying the district heating in larger cities, while heating plants (only providing heating) represent 28% and decentralized CHP plants represent 12%. The latter typically provide energy for district heating in towns and smaller cities. In addition, about 20% of the heating supply is based on “surplus” heat from other production facilities (e.g. industries). (Statistics Denmark, 2017)

With regard to transport, the penetration of electric vehicles is very low in Denmark. During the period 2003-September 2016, the total number of new registered EVs was 8,286 passenger cars (Statistics Denmark, 2016b). In comparison, the total number of new passenger cars registered in 2016 alone was 222,475 (statistics Denmark, 2017)

Denmark’s gross energy consumption is calculated as the consumption of oil, natural gas, coal and renewable energy, and is adjusted for import and export of electricity. Denmark has been self-sufficient in energy since 1998 thanks to an increasing extraction of crude oil and natural gas from the North Sea and the production of renewable energy. Due to a gradual decline in the extraction of oil and natural gas, a major drop in the Danish energy production has occurred since the mid-2000s (cf. figure 3 below). The energy production dropped below the gross energy consumption in Denmark by 2014 (Statistics Denmark, 2016c).

Figure 3: Gross energy consumption (not including bunkering) and production



Source: Statistics Denmark, 2016c

The production and consumption of renewable energy in Denmark has increased substantially for all renewable sources since 1990, but in particular for wind power and biomass (cf. table 1). In 2015, wind power represented 42% of the Danish electricity supply.[6] In addition, waste used for heat and power production based on incineration has also increased considerable.

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[6] http://energinet.dk/EN/El/Nyheder/Sider/Dansk-vindstroem-slaar-igen-rekord-42-procent.aspx. Accessed: 03.11.2016.

Table 1: Consumption of renewable energy in Denmark (in 1.000 GJ)

	1990	2000	2014
Gross energy consump., total	**1 461 040**	**1 903 508**	**1 830 087**
Renewable energy	**45 509**	**78 541**	**191 086**
Wind power	2 197	15 268	47 083
Wood pellets	1 575	5 145	37 093
Waste, renewable	8 524	16 715	21 095
Firewood	8 757	12 432	18 413
Straw	12 481	12 220	18 409
Wood chips	1 724	3 049	16 660
Bio oil	744	49	9 669
Heat pumps	2 267	3296	7 245
Wood waste	6 191	6 895	6 686
Biogas	752	2 912	5 143
Solar power	0	4	2 144
Solar heat	100	331	1 227
Geothermal	96	116	166
Water power	101	109	54

Source: Statistic Denmark, 2016a

Denmark is often mentioned as a ‘frontrunner’ regarding innovation and regulation within fields such as energy efficiency in buildings, energy retrofitting, renewable energy and smart grids (Winston, 2013), but still, the country’s average CO_2 emission per capita is slightly above the EU average: In 2013, the Danish CO_2 per capita emission was 6.8 tons/year, compared with the EU average of 6.7 tons/year. However, the Danish emission is somewhat below the emission of Norway (11.7 tons/year) and Austria (7.4).[7]

As Figure 4 shows, the total CO_2 emissions from the Danish energy consumption has been reduced from about 62 million tons in 1980 to about 39 million tons in 2015 (a reduction of 36%). The reduction has mainly been realised through higher energy efficiency, massive extension of district heating since the early 1980s and phasing in renewable energy (especially wind power).

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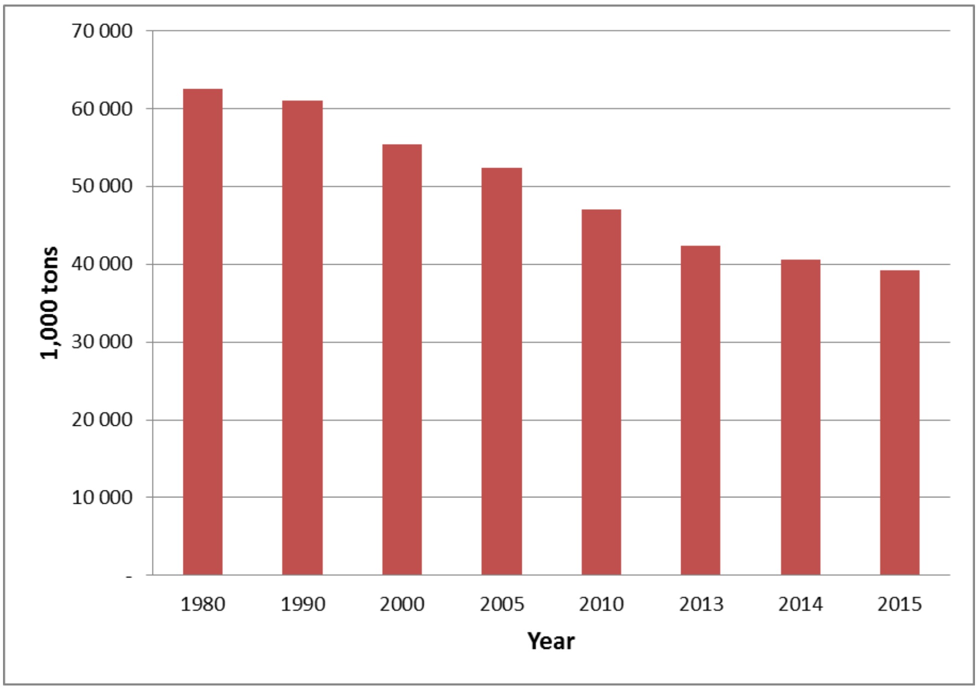
[7] The World Bank: http://data.worldbank.org/indicator/EN.ATM.CO2E.PC?year_high_desc=false (accessed 2017-02-15). These figures only includes national carbon dioxide emissions from the burning of fossil fuels and cement manufacture. Thus, it leaves out emissions of greenhouse gases from agricultural and forest activities, as well as emissions of CO_2 due to the embodied energy consumption related to import of products consumed in the countries.

Figure 4: CO_2 emissions from Danish energy consumption (1980-2015)



Source: Danish Energy Agency, 2017 (emissions are corrected for heating degrees variations)

However, some of the savings realized through increased energy efficiency has been outbalanced by rebound effects such as increased comfort and larger housing facilities. Especially if greenhouse gas emissions related to other consumption and production areas than energy are included, the Danish per capita emission is among the highest in the world, which to a high extent reflects the high living standard and the intensive agriculture production (Larsen et al., 2017).

According to the *Climate Change Performance Index 2015*, prepared by the German NGO *Germanwatch* and the European *Climate Action Network Europe*, which is an index that evaluates and compares the climate protection performance of countries, Denmark ranks as number 1, primarily because of a high ranking with regard to emissions development (the ongoing reductions) and ambitions of the energy and climate policies (Germanwatch & Climate Action Network Europe, 2014). However, with the 2017 index, Denmark dropped down to rank 13, even though it still “remains in the ‘good performance’ group” (Germanwatch & Climate Action Network Europe, 2016:14).

1.3 Policy and regulation of the energy market

Denmark’s long-term energy goal is to become fully independent of fossil fuels by 2050. In 2011, the Danish government published *Energy Strategy 2050*, which is a detailed and ambitious policy paper that, building on existing policies, proposes a range of new energy policy initiatives to transform Denmark into a low-carbon society (IEA, 2011). To reach the target, all parties in the Danish parliament (except for one smaller party) made an energy agreement with the overall aim of reducing the Danish CO_2 emissions by at least 34% in 2020 (compared to emissions in 1990) and with the long-term aim of making the Danish energy system 100% based on renewables by 2050. The plan includes specific measures covering the period of 2012-2020, including the goal of increasing the share of electricity production from wind to 50% by 2020 (Energy Plan 2012). The following table shows the targets set by the Danish government and the Danish parliament, and how in particular major development of wind energy is in focus.

Table 2: The political goals for the transition of the Danish energy system

100% renewable energy in 2050	25% reduction of fossil fuels from 2010 to 2020
100% renewable energy for electricity and heat in 2035	50% reduction of fossil fuels for electricity and heat from 2010 to 2020
All oil-fired burners removed in 2030 (mainly to be substituted by heat pumps)	No oil-fired burners allowed in new buildings from 2013
Wind power shall produce 50% of electricity consumption 2020	Wind power shall produce 50% of electricity consumption 2020

Source: Sorknæs et al., 2013

The Danish Government and energy sector anticipate demand-side management as fundamental to reaching the target for a complete transition. Therefore, consumers' flexibility to time shift their electricity demand is regarded as essential in order to accommodate a renewable energy system by 2050 (Danish Government, 2011; 2013b). See also section 1.5 for more information on the Danish smart grid strategy.

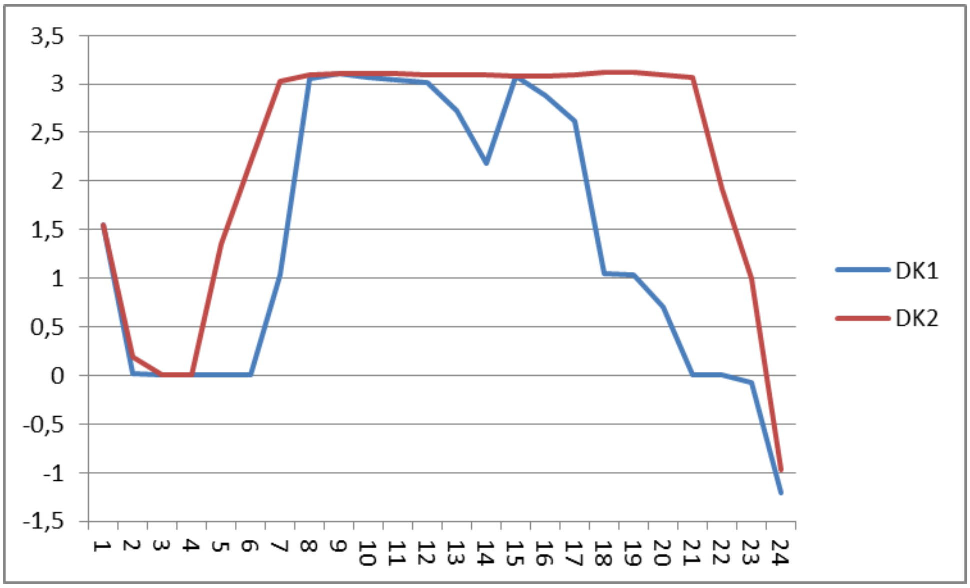
As in other EU countries, the market regulation in Denmark is strongly influenced by EU regulation. Thus, with the EU market liberalization directives and the EU Energy Packages, the Danish consumers have been able to choose their electricity supplier since January 2003. (Aarhus Universitet, 2017)

1.4 Market structure and energy consumption

As already mentioned, the Danish electricity grid is divided into two separate grids (an Eastern and Western); both are part of the Nord Pool day-ahead spot market, but are separate price areas.

The prices on the Danish spot markets fluctuate from even negative prices (in cases with a surplus production of wind power due to high wind speeds and low domestic consumption) to relatively high prices in case of low wind speeds and high domestic consumption. In 2016, the average spot market price were 0.199 DKK/kWh (2.7 euro cent/kWh) on the Western market (DK1) and 0.219 DKK/kWh (2.9 euro cent/kWh) on the Eastern market (DK2). But as the example in Figure 5 shows, the prices vary a lot from hour to hour and day to day. On this particular day, the prices in Eastern Denmark (DK2) were in general higher than on the Western spot market (DK1). Also, prices went below 0 euro cent/kWh in the late evening/night.

Figure 5: Spot market prices on Monday 2017-02-20. Euro cents/kWh by hour.



Data source: Nord Pool website (data retrieved: 2017-02-20)

The actual customer price is much higher than the electricity market prices mentioned above. For small consumers (4,000 kWh per year), the average customer price in the fourth quarter of 2016 was 2.32 DKK/kWh (31 euro cent); the retail price was only 0.28 DKK, while the main components of the customer price were the electricity tax (0.89 DKK), VAT (0.46 DKK), the net tariff for distribution (0.24 DKK) and the Public Service Obligation PSO (0.22 DKK) (Energitilsynet, 2017). The Public Service Obligation (PSO) was introduced in 1998 and covers expenses for subsidies related to renewable energy production, decentralized CHPs and research and development in energy technologies and energy efficiency. However, following a political agreement in the Danish parliament of November 17, 2016, the PSO will be gradually phased out during the period of 2017 to 2022. As a result, the electricity customer prices will be reduced with about 10%, and renewable energy installation and energy research will be funded by the state budget (i.e. regular taxes) in the future.

The Danish *transmission system operator* (TSO) is Energinet.dk, which is an independent public enterprise owned by the Danish state. In addition to the national gas transmission system, Energinet.dk owns the 400 kV electricity transmission system and is the co-owner of the international electricity connections to Norway, Sweden and Germany. (IEA, 2011)

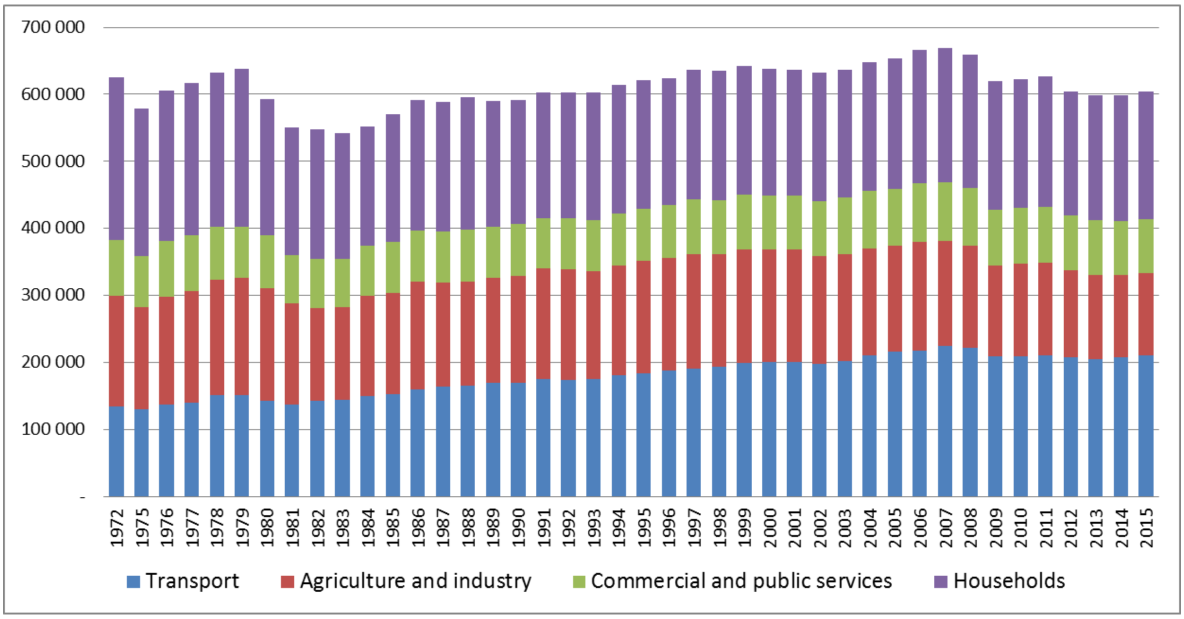
The primary *power producing* companies in Denmark are the Danish Dong Energy (which in November 2017 changed name to Ørsted) and the Swedish Vattenfall. They own the main coal or gas-fired CHP plants in Denmark (many of these currently being phased out due to increased wind power production or changed to biomass as fuel) and much of the wind power capacity. In addition, there are about 250 decentral CHP plants, typically supplying a small or medium-sized town or even village with district heating in combination with power production for the grid. These are often fuelled by natural gas, waste (incineration) or biomass. Some of these are owned by multi-national companies like E.ON, but most are either owned as co-operatives (typically with the district heating customers as the owners) or by municipalities. In addition, a minor share of the renewable power production is owned by private citizens either as privately-installed PVs or through shares in wind power cooperatives.

There are about 50 *distribution system operators* (DSOs) in Denmark (Bogetoft et al., 2014). They hold the monopoly on the physical delivery of power to customers (it is a geographical monopoly). They also have the responsibility for providing energy saving advices to the customers. The DSOs are owned by municipalities, co-operatives (with the customers being the owners) or act as commercial companies. They differ in size from

DSOs covering smaller cities or rural areas to the largest DSO, the commercial company Radius, which covers Copenhagen and Northern Zealand.

Finally, there are a number of *electricity suppliers* (retailers) who offer electricity to the customers. This is a market of competition and the customers can choose between about 50 retailers. In 2015, 7.3% of the Danish customers changed to another electricity supplier, which was a record compared to previous years (Dansk Energi, 2016). Some of the retailers offer specialized products to customers with “green” or renewable electricity, although it does not appear to have reached a significant market share.

Figure 6: The Danish final energy consumption by sectors (TJ), 1972-2015. Corrected for heating degree variations (climate) and not including energy consumption for non-energy purposes.



Data source: Danish Energy Agency, 2017 (data retrieved: 2017-04-27)

Figure 6 shows the development in the Danish final energy consumption from 1972-2015 (distributed by sectors). This shows that the final energy consumption of 2015 is more or less the same as in 1972. Throughout the period, there have been some variations (mainly as temporary reductions following economic crises; the first and second energy crisis in 1970s and the financial crisis in 2007-08). Overall, the energy consumption for transport has been steadily increasing, while the energy consumption for agriculture and industry as well as for households has been decreasing. In the case of households, there has been a reduction of 22% (2015 compared with 1972). Energy consumption for commercial and public services has been more or less constant throughout the years.

1.5 The Smart grids landscape in Denmark

In April 2013, the Danish Ministry of Climate, Energy and Buildings published a smart grid strategy (Ministry of Climate, Energy and Building, 2013). Together with a number of other strategies and analysis papers covering energy-related topics, the smart grid strategy supplemented the previously mentioned energy agreement from 2012. Thus, the smart grid strategy should support the realization of the ambitious goal of introducing 50% wind power in the electricity system by 2020 and making the energy system entirely based on renewable energy by 2050. In the foreword of the strategy, exactly the challenge from increasing wind power capacity (together with solar power) is highlighted as a main reason for preparing the strategy. Another main reason is the expected electrification of transport and heating. Thus, the core problem identified in the current Danish smart grid strategy relates to the balancing challenge of intermittent renewable electricity production; “... large amounts of wind power, and an increasing amount of solar energy, require more flexible electricity consumption" (ibid.: 5). And later: "An energy system with a smart grid design requires greater exploitation of the energy from wind as soon as it is produced, for example by heat pumps and electric cars. This will allow for greater exploitation of cheap wind turbine electricity, and it will mean less need to expand the electricity infrastructure to meet new electricity consumption." (Ibid.: 7) In other words, flexibility and demand-side management (demand response) is the key focus area for the Danish smart grid policies.

The main initiatives of the smart grid strategy are presented in Table 3.

Table 3: Main initiatives in Danish Smart Grid Strategy and status by Medio 2017.

Initiative	**Status for "small consumers" (by summer 2017)**
Provide consumers with the option of settlement by the hour (i.e. time-of-use pricing) – and in relation to this promote the rollout of hourly-read meters (smart meters)	Still, only very few small consumers have time-of-use pricing schemes. More than 50% of the Danish households have smart meters installed, and according to Danish regulation, the rollout of smart meters should be completed by 2020.
Stronger price signals (time-of-use pricing) should strengthen the incentive of consumers to move electricity consumption to off-peak hours. This could be variable net tariffs or specific "flexibility products" offered on the retail market (i.e. price savings in return for offering regulating power to the grid companies, e.g.)	Time-of-use pricing not introduced yet and no "flexibility products" have been developed for the retail market.
Wholesale model (electricity-trading companies being the only players with direct access to consumers) is envisioned to make greater competition and, through this, to increase the number of tailored smart grid products offered customers.	So far, there has not been any visible increase in the diversity and number of "smart grid products" offered small consumers
Integrating the electricity sector with other sectors: It is envisioned that the "next step" in the development of the smart grid is to utilise and store wind energy in other energy sectors "and thus render the entire energy system smart". Using electricity to produce heating (e.g. via heat pumps) in the district heating system and hydrogen (via hydrolysis) for the gas system are mentioned specifically.	Some R&D projects have been funded within this area. The integration of sectors are not realised as such.
Establishment of partnership with broad participation from the energy sector.	Has been established (called the *Smart Energy Networks*)

The development of the smart grid (or smart energy) system is still primarily happening within the R&D and demonstration field. Yet, no large-scale market-based solutions targeted small consumers have been rolled out on the market. Even electric vehicles, which in some countries like Norway and the Netherlands have got some diffusion and "mainstreaming", are still only representing a marginal share of the market (as mentioned earlier). Thus, the smart grid continuous to be more of a visionary idea among energy planners, politicians, engineers and energy companies than a "reality" experienced among regular customers.

However, there have been many R&D and demonstration projects in Denmark within the smart grid field within recent years. These have been funded by both national and international (primarily EU) programmes.

A review of Danish smart energy projects and the state-of-the-art within the smart energy field was published in 2015 (Mathiesen et al., 2015). It shows that within the period of 2005-2015, almost 8 billion DKK (1.1 billion euro) has been granted for energy research in Denmark; hereof, about 1.5 billion DKK (0.2 billion euro) has been granted the smart energy area (covering all energy sectors; electricity, heat and transport). The review identified 225 projects. Projects related to the electricity sector have received the majority of the funding, while the thermal sector received the lowest level of funding. While focus in the beginning was almost entirely on the electricity sector, the review finds a tendency within recent years to focus also on other sectors and on cross-sectorial projects (i.e. looking into synergies between sectors).

The review also finds that very few projects focus solely on non-technical aspects of smart energy (5 in total), although non-technical aspects are part of several “technical” projects. When it comes to projects including non-technical aspects, most of these are feasibility studies, second most focus on socio-economic analyses and third most on user/consumer behavior (if measured by size of total granted budget). In particular, very few projects focus on issues related to ownership or the role of institutions and organisations. Within funding for electricity-sector projects, most funding goes to ICT and development of appliances, and in particular the system challenge of balancing demand and supply has been in focus. Overall, the review identifies the low level of research into the integration and interaction of different energy sectors as the most significant research gap.

With regard to the integration of households in the smart energy system, the review concludes that there has been a limited success so far; “[t]his raises the question whether the previous approaches to households have been relevant” (ibid.: 20). Later, the review concludes that more research is needed into how “the development of Smart Energy systems can improve the development of possibilities of local citizens, local communities, and local businesses as well as local and regional authorities. There is an increasing requirement for concrete collaboration and coordination procedures between the state level, municipalities, producers and owners of renewable energy plants, consumers and producers of heat, biomass and power, and also in a learning process of the democratic base, the households.” (Ibid.: 20)

Also in 2015, and partly based on the above-mentioned review, the Smart Energy Networks published a revised *Vision for smart energy in Denmark: Research, Development and Demonstration* (Smart Energy Networks, 2015). With regard to small consumers, the vision specifically mentions “inadequate end-user engagement and insights” as one of the main challenges on the socio-economic level. Another important challenge is the lack of incentives “among system owners, building owners, authorities and end-users for flexible consumption” (ibid.: 5).

2 Danish case studies

The three selected Danish cases represent different solutions related to the future smart energy system, even though there are also similarities between the cases with regard to the aspects addressed and the approaches pursued. Two of the cases are focusing on the general transition of a geographical area to a post-carbon energy system; these cases are *ProjectZero* in Sønderborg municipality (close to the German border) and the *Renewable Energy Island* of Samsø (an island between Zealand and Jutland). In both cases, the aim is to facilitate a thorough transition of the energy system to make it based entirely on renewable energy. Also, in both cases, an independent organisation plays a key role in facilitating this transition (ProjectZero in Sønderborg and Samsø Energy Academy on Samsø). Finally, in both cases, there is a wide range of activities covering both the energy consumption and production side. However, in our empirical study, we have chosen to focus on slightly different types of activities (socio-technical configurations) for each case. Also, ProjectZero and the Renewable Energy Island of Samsø differ with regard to the size of the geographical area and population they cover each, among other things.

The third case studied – *Innovation Fur and the GreenCom* project – differs from the previous two cases by having a much more thematically focused approach; the GreenCom case is targeted households and aims to create demand response and load control through micro-generation (rooftop PVs) in combination with various smart energy solutions (heat pumps, home battery storage and Home Monitoring and Control). In the GreenCom case, the local DSO Eniig is a key stakeholder in setting up the demo, which is located on the island of Fur (placed in the Liim Fiord in Nothern Jutland).[8]

Table 4. Danish cases in comparison (our study of case 2 and 3 did not cover all activities of ProjectZero and Renewable Energy Island Samsø, respectively, but focused on specific activities)

	Case 1	**Case 2**	**Case 3**
Name	Innovation Fur/GreenCom	ProjectZero (Sønderborg)	Renewable Energy Island (Samsø)
Main focus	Test area for developing future smart grid	Transition to a post-carbon energy system	Transition to a post-carbon energy system
Type of consumers	Households	Households, SME, community buildings	SME, community buildings
DSM	Demand response	Increase energy efficiency, building energy management systems	Increase energy efficiency
Micro generation	Rooftop PV systems	PV systems, waste heat recovery	
Storage	Stationary battery storage	(Car batteries)	

The case sites differ with regard to size of population and area. Fur is a small island, while Samsø is a medium-sized island. However, both are primarily rural areas. The same goes for much of the area of the Sønderborg Municipality, although its main town (Sønderborg) is a medium-sized, Danish provincial town. Being a test and demonstration site for energy transition is a relatively new thing to the island of Fur, while there is a

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[8] ProjectZero, Samsø Energy Academy and Eniig are all MATCH project partners as well as research subjects (with regard to their role in establishing the socio-technical configurations) in the following case studies. They have all had the opportunity to comment on the ongoing research and previous drafts of this report, but the final outcome is the sole responsibility of the authors.

longer history of (renewable) energy initiatives in both Sønderborg and (in particular) on Samsø. These site-specific characteristics are detailed further in the following presentations of the case studies.

The three cases were originally selected because they represent some of the most innovative and comprehensive (smart) energy initiatives in Denmark for the time being. Also, they in total cover the three solution areas originally outlined in the analytical framework for the national case studies (see MATCH deliverable D1). Two of the cases (ProjectZero/Sønderborg and Renewable Energy Island/Samsø Energy Academy) were originally partners of the MATCH project, while the third case (and partner, Eniig) was chosen later because of the relevance of their demand response approach for the MATCH study.

The empirical work of the case studies was carried out by the Danish Building Research Institute (Aalborg University) and was primarily based on qualitative methods; i.e. field trips with visual observations and informal as well as formal, semi-structured interviews with local experts, demonstration project participants, project owners etc. Interview guides were developed before the start of the case studies and used across all three cases (although, of course, adapted to each case and interviewee). The semi-structured interviews were recorded, transcribed and later coded in the programme NVivo. In total, 22 semi-structured interviews were carried out and – in addition to these – a few informal interviews. Below some more details on the empirical work of each site.

Innovation Fur and GreenCom

A field trip to the island of Fur was made in the end of September 2016 and included visits to and interviews with in total 9 households taking part in the GreenCom trial. Households with PVs in combination with either heat pumps or batteries were selected (although, due to miscommunication, it turned out that one of the households neither had batteries or heat pumps in combination with their PVs). Further, in the selection of households, we aimed at some diversity of the sample regarding household size, age and occupation. The interviews typically lasted about an hour, with one lasting only 40 minutes and three lasting about 1½ hour.

ProjectZero (Sønderborg)

We had two field trips to Sønderborg. The first took place in the end of October 2016 and focused on households (taking part in the ZERObolig programme; see section 2.2) and local sports centres (taking part in the ZEROsport programme; see section 2.2). Households with a combination of rooftop PVs and electric vehicles were selected (four households in total), while we chose two rather different sports centres (one relatively big centre, which had been through a thorough energy renovation, and one relatively little centre, a rowing club, which had been subject to a more modest energy renovation). Again, the household interviews lasted about one hour (except for one lasting almost two hours), while the sports centres interviews lasted about 45 minutes and 1 hour and 45 minutes, respectively.

The second field trip took place in the middle of July 2017 and included visits to two supermarkets taking part in the ZERObutik programme (see section 2.2). Interviews were made with the supermarket manager at each site and lasted about one hour. In addition, the ZERObutik programme leader at ProjectZero was interviewed (lasted about ½ hour).

Renewable Energy Island of Samsø

A field trip to Samsø was made in late October 2016 and focused on local SME's taking part in the energy saving programme NightHawks. A supermarket, a local community centre and a hotel & restaurant were interviewed. In addition, two project managers from the Samsø Energy Academy were interviewed about the role of Samsø Energy Academy in the local energy transition. All interviews lasted about 1 hour each (except one lasting about 1½ hour).

A second field trip to Samsø was made in late March 2017 and included visits to more sites and some informal interviews with local shopkeepers etc.

2.1 Case 1: Innovation Fur and the GreenCom project

2.1.1 Background and project characteristics

The island of Fur is placed in the Liim Fiord in Northern Jutland. It has a modest area of 23 km^2 with 771 inhabitants (2017) and about 424 residential homes and 500 summer-houses. Fur is located in the Municipality of Skive with about 47,000 inhabitants (2017), and which belongs to the regions of Denmark experiencing a general decline in number of inhabitants and economic activity.[9] The population on Fur has halved since the beginning of the 20th century, and declined by 19% since 2000.[10] Fur is connected to the mainland via a small ferry (the crossing takes about 3 minutes). Since the beginning of the 20th century, there has been an extraction and local production based on Moclay in two factories on the island. The material resource Moclay (in Danish *moler*) is a diatomitic sediment of the Lower Eocene Epoch. The factories produce products for the international markets within heat resistant materials and tiles (the *Skamol* company) and cat litter, fodder additives etc. (the *Damolin* company, recently changed to *Imerys Industrial Minerals Denmark*). The two companies occupy about 70 employees.[11] Other important commercial activities on Fur are agriculture and tourism (the estimated annual number of tourists on Fur is about 250,000).[12] The island appears to have strong local networks among the inhabitants, often organized in various associations or working groups. Due to the size of the community, many people know each other from associations, meetings, the local grocery etc.

Innovation Fur is a private-public partnership (established in 2011) between the Fur citizens, the Municipality of Skive and the local electricity utility and DSO company (EnergiMidt, now *Eniig*) aiming to create a mini model on Fur of the future sustainable and energy-efficient welfare state. The initiatives on Fur focus on how modern technology, digitalization and energy-efficient solutions can support Denmark's vision on energy and welfare. The ambition is to make Fur carbon neutral in 2029 (originally by 2020) through various initiatives. The specific initiatives so far include information meetings, free energy consultation visits to approx. 145 households, involvement of local craftsmen, energy consultancy to businesses, free courses about energy forms, heat pumps, solar cells, solar heating, biomass boilers, energy consultancy and district heating[13], education about pros and cons of technologies, different kind of subsidies to energy saving, PV demonstration projects and a range of other information and education initiatives. The core target areas are energy saving/efficiency (with a particular focus on heat saving in permanent residences) and individual supply from PVs, and increase the installations of heat pumps and wind turbines.[14]

Innovation Fur was originally a spin-off of a citizen-led project called *Branding Fur*, which aimed at bringing the decline in population size of Fur to a halt and make it more attractive for people to move to the island. In this way, Innovation Fur is also by the local

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[9] Statistics Denmark, http://www.statistikbanken.dk/10021 (accessed 28-07-2017)

[10] Statistics Denmark, http://www.statistikbanken.dk/BEF4 (accessed 28-07-2017)

[11] http://furnyt.dk/4/index.php/component/k2/item/1940-moler-pa-fur and http://www.furnyt.dk/4/index.php/component/content/article/34-artikler/artikel/466-skamol-fra-moler-til-faerdig-braendt-sten (both accessed 28-07-2017)

[12] https://da.wikipedia.org/wiki/Fur (accessed 28-07-2017)

[13] In 2014, an under-water pipe connection was established to a Skamol factory on the mainland, thus utilising the excess heat from their production for district heating on Fur. This was not directly an activity of Innovation Fur, but contributes to the decarbonization of the island.

[14] See e.g.: https://www.information.dk/indland/2013/08/fur-dur and http://voresomstilling.dk/projekt/innovation-fur/96.

community seen as part of an overall strategy of ensuring the future development of the island (including attracting newcomers). (Ministeriet for By, Bolig og Landdistrikter, 2013)

Innovation Fur aims at developing innovative processes in cooperation with private and public actors. The core concept is based on accommodating sustainable transition and consumption change by bottom-up processes facilitated by user involvement. The project's green and smart solutions are thus ideally developed in close collaboration with the citizens living on Fur in order to secure that the initiatives/smart solutions are based on what the citizens/consumers consider meaningful and important. The citizen perspectives are achieved through working groups, courses, workshops and information meetings. The latest annual climate account for Fur (for 2013) shows significant drops in CO_2 emissions and heat consumption for homes and summer houses, increase in renewable energy shares from wind turbines and PV energy, and that the number of heat pumps is increasing. This led to a reduction in total energy consumption for electricity, heating and transportation of 16% compared to 2010. (Innovation Fur, 2016)

One of the projects affiliated with Innovation Fur was the EU-funded demonstration project GreenCom, which has been using Fur as an international test area for developing the future smart grid (the project was concluded in 2016). The goal of GreenCom was to "utilise the flexibility and intelligence in the low-voltage demand and local supply side infrastructure to create increased regulation capacity and reserve power in the centralised power grid by extending the means to effectively and securely manage and control the demand and supply within defined boundaries". In other words, the project aim was to "balance the local exchange of energy at the community microgrid level"[15]. By combining smart grid and IT technologies, GreenCom tested the balance in the energy system through technological equipment installed in "The Intelligent Home" coupled with strategies to increase user awareness. The demonstration included 33 households; of these, 19 were equipped with a home monitoring and control system (HMC), 11 had heat pumps installed (7 air/water, 1 air/water and 3 air/air heat pumps), 20 had PVs installed and 5 had batteries installed with Intelligent Energy Storage (IES) monitoring equipment. The overall experiences from GreenCom were that it is possible for private households to be flexible with PV systems and batteries and PV systems and heat pumps, and that the house owners are interested and cooperative in being flexible if it can help the local DSO. (GreenCom, 2016)

In 2017, a new EU-funded project, Storage4grid, which primarily continues the analysis on electricity storage provided by the 5 installed house batteries, has started.[16]

In the MATCH case study, we have focused only on GreenCom households with PVs in combination with home batteries and heat pumps, respectively. In the GreenCom project, the main actors involved was the GreenCom consortium (in Denmark represented by the energy provider and DSO Eniig), funding agencies (EU and a national R&D programme) and the local citizens (particularly those participating as trial homes). The latter had partly been selected based on their connection to the same "last mile" power line. In this way, they were only partly self-opted. Participants in the trial would acquire the tested technologies with significant subsidies, which made it attractive to participate.

2.1.2 Socio-technical configurations applied in the project

In our study of the Fur case, we specifically focused on two socio-technical configurations, both targeted households and both part of the GreenCom project. The first includes households with a combination of solar power (PVs) and home batteries (for local stor-

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[15] Quotes from project website, http://www.greencom-project.eu/ (accessed 28-07-2017)

[16] http://www.storage4grid.eu/pages/index.html

age), while the other includes households combining solar power (PVs) with heat pumps. It should be noted that all households (except one) also had Home Monitoring and Control (HMC) systems installed. In addition, the heat pumps of the second configuration were installed with Heat as a Service (HaaS) equipment and control, which means that the heat pumps could be remotely controlled in order to utilise them as a flexible load for the grid operation. However, except of a single calibration test of the remote control (to get data on the thermal characteristics of the buildings and how fast the buildings cool down when heat is turned off), this was not tested in "real life" due to technical challenges – and we will not go into further detail with this here. Similarly, the HMS system was never used on a broader scale by the participating households due to a number of technical issues and a low interest among the homeowners.

	PV + home battery	PV + heat pump
Technical elements	Low-voltage grid PV panels (~ 6 kWp each) Home batteries (4,5 kWh storage capacity each) IT control unit of charging of home batteries (Intelligent Energy Storage, IES) User interface for monitoring battery charging via smartphone app or internet browser	Low-voltage grid PV panels (~6 kWp each) Heat pumps (air/water) HaaS control equipment for the heat pumps
Social elements	5 households Households own PVs Batteries own by DSO (project owner) Information meetings related to demonstration R&D funding (EU and national) Subsidies for households (PV and batteries) Loyalty & commitment to demonstration project Gendering in household members' interaction with technologies Account settlement scheme (hourly net metering)	11 households Households own PVs and heat pumps Information meetings related to demonstration R&D funding (EU and national) Subsidies for households (PV and heat pumps) Loyalty & commitment to demonstration project Gendering in household members' interaction with technologies Account settlement scheme (hourly net metering) Family status (children or not) Developing new (embodied) routines for time shifting consumption Weather (annual/daily sun cycles)

Both configurations relate to the low-voltage grid (as the overall focus of the GreenCom project was to test new technologies and their possible use for managing the local low-voltage grid) and include PV rooftop panels (owned by the households). Also, both configurations depend heavily on external funding from EU and, partly, national funding from the Danish ForskEL programme, some of this funding being transferred to the households as subsidies for acquiring PV panels and heat pumps. The batteries were the ownership of the DSO. Further, loyalty and commitment to the demonstration project was found among the participating households in both configurations, i.e. that they were in general committed to follow the instructions and recommendations (scripts) conveyed by the project owners through information meetings and participant workshops. Finally, both configurations share a relatively strong gendering with regard to which household members who engage most actively in the new technologies and are planning consumption according to their own production of electricity from the PVs (as will be elaborated further in the Discussion section).

Zooming in on the specific configurations, the first combines PVs with batteries. This was part of the GreenCom project's focus on exploring the potential for an Intelligent Energy Storage (IES) business model; both seen from a household perspective (making it possible for households to consume a larger share of their own PV generation and, in this way, save money) as well as from the perspective of the DSO (by reducing grid load peaks by covering some of the peak consumption by electricity delivered from the battery). Thus, focus was on the implications of the battery + PV constellation on how the households act as a load on the low-voltage grid (GreenCom 2016). In order to optimize the performance of the battery, an IT control unit (Intelligent Energy Storage, IES) controlled the battery charging, making sure that the battery would only be recharged during periods with a surplus PV generation (i.e. when the household is consuming less power than is produced by the PVs). Conversely, the battery would discharge during hours with higher consumption than PV production (in this way replacing some of the power that would otherwise be drawn from the grid). Finally, a user interface was offered the households (run via a smart phone app or an internet browser) that enabled them to monitor the battery charge status and energy flows of the home on a near-real-time basis. However, only one of the interviewed households had managed to make this work (or figured out how it worked).

In the final analysis, the GreenCom project partners conclude that the PV + battery configuration significantly increases the level of self-sufficiency by about 50%; increasing the average self-sufficiency rate[17] from about 20% without batteries to about 30% with batteries.[18] Measured by the rate of utilization of the PV power generation, the PV + battery combination almost doubles the utilization rate from about 30% for direct energy consumption to about 60% including the battery. Also, it is concluded that the PV + battery combination typically reduces the peak load with 35-70% for 1,5-2 hours in the peak period. However, the data also shows great seasonal variations with relation to both self-sufficiency rate and peak load reduction, as the battery is typically fully recharged every day during the summer months, while it during the winter months might not even be recharged at all (due to limited solar influx). Regarding the business case, the demonstration shows that without subsidies like those in the GreenCom, it is not yet profitable for households to invest in the PV + battery combination, primarily due to batteries still being too expensive.[19] Also, the solution is not yet profitable to the DSO because of battery prices still being high and because of a general over-capacity of the local, low-voltage grid. (GreenCom, 2016)

The second configuration combines PVs with heat pumps. This was part of GreenCom's exploration of the Heat as a Service (HaaS) business model, i.e. remote control of heat pumps via a HaaS control unit in order to offer different flexibility services to the DSO. The ideal is that the household will benefit from entering a HaaS contract by getting a reduction in their electricity bill in return of offering flexibility within certain limits defined by maximum and minimum acceptable indoor temperature levels, while the DSO will get the possibility of controlling the load on the grid (through the flexibility offered by the households). The DSO can control the performance of the heat pump remotely via the HaaS unit, which is connected to the heat pump. However, the HaaS concept was not

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[17] I.e. the share of the residential electricity consumption covered by electricity from the PV (either consumed directly or stored in the battery for later delivery to the household)

[18] It should be noticed that these figures are not based on a full year, but the period from Mid-August 2015 to Mid-May 2016, leaving out the summer months of June and July. Therefore, the actual, annual self-sufficiency might be expected to be somewhat higher.

[19] With the subsidies of the GreenCOM project, the use of the batteries were free of charge to the households, which means that the households in the project saved money by increasing their rate of self-sufficiency (for each extra kWh consumed locally instead of sold to the grid, the households would save about 1,5 DKK).

tried out in real-life in the demonstration project, although one calibration test was run for each of the seven households taking part in the trial (GreenCom, 2016). In the final analysis, GreenCom (2016) concludes that the HaaS method potentially can be used for load shaving and in this way help the grid operator.

With regard to the social elements, the interviews show that the households taking part in this configuration were sensitive to the type of account settlement scheme (hourly net metering), as this in general incentivised them to shift parts of their electricity consumption from evening/night hours to daytime hours in order to utilize their own PV power generation the most (saving them on average 0.20 euro for each kWh shifted).[20] It was primarily dishwashing and laundering that the households shifted (manually or by use of timers on the appliances), while none of the households shifted their heat consumption. Those who actively time shifted their electricity consumption appeared to develop new, routinized (embodied) habits in relation to this (detailed further in the following section), which to some extent were built on day-to-day observations of the weather (whether the sun would shine or not during the daylight hours). Finally, it appears as time shifting was most prevalent among households without children living at home, which indicates that the degree of flexibility regarding time shifting consumption is lower for families with younger children.

2.1.3 Discussion: Success and outcomes

Seen from the perspective of GreenCom project (and the project consortium), the demonstration succeeded in providing concrete experiences with new smart grid solutions, including combinations of PVs with heat pumps and battery storage, respectively. Thus, measured by the R&D goals, it was a successful project. However, at the same time, it also showed the existence of both technical and non-technical challenges related to setting up complex systems like these. In particular, with current investment costs related to PVs and batteries, and current electricity costs, the battery + PV combination is not yet profitable seen from the perspective of households or the DSO (neither for optimising the utilization of the PV generation or as part of a load management strategy in general). Another key finding of the demonstration was that the capacity of the low-voltage grid on Fur (and in Denmark in general) is oversized. This means that even with a high penetration of new technologies like PVs, EVs and heat pumps, the DSOs are in general not expected to face grid capacity problems related to peak loads. In other words, the Danish DSO member of the GreenCom project lost some of its initial interest in the prospective future use of DSM solutions throughout the demonstration. However, the GreenCom project, being an international project, discovered that this might differ from many other European countries, as “many of the European LV [low-voltage] grids are not as heavily over dimensioned and strong as the Danish LV grid” (GreenCom, 2016: 4). Interestingly, this also points to the importance of the physical characteristics

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[20] Depending on when the PVs were installed, Danish household accounts are settled according to two different net metering schemes: the original net metering scheme from 2005 was based on annual net metering, which means that, e.g., surplus PV production in the summer months is deducted from surplus consumption during winter months (as the account is only settled one time a year). With falling prices on PV installations, this net metering scheme became increasingly profitable for private household, which spurred a take-off in installations of privately-owned PVs in 2011. This threatened to undermine the tax revenue from electricity consumption. In response, the Danish parliament passed a new bill in December 2012 that changed the net metering to be hourly based, which stalled the installations of new PVs in private households (Wittrup 2016). With the new scheme, the account is settled every hour, meaning that for each hour the amount of electricity delivered to the grid (in case of higher PV generation than on-site consumption) is deducted the amount of electricity delivered from the grid to the household. If the resulting figure is positive (i.e. the household has consumed more electricity from the grid than it has delivered to the grid), the household pay the ordinary electricity price for the net consumption. If the resulting figure is negative (i.e. the household has been a net exporter of electricity within the hour), the household gets a fixed price per kWh for the net export. However, the household gets only 8 eurocents per kWh delivered to the grid, while it pays about 30 eurocents per kWh (including taxes) consumed from the grid. Thus, with hourly net metering, there is a strong economic incentive to consume as much of the PV power on site, and within the hour of production, as possible.

of the existing electricity grid, including the history related to the level of investments in, and original capacity design criteria of, these grids.[21]

The households were in general happy with participating in the demonstration. Their acquisition of new technologies was partly subsidized by the project, which likely influenced both their initial interest in enrolling for the trial and their satisfaction with being part of it. Even if they did not necessarily have exact numbers on their energy costs before and after the installation, the households in general believed that they had benefitted economically. Also, the households with heat pumps were happy about their new heating system (the heat pumps replaced previous systems such as oil or biomass burners). They experienced a higher indoor comfort and also experienced the heat pump to be a reliable technology that did not require much attention (e.g. compared to biomass burners). In both cases, this indicates the importance of convenience in relation to heat pumps.

With regard to the influence of the demonstration on the everyday life and consumption patterns of the households, the interviews show that many households to various degrees incorporated new routines of time shifting their electricity consumption (this in particular apply to the households with PVs + heat pumps). In particular dish washing and laundering were shifted to daylight hours in order to optimize the consumption of the PV generation. The time shifting was motivated by mainly two reasons: First, the project partners had through information meetings and workshops conveyed the message that the householders would save most money by time shifting their electricity consumption. This – in combination with the householders' general commitment to the trial – appeared to influence their daily habits. Second, the hourly net metering scheme was mentioned by many as a reason for time shifting, as this would save them most money. In addition, the notion of "consuming one's own electricity" also appears to have an influence on the householders' motivation with regard to time shifting. Typically, the households would develop new routines in relation to time shifting their consumption. In a few cases, the households even had developed more "advanced" and reflexive practices related to monitoring PV generation and planning the time shifting of everyday practices. In all these cases, it was the male adult member of the household who had developed these routines (although the performance of the routines also depends on communication with their spouse, e.g. in relation to plan the timing of laundering). Interestingly, the motivation for time shifting consumption was less prevalent among the households with home batteries; these households to some extent delegate the activity of balancing (synchronizing) PV generation and consumption to the batteries and the IES control unit.[22]

On a more general level, it appears as the GreenCom demonstration project strengthens already existing local ties and networks among the citizens on the island. This happens in two ways: First, the information meetings and workshops held by the project owners worked as a setting for people to meet (an additional setting to the other settings on this island, e.g. in relation to the islanders' participation in local associations). Second, some of the participants explained how they on an informal basis exchanged personal experiences with the new technologies with their neighbours or work colleagues when meeting these. In particular, production data of the PVs was something that was shared, partly – it appears – as a friendly "competition" among households with regard to who produces the most electricity (e.g. on a sunny day). Again, it was only male interviewees who told about this kind of habits. In this way, these technologies – and the trial setting – appear to invite to informal knowledge exchange (and perhaps even shared learning) within the local community. Further, the media coverage of the trial and frequent visits of external professionals within the electricity sector might also have contributed to a general positive image and "branding" of the island similar to that of Köstendorf (although not at all

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[21] These observations and conclusions only relate to the use of load management (demand response) for managing potential grid capacity problems. Demand response might also be interesting in relation to balancing the consumption side with (intermittent renewable) electricity generation; however, this was in focus in the GreenCom project.

[22] See Christensen et al. (2017) for a more detailed analysis and examples of how the households time shift consumption.

on the same level of size). In this way, one can argue that the GreenCom demonstration contributes to the overall aims of the original *Branding Fur* and *Innovation Fur* initiatives.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: The GreenCom demonstration provided important R&D insights in relation to smart grid solutions in homes. It was shown that the PV + battery combination reduces peak loads significantly (35-70%) as well as increases the level of self-sufficiency at the household level. And even though the remote control of heating in the PV + heat pump combination was not tested under ordinary operation (due to technical challenges), the calibration tests indicated a potential flexibility of 1 kW in load demand per household (i.e. 1 kW that can be shifted from peak hours to other hours). However, due to a general over-dimensioning of the low-voltage grid in Denmark, grid capacity is not expected to become a major challenge in the near future (even with more EVs and PVs). Therefore, demand response is not expected to become needed for grid capacity management.
- Actors: The DSO to some extent lost interest in the technical solutions due to the above-mentioned over dimensioning of the LV grid. The households were in general happy with participating in the trial and believed they had benefitted from it economically. Also, some saw the trial as part of the larger vision of a renewable energy system and the branding of the Fur island. Further, several householders were actively engaged in time shifting their electricity consumption (mainly dishwashing and laundering) in order to optimise the utilisation of the PV generation. Also, the community of the island might have benefited from the trial in more general terms through strengthened local networks and publicity in Danish media.
- Market: As mentioned above, the tested solutions (business models) were not commercial viable without public subsidies (the funding of the project). The households benefitted economically from participating in the trial through increasing their level of self-sufficiency (saving money on the electricity bill) and by getting new equipment to reduced prices. More generally, the hourly net metering scheme has a positive influence on households' motivation and engagement in time shifting (some of) their electricity consumption.

2.2 Case 2: ProjectZero in Sønderborg – ZEROhome, ZEROshops & ZEROsport

2.2.1 Background and project characteristics

The municipality of Sønderborg is located in Southern Jutland (close to the German border). The municipality covers 496 km^2 with the island of Als representing 321 km^2 of this. The island is connected to the mainland by two bridges. The number of inhabitants in the municipality of Sønderborg are 75,000 (by 2017), of which 28,000 live in the main city Sønderborg. The municipality of Sønderborg belongs to the declining regions of Denmark, although the decline in population is less marked here as in other declining regions. Thus, the number of inhabitants dropped by 2% from 2010 to 2017, but with a slight increase from 2016 to 2017.[23]

Industrial production holds a strong position within the Sønderborg area, with the largest company being *Danfoss* (developing and producing mechanical and electronic components and system solutions). Danfoss is an international company with about 24,000 employees worldwide. The head office is placed on the northern Als and employs about 5,000 people (at the head office and the factory).[24] In addition, there are other manufacturing companies in the municipality. Agriculture is also an important business (as in

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[23] Statistics Denmark, http://www.statistikbanken.dk/BEF4 (accessed 28-07-2017)

[24] http://www.danfoss.dk (accessed 01-08-2017)

most regions of Denmark outside the major cities). Compared to other declining regions, there is a higher share of knowledge-based industries and jobs. Similarly, and partly due to the local technology-advanced companies, there is a number of educations in Sønderborg, including a local branch of University of Southern Denmark.

ProjectZero was founded in 2007 as a public-private partnership between the local DSO and energy provider SE, the Bitten & Mads Clausen Fund (related to Danfoss), the Danish energy company DONG Energy (now *Ørsted*), the Nordic bank Nordea and the Municipality of Sønderborg. The aim of ProjectZero is to promote and facilitate a transition of the municipality of Sønderborg to a CO_2-neutral community by 2029 through a variety of initiatives facilitated by the ProjectZero Secretariat. In 2009, a masterplan for this transition was published (ProjectZero, 2009). The goal only relates to CO_2 emissions (not other greenhouse gases, e.g. methane). Further, only CO_2 emissions from direct energy consumption within the Sønderborg area as well as related to imported/exported energy are covered by the ProjectZero vision and strategy (i.e. CO_2-emissions related to import of goods, e.g. food, and transport outside of the area, e.g. citizens on holidays, are not included). The end goal of CO_2 neutrality in 2029 is complemented by mid-term CO_2 reduction goals; 25% reduction by 2015, 50% by 2020 and 75% by 2025. The baseline year is 2007. In addition to the climate goal, the vision also aims to create new and keep existing work places within the “knowledge-intensive business”. This is thought of as a spin-off of the activities related to the realisation of the CO_2 neutrality vision. In other words, work creation is also central. More generally, the vision is anchored within a market-driven and growth-based paradigm, as also stated on the website of ProjectZero: “We will show, how a market-driven and growth-based energy and climate transition to a CO_2 neutral society in 2029 can be done in practice”[25].

According to the masterplan, the realization of the vision is going to happen through three overall approaches: 1) Substantial energy efficiency measures, 2) transition to renewable energy within the energy supply and 3) transition to a dynamic energy system. The latter relates to the interaction between energy sectors and the goal of balancing intermittent RE production with the consumption side. The latter approach is specifically emphasised as being “essential for a sustainable energy system” (ProjectZero, 2009:8).

The ProjectZero initiatives are facilitating new business concepts, new partnerships and new solutions that are climate friendly. The initiatives are strengthened by involvement and participation of local citizens, shops, institutions, businesses, craftsmen and others, which through cooperation aim to create local “green” jobs and economic growth. Hence the strategic efforts to reduce CO_2 emissions through energy efficiency improvement and smart grid solutions are based on participation from local stakeholders. Moreover, energy retrofitting, conversion to district heating, installation of PVs and heat pumps comprise some of the pivotal solutions to accommodate the reduction.

The specific initiatives are being developed and detailed in the so-called Road Maps, each covering a specific time step in the transition. So far, two road maps have been published (in 2009 and 2013).[26] The 2013 road map identifies six strategic areas for the efforts until 2020:

- Citizens (focus on energy reduction, e.g. through a network of local energy consultants)
- Companies (focus on providing access for companies to knowledge about energy saving, transition and CO_2 reductions)
- The public sector (focus on making the Sønderborg area into a test site for new and smart energy and climate solutions that create growth, jobs and CO_2 reductions)
- Intelligent Energy (a new business concept, which aims at optimising the energy consumption and increase the RE share)

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[25] http://www.projectzero.dk/da-DK/TopPages/Om-ProjectZero/Hvad-er-ProjectZero-.aspx (accessed 01-08-2017)

[26] See: http://www.projectzero.dk/da-DK/Publikationer/City/Roadmaps.aspx (accessed 01-08-2017)

- Bio energy (focus on facilitating an optimal utilisation of the local biomass resources)
- Green Transport (focus on optimising public transport, commercial transport, reduce transport in urban areas, increase ride sharing and support a transition to transport based on electricity and biogas)

By 2016, the total CO_2 emissions from the Sønderborg area had been reduced by 36% (compared to 2007), while the energy consumption had been reduced by 18% (ProjectZero, 2017). As the 2015 mid-term goal was a 25% CO_2 reduction, this shows that the realized reductions are far ahead of the projected. The main reasons behind the reductions are a combination of increased energy efficiency and a shift to less CO_2-intensive energy forms or renewable energy (e.g. conversion to district heating and the phase in of biomass and solar heating in district heating). It should be noted that part of the reduction is caused by the national decarbonization of the electricity supply (primarily through new wind power capacity).

In the MATCH case study, we have focused on three of the ProjectZero initiatives: ZERObolig (in English: ZEROhome), ZEROsport and ZERObutik (in English: ZEROshop). As indicated by the names, ZERObolig targets the residential sector, ZEROsport the local sport centres and sport facilities and ZERObutik the local shops. All initiatives are primarily focusing on promoting energy saving.

ZERObolig motivates homeowners to energy retrofit their homes (partly by offering free energy consultant visits)[27]. However, in this study we focus on homes, who have invested in PVs in combination with electric vehicles (EVs) and heat pumps. ZEROsport aims to make the sport facilities in the municipality more energy efficient and green by engaging sport facility associations. Together with the Leisure Department in the municipality, the secretary has developed the ZEROsport-programme, which is a two-years certification targeting sports facilities and clubhouses working to reduce their energy consumption and CO_2 emissions. The initiative's purpose is to increase awareness and daily energy management in the buildings through active participation of the users in their leisure time. The core assumption is that the network around leisure activities have a crucial impact on consumers' energy awareness and activities in general. The ambition is also that the activities at the sports facility site should inspire the local citizens (the users) to change behaviour in their own everyday life outside the sports facility. Finally, ZERObutik offers a certification of local shops according to the size of their realized energy saving. The shops can get different types of certificates, ranging from a white certificate (10-20% reduction) to a green certificate (more than 70% reduction). At regular public events, the certificates are handed over to new members of ZERObutik. Typically, it is the mayor of Sønderborg Municipality that presents the certificates. So far, about 135 shops have got a certificate. None have got the green certificate yet, while only a few groceries (convenience stores/supermarkets) have got the gold certificate (51-70% reduction). As part of the ZERObutik programme, the shops are offered a free visit by an energy consultant (a so-called "ZERObutik partner"), which is done by local electricians who have followed a course in energy advisory. The most typical measure done by the shops is replacing traditional light spots with LED spots. However, some shops also do more comprehensive measures like changing the heating system.

2.2.2 Socio-technical configurations applied in the project

Three socio-technical configurations have been identified related to ZERObolig, ZEROsport and ZERObutik.

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[27] Since 2007 approximately 16,800 home owners have energy retrofitted their houses.

	Households (ZERObolig) *PV + EV + heat pump*	Sport centres (ZERO sport) *Local sports centre*	Shops (ZERObutik) *Supermarket*
Technical elements	PV panels (~ 6 kWp) Electric vehicles (EVs) Limited EV driving range Heat pumps (air/air, ground/water)	Complex energy system and controls (PVs, solar heating, heat pumps, ventilation systems with heat regeneration etc.)	Various conventional energy saving solutions like replacing incandescent bulbs with LEDs Heat recovery of "waste heat" from cooling
Social elements	Annual vs. hourly account settlement schemes Local network for knowledge sharing, support & inspiration Independence and resilience Test an EV campaign	Advanced skills for managing the system Funding (and skills for raising funding) Dedicated volunteers ProjectZero certification scheme National competitions and prices Partly demonstration project	Local (informal) network Danfoss company (the supermarket being a test site for new solutions) ZERObutik certification scheme (publicity/branding) Partly demonstration project Energy supply contract with local district heating National tax rules on selling "waste heat"

For the first configuration (the households), the PVs, EVs and heat pumps are obviously core technical elements. In addition, two households combine the heat pump with woodstoves and one with a masonry stove.[28] Also, all households combine the EV with a regular combustion engine car (due to limited driving range of the EV). Typically, the EV is used primarily by one of the adult household members (typically for daily commuting and shorter trips), while the combustion engine car is used for longer trips (e.g. visiting friends or relatives in other parts of Denmark) or when they need to use a car trailer. The households do not think that their transport needs can be covered by EVs only; it is in particular the limited driving range per battery charge that is regarded as limit to EVs. Two of the four interviewed households had also two cars before they acquired their EVs, and in these cases the EVs are replacing combustion engine cars. The two other households did not have two cars before they got the EVs.

Furthermore, for two of the interviewed households, the excess of electricity from the PVs worked as a motivation for acquiring the EV. This relates to the type of account settlement (featuring as a social element in the table above): All households, except for one, were on the annual net metering scheme (see also previous footnote no. 12). This means that if the households have an annual surplus of electricity (i.e. the PVs are generating more electricity that the household consume on an annual basis), there is an economic incentive for the households to use the "surplus" electricity generation, as they typically get only about 8 eurocents per kWh of surplus electricity delivered to the grid. Thus, the additional electricity costs of adding new electricity-consuming products like EVs or heat pumps are minimal (at least until the added electricity consumption equals the annual surplus PV production). This shows how the old scheme (annual net metering) promoted increased electricity consumption; an indirect effect that resembles the so-called rebound effect. However, this has changed with the new hourly-based scheme (hourly net metering). One of the interviewed households was on the new scheme, and

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[28] In the household with the masonry stove, the air/air heat pumps are actually used more as supplementary heating to the stove. This household also have solar heating for combined hot water and central heating (space heating).

they did time shift various electricity-consuming activities on a regular basis (especially during the summer), including dishwashing, laundering, tumble drying and – to some extent – baking. This was in order to save money by increasing the degree to which they consume the generated PV electricity within the same hour as it is produced.

Other social elements: In particular two households emphasised the role of local (informal) networks for knowledge sharing, mutual support and inspiration. Further, ideals of energy independence and resilience (for instance from rising energy prices, blackouts due to supposed terror attacks on vital infrastructures or being resilient to "the turmoil around the world") were mentioned by two households as motivations for investing in PVs and for their general interest in acquiring home batteries in the future (if the prices on batteries fall enough). Finally, two households had previous experiences with driving EVs from a national EV "test pilot" campaign called "Test an EV", which ran across Denmark a few years earlier. In this campaign, households could borrow and "test" an EV for three months. It appears as the participation in this campaign had "demystified" the idea of acquiring an EV for these households.

The second socio-technical configuration relates to sport centres being part of the ZEROsport initiative. We visited two sites (a rowing club and a local sports centre). However, in this analysis we focus mainly on the sports centre as this represents the most ambitious and advanced example of an energy renovation. The sports centre is called *Diamanten* and is placed in the town Fynshav on the eastern part of the island of Als. Originally, the sports centre was a traditional Danish sports centre with a main hall for sport activities (like playing hand ball), showering facilities and a cafeteria. In the mid-2000s, the volunteers behind the centre decided to work on getting an extension to the existing hall (they needed a place where people could warm up before matches etc.). In other words, a relatively simple project with no specific focus on energy issues. However, a contact at the local municipality made them aware of a funding call from the so-called *Lokale og Anlægsfonden* (in English: The Room and Facility Fund), which is a Danish fund supporting construction works within the sports, culture and leisure time sector. They decided to apply for support, and as part of the project description they also put emphasis on energy efficiency (this was partly inspired by ProjectZero suggesting them to make energy saving a pivotal element of the refurbishment proposal). They got funding[29], and then followed some hectic years for the volunteers with a lot of work related to obtaining additional funding from other funds and programmes. According to the interviewees from the Diamanten, an important reason for their success in getting funding was that one of the volunteers was competent in preparing applications. The total budget was 37 million DKK (5 million Euro), which was funded by the municipality, external funds and loans. The design of the renovation (including considerable extensions) was facilitated by external architectural and engineering companies. The design process continued for two years and involved several meetings and workshops for the volunteers. The volunteers were organized in several working groups. The renovation took place during 2009-10. Despite an increase in the total floor space of 1300 m^2, the energy costs were reduced by almost 60% with the new centre. The energy saving initiatives include (among other things): Insulation of the original hall, low-temperature heating system, solar heating (70 m^2 on rooftop), PV panels (90 m^2 on rooftop), LED lighting, ground-source heat pumps and a low-energy ventilation system based on natural ventilation, heat recovery and air-cooling based on heating cold tap water (intended for being used as hot water), natural overhead lighting, etc.

Main focus has been on optimising the (internal) energy flows of the building and to use "waste energy" from some subsystems for heating in other subsystems in order to minimize the energy consumption of the building. The example of pre-heating hot tap water by using the cold water for cooling the intake of air (in the summer period) is an example of this. The use of the electricity produced from the PV rooftop panels (6,6 kWp) for run-

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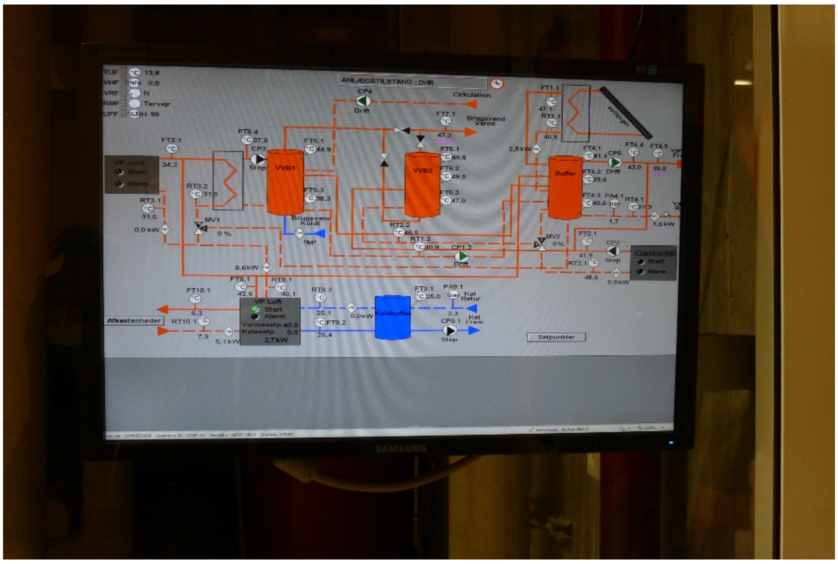
[29] http://www.loa-fonden.dk/projekter/2010/diamanten-idraets-og-kulturcenter-i-fynshav/ (accessed 01-08-2017)

ning the installations (e.g. circulation pumps, heat pump etc.) is another. In that sense, this is a "smart" designed and controlled building, although the aim has not been to make the building interact with the external grid in any "smart" way.

The sports centre Diamanten

The main hall (this is the old, now refurbished, hall). Notice the natural lighting from above.



The energy system is mainly controlled via a control board. This screen shows an overview of the system and its energy flows.

Many elements of the solution were quite innovative and new, at least for sports centres in general in Denmark – and some turned out to work less effectively than others. For instance, the initial idea was to include a thin-layer PV material to be integrated with the outdoor construction materials. However, they turned out not being effective in generating electricity and were eventually skipped.

Overall, the technical system is rather complex and involves flows of energy between different subsystems. The daily maintenance and monitoring is carried out by the daily manager (who is one of the two employees at Diamanten). This person, who has a background as a carpenter, has developed a knowledgeable insight into the system and how it works over the years. This knowledge was developed during his participation in the planning and development phase as well as through his daily interactions with the system in the following years.

Diamanten is often used by ProjectZero as a demonstration case; thus, about twice a month, ProjectZero staff come by to show the centre to their visitors. Also, the sports centre on a regular basis submit energy consumption data to ProjectZero (part of the obligations to be ZEROsport certified) and they take part in quarterly meetings for all ZEROsport members. ProjectZero has been a good help with regard to getting publicity around the Diamanten and their refurbishment. Finally, it should be mentioned that the sports centre won the national 2014 Refurbishment Price[30].

The third socio-technical configuration, the ZERObutik initiative, is studied on basis of experiences from two ZERObutik certified groceries. Both are local branches of the large Danish grocery chain called COOP. In the following, focus is on the largest of the two groceries (called the “Supermarket”), as this grocery shop had done the most advanced and comprehensive measures in order to reduce their energy consumption. The supermarket is a middle-sized grocery (while the other ZERObutik COOP shops are smaller). Due to a fire in 2010, they had to make a thorough renovation of the shop. As part of this, they decided to replace the old cooling system (a central cooling system for the refrigerated counters) with a new one based on CO_2 instead of Freon (as the old one). The chairman of the association (formally owing the shop) did also work at the Danfoss company, and as they specialize in larger cooling systems (among other things), he suggested that the Supermarket should collaborate with Danfoss in order to develop a solution that would utilize the waste heat from the cooling system for the space heating system. This could entirely cover the needed space and water heating of the supermarket. Danfoss was interested in the collaboration as this offered them an option for pilot testing a new system they were developing at a location within convenient distance of the company (and its development unit). Other initiatives, in addition to the heat recovery system, included installing rooftop PVs to supply electricity for the grocery and sliding covers for the cooling counters (has become quite standard in many Danish shops nowadays). More recently, they have also decided to replace existing spot lights with LED spots, and got connected to the local district heating in order to sell excess heat from the heat recovery system to the local district heating company. The latter was also originally suggested by their contact at Danfoss. Thus, the Supermarket has turned the costs for heating (previously based on an oil-fired burner) into an income from selling excess heat. However, due to national rules, taxes were put on the sale of the (excess / waste) heat from the Supermarket to the local district heating company. This made it less attractive for the district heating company to buy the heat and also caused a lot of difficult paper work for the Supermarket. However, the Supermarket got help from the central administration of COOP to solve this and figure out the tax rules.[31] The solution of recovering the heat from refrigeration for space heating and delivering to the local district heating grid has now spread to other supermarkets in the Sønderborg area, including also su-

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[30] http://renover.dk/om-prisen/tidligere-vindere/ (accessed 01-08-2017)

[31] Lately, the tax rules have been changed making it possible for companies to sell excess (waste) heat from their production activities to other customers (like district heating) without taxation.

permarkets related to the other major supermarket chain called *Dansk Supermarked Group*.[32]

ProjectZero did not originally play a role in relation to the initial decisions and implementation, but the Supermarket later became a ZERObutik member and received the first "gold certificate" issued by ProjectZero (for 51-70% energy savings). Also, ProjectZero has used the Supermarket as a "best case" in relation to press releases, news on their website and visits by externals. Thus, ProjectZero helps providing publicity about the initiative. Similarly, Danfoss has also often visited the supermarket in order to show prospective customers and other contacts the technical solutions. Now, the Supermarket uses the ZERObutik certificate actively in their advertising; thus, the certificate is always displayed in connection with their weekly adverts in the local newspaper etc.[33]

2.2.3 Discussion: Success and outcomes

In terms of realized energy savings, both the Supermarket (the ZERObutik configuration) and Diamanten (the ZEROsport configuration) demonstrate impressive results. Surely, both sites represent "best cases" within each configuration, and most of the other sites taking part in these configurations have demonstrated much smaller reductions. For instance, many of the shops in ZERObutik have only received a white certificate (indicating 10-20% reductions). However, with more than 130 shops already having received a certificate, this indicates a rather successful spreading of the ZERObutik initiative among the local shops.

On a more general level, the ProjectZero (with its many and varied initiatives), and the goal of Sønderborg becoming a CO_2 neutral area by 2029, appears to be rather successful. As mentioned, the overall CO_2 emissions have been reduced with 36% by 2016 (compared to 2007) and the energy consumption by 18%. In comparison, the national figures of CO_2 emissions related to energy consumption (all sectors) show a reduction of 31% from 2007 to 2015[34], while the final energy consumption shows a reduction of 11% from 2007 to 2015[35]. This shows that the reductions within the Sønderborg area is well above the national average (particularly on energy reduction), although it also demonstrates that much of the achieved local reductions can actually be attributed to the outcome of national energy policies. In other words, it seems fair to conclude that the initiatives in Sønderborg contribute to a local strengthening of the national trends of decarbonization and increased energy efficiency.

The interviewed shops and sports centres also regarded their measures as successful in the sense that they had realized significant energy savings – and thereby also economic savings (in the case of the Diamanten even despite a considerable extension and standard improvement of the facilities). The interviewees talked about economic savings as the primary motivation for implementing the saving measures, whereas environmental reasons were mentioned more sporadically.

For the shops and sports centre Diamanten, it is interesting to notice that competitions and rewards in several ways played a key role. The ZERObutik is built almost entirely on the idea of promoting action through the public recognition of energy saving actions by issuing certificates (typically handed over by the mayor at a public event with local media coverage). Also, it was originally a call (competition) for funding applications that played

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[32] http://www.projectzero.dk/da-DK/Artikler/2017/Marts/Varmen-fosser-ud-af-Bilka-F%C3%B8tex.aspx (accessed 08-11-2017)

[33] However, this does not apply only to the Supermarket, but also all the other groceries being members of the local co-operative association, which organizes the local COOP supermarkets.

[34] Statistics Denmark, https://www.statistikbanken.dk/statbank5a/default.asp?w=1333 (accessed 02-08-2017)

[35] Calculated on basis of the annual national energy statistics from the Danish Energy Agency (*Energistatistik 2015* & *Energistatistik 2007*). https://ens.dk/service/statistik-data-noegletal-og-kort (accessed 02-08-2017). Notice that the energy consumption calculation includes all sectors, although only road transport in relation to the transport sector.

a key role in initiating the ambitions of creating a low-energy building at Diamanten. This indicates that competition, recognition and general publicity can motivate organisations like shops and sport centres to take part in energy saving initiatives.

With regard to the households, they also appeared to view the outcome of their investments and efforts as successful. Again, money savings were most often mentioned as a reason for doing the measures (even though the householders in general found it difficult to say how much they had actually saved), but also environmental reasons as well as considerations of being part of the overall energy transition were mentioned. In addition, some talked about developing individual solutions that would make them more energy-independent and resilient to external threats.

Compared with the households on the island of Fur, the awareness of time shifting electricity consumption in order to balance PV generation with consumption did not feature high in the Sønderborg interviews. It appears that the main reason behind this is that most of the Sønderborg households were on the annual net metering scheme, which does not incentivize time shifting economically (see previous on the difference between the hourly and annual net metering schemes). Interestingly, the only household on the hourly net metering scheme was also the only household reporting that they had changed daily habits in order to time shift consumption.

The households in general plugged-in the EV and started recharging upon home arrival in the late afternoon / early evening. This indicates a potential future systemic challenge as it adds additional power consumption to the already existing afternoon/evening peak (the “cooking peak”) between 5 and 7 PM of households. Also, the EV recharging does not synchronize with the midday peak in PV electricity generation. Automated or remotely controlled recharging is often promoted within the smart grid field as a solution to this problem. However, the Sønderborg interviews indicate that these kind of solutions may face a challenge, as the habit of starting recharging upon home arrival also relates to a feeling of security associated with always being able to go for possible (unexpected) rides later in the evening. Finally, the limited driving range of EVs still means that the EVs in these households have not yet fully replaced the combustion engine car (used typically for longer-distance trips).

ProjectZero clearly plays a key role in facilitating, promoting and communicating the energy transition of the Sønderborg area. Based on the study of ZERObolig, ZERObutik and ZEROsport, it appears, however, that this role is less about *direct* consulting or implementation of measures, but more about supporting knowledge sharing, keeping energy savings and CO_2 neutrality on the local agenda and promoting publicity around measures taken by local actors. In a sense, a key contribution by ProjectZero is to ensure that “the pot is kept boiling”. This is also seen in the stories of most of the visited sites (households, shops and sports facilities); in case of the households and the Supermarket, formal contact with ProjectZero was not in general made before the decision about energy saving measures had already been taken (and often not before their realization) – although it might be argued that the general awareness about the Sønderborg climate targets and ProjectZero might have influenced the decisionmakers indirectly. However, an exemption is Diamanten, where it was a central figure from ProjectZero, who originally suggested them to incorporate energy measures in the renovation project (but even in this case, ProjectZero did not directly engage in the sketching and realization of the project).[36]

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[36] The direct influence of ProjectZero seems slightly more visible in relation to the ZERObutik sites more generally (except the Supermarket), as ProjectZero is active in reaching out to local shops (e.g. through personal visits) in order to make them interested in taking part in the ZERObutik initiative. However, also here, ProjectZero is not as such giving specific advices (offering consultations) to the shops, but instead provide inspiration through sharing best cases from other shops (e.g. via online newsletters and local media coverage) and in supporting the establishment of a local network of electricians (the energy consultants or “ZERObutik partners”), who can offer advices.

It is interesting to compare the role of ProjectZero with the role of Samsø Energy Academy (see later), where the active contribution by the latter appears to be much more "substantial" in the sense that the Energy Academy is often directly involved in developing and carrying out energy measures locally. ProjectZero identifies their own role and activities as being "transition management" or "transition leadership" (in Danish: Omstillingsledelse). In their own interpretation of this (Christiansen & Rathje, 2015), transition leadership incorporates a number of key skills and approaches, especially: Network building (engaging local actors and facilitate their mutual cooperation), being a catalyser for change (initiate and facilitate rather than design and control), bring the vision and strategies into focus and to debate locally, and create collaboration between universities (knowledge institutions), companies and authorities (the Triple Helix idea).

It was evident from our visits to the Sønderborg area that the vision of Sønderborg becoming CO_2 neutral was something that also "regular citizens" of Sønderborg had heard about and knew. In this way, ProjectZero has succeeded in creating and anchoring the vision within the local community as a shared vision.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: The solutions developed at Diamanten (ZEROsport) and the Supermarket (ZERObutik) were quite innovative and were in both cases developed in close collaboration with local companies. This shows the importance of the collaboration between companies and local consumers in the ProjectZero case, which also feeds into their vision of the green transition as contributing to local economic growth. The technical solutions applied in the households were not in a similar way innovative.
- Actors: Seen from the perspective of the actors, the initiatives were regarded as successful. Economic savings was in most cases reported as the main reason for engaging in these initiatives, although also considerations for the environment or the overall energy transition were also mentioned (and increased resilience through self-sufficiency with energy in some of the households). ProjectZero plays an interesting role in relation to developing and maintaining existing networks of actors and, in particular, nurturing the awareness of the CO_2 neutrality vision and goals.
- Market: Like on Fur, subsidies played a role in most of the studied examples (except for the ZERObutik sites). Thus, households got their investments subsidized through general tax exemption on EVs and favourable account settlement schemes (implying tax exemptions), while the sports centres received funding from private and public funds and programmes for their investments. In this way, most of the solutions studied are not "truly" commercial in the sense that they would work without subsidies of various kinds. But given these subsidies and external funding, the solutions were in general profitable to the households and sports centres. [37] However, the Supermarket is an exemption from this, as the technical solution (utilising "waste" heat from refrigeration for space heating) was profitable even without subsidies. This is also seen in that the solution developed at the Supermarket is now being implemented in other local supermarkets.

2.3 Case 3: Samsø – Denmark's renewable energy island and the NightHawks project

2.3.1 Background and project characteristics

The island of Samsø is located between the island of Zealand and the mainland of Jutland. It has ferry services to both Jutland and Zealand. The area of Samsø is 114 km^2

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[37] However, it can be problematized to what degree the current market is successful in internalising the externalities of the economy, e.g. environmental and societal costs related to pollution, and in that sense is working as a "proper market". In other words, public subsidies can sometimes be seen as "corrections" to a failed market dynamic.

and it is the home of about 3,700 inhabitants (by 2017). The population of Samsø has almost halved since the beginning of the 20th century and is still in decline (was reduced by 12% between 2010 and 2017). [38] The island has its own municipality (the Municipality of Samsø). Agriculture and tourism are the most important businesses on Samsø. Among other things, the island is famous in Denmark for its "Samsø potatoes" (the Samsø potatoes are typically harvested earlier than potatoes from most other places in Denmark due to the mild climate on Samsø). The biggest town on Samsø is Tranebjerg (about 800 inhabitants) placed centrally on the Southern part of Samsø.

Energy saving and renewable energy transition has a long history on Samsø. In 1997, a group of islanders submitted an application for a competition of becoming the first Danish Renewable Energy Island project (applications from four other islands were also submitted). The competition was initiated by the Danish Ministry of Energy. Samsø won the competition with their plan on becoming fully self-sufficient with renewable energy within ten years. Then followed ten years of work on realizing this goal, which were to a high extent carried though by local NGOs and working groups of volunteering citizens. The goal was achieved by 2007, particularly through the following main measures: Installing new wind power capacity (11 x 1 MW onshore) owned by local citizens or windmill guilds (co-ops) and an offshore wind farm south of Samsø (10 x 2.3 MW wind turbines), expanding existing and creating new district heating areas based on local biomass and solar heating, helping homes outside district heating areas to save energy and convert to biomass-fired burners or heat pumps and installing new PV capacity. The key figures of the Renewable Energy Island (REI) Samsø initiative managed to engage a wide range of local citizens, businesses and organisations through what has been defined as "hope management", which "focuses … on the careful building of a process taking individual or group stakeholders' interests and worries as a starting point of situated negotiations" (Papazu, 2015: 197). Thus, even though the formal goal was to realize the REI plan, the transition was by the key initiators very much framed within the context of addressing local threats and challenges, such as local job creation, as a strategy to combat the decline in the island population. In this way, the initiative and transformation were flexibly adapted to the local citizens' and stakeholders' interests and aspirations. For instance, besides some idealistic viewpoints, the local farmers were encouraged by the economically-driven incentives related to owning land sites that were suitable for renewable production (wind power). In particular, cooperative ownerships have increased the acceptance of energy projects.

With the realization of the REI plan in 2007, the island had become self-sufficient, if measured by the annual, total renewable energy generation. However, there is still an exchange of energy with the mainland of Jutland through a sea cable, and the island is not as such "truly" independent of the wider energy system. Thus, on calm days, the island imports electricity from the mainland in order to cover the lack of local wind power generation. Also, the transport sector and some of the individual heating outside district heating areas are still fuelled by fossil fuels (even though this consumption can be said to be "offset" by the annual surplus of RE generation).

Thus, the new challenge of Samsø is to get entirely rid of using fossil fuels, i.e. in particular replacing fossil fuels for transport with renewable alternatives. On the national level, this is expected to be achieved in 2050 (see previous on Danish energy policies), but Samsø aims for reaching it by 2030, as a pilot project for the rest of the country. In relation to this, seven goals to realize the vision have been formulated. These were developed by the Samsø Energy Academy (see below) in collaboration with the Danish energy planning consultancy EnergiPlan and with input from the municipality, local citizens and other stakeholders (local businesses, associations etc.) through, among other things, so-called "open space" meetings, which is structured debates and brainstorm meetings. One of the seven goals is that half the local cars must be electric by 2020 (however, not likely to be reached in time, according to the Academy). Another goal is that heating in

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[38] Statistics Denmark, http://www.statistikbanken.dk/BEF4 (accessed 28-07-2017)

local households must be reduced by 33%. Also, the Samsø Municipality, supported by Samsø Energy Academy (see next), are currently working on plans for a local biogas plant, which – on basis of local biomass resources – can produce biogas that could fuel the local public bus line or the ferries to Jutland.

The Samsø Energy Academy (opened in 2007) is a demonstration and meeting place for local citizens, guests and visitors with a general interest in sustainable energy, community power and sustainable development.[39] Visitors particularly wish to hear about the island's experiences with anchoring projects through involvement of local citizens. Also, the Samsø Energy Academy (SE) works on many different projects related to the continuous development of Samsø to become a fossil-free island. The staff of SE includes about nine employees, who work on different projects typically funded by national or international programmes. Formally, SE is owned and managed by the association of the same name (Samsø Energy Academy) with the purpose to be "instrumental in the development of competencies within sustainable community development and the communication of knowledge about holistic processes of co-operation. The association is to promote and encourage co-operation between citizens, businesses, public authorities and research and educational institutions on the basis of Samsø as a sustainable local community."[40] The board of the association consists of 7-8 members elected among the members, although Samsø Municipality and Region Midtjylland (the local region) each appoints one member.[41]

Lately, the SE has set out a range of initiatives to reduce the energy demand. Some initiatives focus on installation of smart electricity loggers in buildings to identify unnecessary consumption, decrease heating demand and increase energy efficiency. Also, as part of an EU-funded international project called *NightHawks*[42], The Academy visited 16 shops and other local businesses during 2014-15, offering them consultancy about possible energy savings. Moreover, the business staff was offered education about energy saving. During the visits, temperature data-loggers were installed in different places in the buildings to gain information about the opportunities to reduce the heating or cooling. These visits have resulted in concrete advices to save energy and, all in all, reduced the average energy consumption by 11% since 2014.

In the following, we will focus on the shops and other local businesses taking part in the NightHawks initiative. In total, two shops (a supermarket and a convenience store), one community centre and a small restaurant & hotel have been visited as part of MATCH project.

The original idea behind the NightHawks project was to do so-called "night walks". As the project website explains: "Night walks are on-site energy surveys held at times when businesses are closed to the public. Energy experts conduct the survey with a view to identifying areas of energy waste within a business, in order that a bespoke action plan can be produced and implemented so as to enable direct and significant energy savings."[43] However, the SE slightly modified and adapted the concept to the local context on the island. First of all, they visited the businesses during day hours, which made it

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[39] The domicile of the Energy Academy houses in addition a variety of actors (e.g. researchers and scientists) running a broad spectrum of energy counselling services for commercial and private customers and organize guided energy tours, workshops, and seminars etc.

[40] http://arkiv.energiinstituttet.dk/71/ (accessed 08-11-2017)

[41] Before 2007, the energy initiatives – and the Renewable Energy Island project – was anchored to the association "Samsø Energy and Environment Office" (established in 1997) and the Samsø Energy Company, which was founded by the Samsø Municipality, the local Business Council, the local Farmers' Association and Samsø Energy and Environment Office. The Samsø Energy and Environment Office and Samsø Energy Company (established in 1998) had a close collaboration and shared secretariat. They were primarily financed by public money and project funding. Due to lack of funding the Samsø Energy Company closed in 2005. The Samsø Energy and Environment Office is now part of Samsø Energy Academy.

[42] See http://www.night-hawks.eu/

[43] Quotation from: http://www.night-hawks.eu/night-walks/ (accessed 03-08-2017)

possible for them to talk with the business owners and staff members about their daily routines etc. With regard to identifying areas of energy waste, SE instead used smart meter data and data from temperature data-loggers to map the 24 hours energy performance of the buildings. The latter were used to identify (unnecessary) high energy consumption and develop suggestions for energy saving measures. Focus of the site visits and the analysis of the measured data were in particular on options for energy optimising the heating system (e.g. by night set-back), cooling (e.g. by turning off bottle coolers during night hours) or replacing inefficient lighting with LEDs etc. In explaining the underlying approach behind the initiative, SE emphasises that it was important to come up with ideas that would not compromise comfort, sales or the daily work routines at the supermarket.

2.3.2 Socio-technical configurations applied in the project

Even though the sites visited as part of the MATCH project are rather different (a supermarket, a community centre and a small restaurant & hotel), they were all part of the NightHawks project and in this way part of the same socio-technical configuration. In the following, the key elements linking the sites together through the intervention of the Samsø Energy Academy are identified (the role of SE will also be explored separately in the following). Below, the supermarket is used as a through-going case, while comments/observations from the other sites are included when relevant.

	Energy savings in local business *NightHawks*
Technical elements	Monitoring consumption (smart meter data, temperature dataloggers) Conventional technologies (timers, LED lights etc.)
Social elements	The Samsø Energy Academy Trust Dialogue-based processes Local networks Funding

On basis of several site visits, dialogue with the staff and monitoring the smart meter data and profiles of logged temperature data, the SE came up with a variety of suggestions of energy saving measures in the supermarket (see the list of suggested measures in Jantzen et al., 2017, and the theoretical background in Jantzen & Kristensen 2014). The management of the Supermarket decided to apply a number of these measures. The SE calculated that the total savings of the implemented measures would account to about 7.5% of the annual energy budget of the shop, i.e. about 8,400 Euro/year or about 58,000 kWh/year. At the end, the management states that they had saved even more than the calculated.

One of the implemented measures was to lower the room temperature of the Supermarket during night hours (the shop is closed from 8 PM to 8 AM). The SE proposed a 1 °C reduction (from 20 to 19 °C), which alone should save about 8% of the total energy consumption for heating. This was realized by simply adjusting the control of the heating system of the building (i.e. no need for installation of new technology). However, it took some dialogue and negotiation with the staff to settle on the specific timing of when the night set-back should start and end. For instance, a cleaning worker is cleaning the shop during night, and some members of the staff (e.g. the butchers) are meeting early in the morning. In other words, the specific settings of the control had to be adjusted to the practices of the staff members. This exemplifies how prolonged dialogue is a key (social) element of the work of SE and the realisation of the suggested measures.

Closely related to this, trust is also a key social element. In general, the sites approached by the SE for the NightHawks project welcomed the SE and were happy to collaborate. Typically, they would provide the SE with the login credentials for the online access to their historic electricity consumption data (collected via smart meters). Also, the SE was generally allowed to walk around in the shops on their own while doing their observations and measurements (which implied many recurrent visits). In this way, the SE could more or less “come and go” as they liked. It is likely that this trust in SE to a high extent is based on the long history of the energy transition project on Samsø as well as that people in general know each other from other contexts (cf. the small population size of Samsø). Also, the key staff members of SE where also active within other arenas (e.g. local policy). All in all, SE and its staff members appear to have become household names to most people on Samsø. As several of the MATCH interviewees explained, they believed that the people from SE were the one’s on the island that knew most about energy and energy savings – and they also trusted that advices from the SE would be impartial. Over the years, trust in SE has been built up, and is probably one of the most valuable “capitals” of the SE today.

When it comes to the technical elements, these are – as already indicated – rather conventional in the sense that none of the solutions included demonstration of (radical) new technical solutions (as was the case on Fur and in ZEROsport and ZERObutik, cf. previous). Instead, the “innovative” aspect of the NightHawks project (as carried out by SE) is more related to how the process of identifying and carrying out energy saving measures is organized and performed by SE. Here, SE works both as a facilitator of the process (e.g. directing the awareness of businesses towards the issue of energy saving) *and* is strongly involved in the realization of the measures. Thus, they frequently visit the sites to see if “things are working properly” and talk with the owners or staff members if there are any problems. In this way, SE continuous to be the “supervisor” to be contacted if the businesses experience any issues with the energy saving measures. This seems partly facilitated by Samsø being a small island and that the SE staff therefore often happens to “pass by” a site and “pop in” for a talk or to look at something. However, the exact role of SE is manifested slightly different from site to site. In the Supermarket, the SE staff is clearly ascribed a role as the energy experts. Thus, the new director does not really know much about what energy measures that have been carried out or how they work. Therefore, he relies almost entirely on the support of the SE for the continued monitoring and maintenance of these measures. Different from this, one of the key persons at the community centre (a volunteer who has retired from her work) is the one who is actively managing the energy and ventilation system. She originally got help from SE to figure out how the system works and how to make it more efficient (by adjusting the running hours of the system to the actual needs in the buildings), but is now the person who manages the system on a day-to-day basis (although she still relies on the SE if she encounters more complicated (technical) issues). Based on these observations, it appears as SE has developed an approach or practice that makes them flexible with regard to adapting their interaction and role to the characteristics and specific needs of the individual site.

Even though the (technical) solutions appear rather simple, it in many cases turns out to be more complicated to develop and carry out the saving measures. For instance, the energy consuming devices are in some cases third-party property. One example of this is some of coolers in the supermarket that are provided by the suppliers of, e.g., beverages. Typically, an agreement is made between the supplier and the shop, which gives the shop higher profits of the sales from the cooler. In return, the shop must accept that the supplier installs its own coolers with its logos etc. It is the responsibility of the supplier to maintain the cooler, but the energy costs are paid by the shop. This exemplifies the so-called principal-agent problem (Eisenhardt, 1989), i.e. an uneven distribution of energy saving investment costs and energy saving benefits between agents. In this example, the supplier has no incentive to provide the shops with energy efficient (but often more expensive) coolers, as the energy costs are paid by the shops themselves. Also, this type of arrangement complicates doing energy saving measures (e.g. controlling the cooling with timers turning of the coolers in the night or changing set temperatures), as tinkering with the devices potentially can violate a third-party property. For instance, the owner of the restaurant & hotel has not installed a timer on beer cooler because the supplier (a brewery) has told him that it must not be turned off.

Local networks and relations also play an important role for the development of this socio-technical configuration. First, the businesses participating in the NightHawks project were mainly chosen through the local network of the SE staff. Second, the energy saving measures are spreading between businesses via informal networks. An example of this is two smaller convenience stores, where the managers know each other privately and are exchanging experiences with different initiatives to save energy. Also, one of these managers originally contacted the SE for help and advices, because the chairman of the association behind the convenience store also was chairman of the local district heating utility and, through this, knew the SE people very well.

Finally, like in the previous cases, external funding also plays a key role for the development of this configuration. Partly through direct EU funding of the NightHawks project, partly through the general public funding of the SE, which makes it possible for the staff to continue their engagement in the businesses (even after the funding of the NightHawks project has concluded).

2.3.3 Discussion: Success and outcomes

Is the NightHawks project a success or failure? On one hand, it certainly appears as a success: Significant energy reductions were achieved through rather simple socio-technical solutions and typically with very small investments in new equipment (if any). Often, the savings were achieved simply by a more energy efficient management of the energy systems of the businesses. Also, the businesses taking part in the project appear to be happy about the interventions and believing that they save energy expenses. As discussed in the previous, the successfulness of the initiative appears to a high extent conditioned by the general history of the REI and, specifically, the trust in the SE that has been developed on the island over the years. However, this might also limit the extent to which the method and lessons learned from Samsø can be transferred to localities without the same level of trust in a local entity like SE.

On the other hand, it appears to be a relatively expensive method, as it requires many hours of work (of SE) to develop and implement the measures – as well as continued help and supervision afterwards.[44] At least if compared to solutions based on “do-it-yourself” check lists or instructions, although the latter methods might not be as efficient as the approach of NightHawks and SE. It is therefore an open question to what extent this could work on market conditions and without public funding.

A final comment on the character of the work carried out by SE: At first glance, the method employed by the SE might seem rather simple. However, the sites of intervention often turn out to be surprisingly complex. A site like the Supermarket, e.g., is a complex of interrelated practices and networks of actors. Even apparently small modifications like a temperature night-setback might interfere with practices of cleaning during the night or staff members meeting early in the morning. Similarly, installing timers on coolers might interfere with third-party properties (not to mention national regulations governing storage of foodstuffs).[45] Consequently, instead of being a “simple technical” intervention, it is rather a complex social and organisational task, which also means that a successful intervention in general depends on many actors’ active involvement.

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[44] In the NightHawks project, this was financed by EU – and the consultancy was free to the participating businesses.

[45] See also Jantzen et al. (2017) for an example related to replacing traditional light spots with LED spots.

Finally, it should be noted that the case study shows differences between the sites (businesses). Compared with the community centre and the restaurant & hotel, the Supermarket appears to be the most complex site; both in terms of material and technical complexity (many relatively advanced energy systems, partly interrelated and interfering with each other) as well as organizational complexity related to the size of the staff (many practices and many people to involve), ownership models (e.g. coolers owned by third parties) and the role of the central office at the supermarket chain (of which the Supermarket is a branch). By contrast, the other sites typically had one person in charge of the energy system and the decision-making related to doing changes.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: Only “conventional” technologies were applied in this configuration, because focus was not on technology development as such. The innovative aspects of the NightHawks project were on the approach of identifying and realising (organising) energy saving potentials, for example by placing temperature loggers in the shops.
- Actors: Seen from the perspective of the actors (SE and the businesses), the initiative was rather successful. The relations between SE and the shops etc. are embedded within the local social networks on the island, and in particular shaped by the long history of the REI and SE (including a high level of trust in the SE).
- Market: Like on Fur and in Sønderborg, subsidies play a key role for this configuration. It is questionable if this initiative could have been realized without external funding. The realized energy savings can be considerable and do not require significant investments in new equipment or installations. However, the costs are mainly related to working hours connected with identifying, carrying out and maintaining the saving measures.

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Case study report Norway

Findings from case studies of PV pilot Trøndelag, Smart Energi Hvaler, and ASKO Midt-Norge

Version 1.0

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Disclaimer

About ERA-Net Smart Grids Plus

ERA-Net Smart Grids Plus is an initiative of 21 European countries and regions. The vision for Smart Grids in Europe is to create an electric power system that integrates renewable energies and enables flexible consumer and production technologies. This can help to shape an electricity grid with a high security of supply, coupled with low greenhouse gas emissions, at an affordable price. Our aim is to support the development of the technologies, market designs and customer adoptions that are necessary to reach this goal. The initiative is providing a hub for the collaboration of European member-states. It supports the coordination of funding partners, enabling joint funding of RDD projects. Beyond that ERA-Net SG+ builds up a knowledge community, involving key demo projects and experts from all over Europe, to organise the learning between projects and programs from the local level up to the European level.

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Preface

This report is the outcome of work package 2 *Detailed case studies of the ERA-Net Smart Grids Plus project Markets, Actors and Technologies: A comparative study of smart grid solutions* (MATCH), which involves partners from Austria, Norway and Denmark.

The aim of MATCH is to explore how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. This is studied on basis of detailed national case studies carried out in each of the three participating countries. This report (MATCH deliverable D2.3) presents the main findings from the Norwegian case studies.

The national case studies establish the empirical foundation for the comparative analysis across cases and countries in work package 3 *Identifying determining factors for integrated and successful smart grid solutions* and for the later work package 5 *Recommendations for designers, planners and policy makers*. The deliverables from these work packages will be published on the website of MATCH (http://www.match-project.eu/), which also includes further information about the project and its other publications. The latter includes coming scientific papers that are going to explore differences and similarities between cases in further detail in relation to specific research questions.

The empirical work in relation to the national case studies was guided by an analytical framework developed in the MATCH work package 1 *Design of overall analytical framework for case studies*. This deliverable (D1) can be downloaded from the MATCH website. The framework combined different theoretical perspectives in order to establish a shared understanding of how we should approach the cases and what kind of data to collect. This ensured a certain degree of empirical homogeneity between the national case studies.

In order to support the comparative analysis, the national case study reports (D2.1-D2.3) follow the same outline. Thus, in the following, we will first present the national context of the Norwegian case studies (Chapter 1). This includes a brief introduction to the national profile of Norway in addition to a presentation of the Norwegian energy system, policies & regulation, market structure & energy consumption and, finally, the smart grid landscape. Then follows the main part of the report (Chapter 2), which presents the outcome of the Norwegian case studies. A brief description of the empirical work carried out introduces this chapter, and is followed by three sub-sections presenting the findings from the three national cases: Two solar PV demonstration projects in Trøndelag by the two energy companies in this region, TrønderEnergi and Nord Trøndelag Energi (section 2.1), Smart Energi Hvaler on the archipelago of Hvaler (section 2.2) and a large solar pilot driven by ASKO midt-Norge, which is an SME dealing with wholesale of groceries (section 2.3). Each of these case presentations is organised in three sub-sections: Background and project characteristics; socio-technical configurations; Discussion of successes and outcomes.

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Trondheim, 17th November 2017

1 National context factors

1.1 Country profile of Norway

The kingdom of Norway is situated on the Scandinavian Peninsula and has an area of 323,802 km^2 and a population of 5,258,317 as of January 2017. Apart from the mainland, the country also consists of the island of Jan Mayen and the archipelago of Svalbard, the inclusion of which makes the total area of the country 385,252 km^2. Norway shares a long border with Sweden, and borders Finland and Russia to the northeast and Denmark across the strait of Skagerrak to the south. Its coastline, meandering along bays and fjords, stretches for 28,953 km. If including the 239,057 registered islands, the total coastline is 100,915 km long, the second longest in the world after Canada (SNL 2017). Norway reigns over 1,979,179 km^2 of ocean divided into three areas including the mainland economic zone (878,575 km^2) and fishing zones near Jan Mayen (293,049 km^2) and Svalbard (803,993 km^2, see Kartverket, 2017).

Norway is sparsely populated, due to its large and geographically uneven territory. It is a very long and narrow country, and stretching 2562 km from 57° north at its southernmost point to 71° north, the country is host to the polar circle at 66°. As much of the country is mountainous, permafrost can be found all year in the higher areas, together with numerous glaciers. Because of its location far to the north and the length of the country, it experiences a wide variety in climate and daylight conditions. Due to the Gulf Stream however, which travels along the coast of Norway on its way to the arctic sea depositing warm weather along the way, Norway’s climate is warmer than it would have been thus far north. In the northernmost parts, it exhibits a maritime subarctic climate, but the southern regions have weather not that different from central Europe. The country has four distinct seasons, enjoying pleasant if somewhat short summers compared with southern latitudes. Daylight conditions is another aspect which is influenced by the northern placement, and even the southern regions experience only a few hours of daylight (~0900-1500) in winter and almost no darkness during night in the peak of summer. In the north, these conditions are more extreme, resulting in no daylight at all during winter solstice, but never ending days in mid-summer.

In spite of a steadily ageing population it is still increasing slightly. About half of the increase consists of immigration. Norway has about 2.3 million households with an average of 2.2 persons. The home is the primary object of investment for a majority of households, resulting in a very high home ownership. It is estimated that 4.2 million live in owned housing (SSB 2017a). The majority of housing arrangements consist of single-family detached dwellings (52.9%). The second most common living arrangement are multi-dwelling buildings (22.7%) followed by row houses (11.8), semi-detached (9.2), and other residences (3.4%).

Norway is a constitutional monarchy, and divides state power between parliament, cabinet and supreme court as defined in the constitution of 1814. Current head of state is King Harald V and the prime minister is Erna Solberg. Norway has administrative and political subdivisions on two levels, and consists of 426 municipalities across 19 counties. Although not a member of the European Union (membership was dismissed by referendums in 1972 and 1994) the nation remains in close collaboration with it as well as the United States. In lieu of a membership in the EU, Norway maintains ties through the EEA-agreement, which makes the country a member of the European Economic Area, requiring it to adopt EU law and regulation in a fashion more or less similar to that of the other EU members. In practice Norway has had its policies on financial affairs, foreign policy, social affairs, infrastructure, energy, and climate influenced by EU to a comparable degree to the rest of its nations. Through the EEA-agreement, Norway is mandated to let the European Free Trade Association (EFTA) Surveillance Authority, and in a last resort the EFTA-court, ensure that Norwegian authorities and other entities act in accordance with the agreement. Norway does not have veto powers over the EU, as the Storting, which is the Norwegian Parliament, may decide whether rules and regulation shall be accepted. This is called the reservation right, and has only been used once[1]. Apart from being a founding member of the UN, NATO, the European Council, the Organisation for Security and Co-operation in Europe, and the Nordic Council, the country is a member of the World Trade Organization, Organisation for Economic Co-operation and Development, and a part of the Schengen area. The country is part of the EU Emission Trading System and it has signed the Paris Agreement and reported an Intended Nationally Determined Contribution (INDC) with a commitment to reduce absolute greenhouse gas emissions by at least 40 % by 2030 compared to the 1990 level.

Norway has experienced a strong economic development during the last few decades. It bases its economy on oil, gas, mining, timber, seafood, and hydropower. The basic development of the Norwegian economy the last 100 years can be ascribed mainly to hydropower, but the rapid increase in this development the last 50 years is due to oil and gas production and adjacent sectors, which today contributes about a quarter of GDP. The GDP of Norway is thus quite sensitive to the fluctuations in oil prices, which have been prevalent in the last few years. GDP per capita is currently around $74,000, owing largely to the country's role as the world's third largest exporter of oil and gas (IEA 2011). Between 1990 and 2015, the disposable per capita income increased by 89 %, and by the end of the 2000s Norway had become the one member of the OECD countries with the highest per capita income (SSB 2016c). The oil and gas exports have been an important engine in this development. High employment rates, a positive development of real wage rates and private consumption, a relatively equal distribution of economic wealth, strong public finances combined with a well-developed welfare state, are all characteristics of this prosperous period. The period seems to have come to a temporary halt with the drop in the oil price that was experienced in 2015, which resulted in lower activity and layoffs in the oil sector, and with some effects in other sectors. Increasing international instability also add to the uncertainty regarding future development. Even so, the Government Pension Fund Global, consisting of offshore industry revenue and subsequent investment profits, has acted as a buffer to worldwide economic fluctuations. The ability of politicians to use it for covering budget deficits has effectively insulated the Norwegian economy from the latest crises. The value of the fund today stands at around € 800 billion.

In order to describe the context for smart energy technology in Norway, the following will give a short review of recent history. Norway is large in area relative to its population and a wide range of energy resources are available. A long coastline gives potentials for wind, wave and tidal energy, while the inland adds waterfall and biomass resources. Substantial offshore oil and gas resources complement the energy endowment. However, most of this is exported and not a part of the energy system or, in official terms, the carbon footprint. The energy sector in Norway is dominated by two main areas, hydropower and oil/gas.

1.2 The Norwegian energy system

Hydropower

The utilization of hydropower developed through the 20th century and with an increased focus after WW2. This laid the foundation for the power-intensive industry within metals, chemicals, fertilizers etc., brought industrial development to the nation, including rural communities, and created the foundation for the modern Norwegian energy system. Important institutional principles, such the concession system with the reversion principle (ownership of waterfall resources returns to the Norwegian state after the concession

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[1] The dispute was about letting foreign offshore helicopter transport companies operate on the Norwegian continental shelf, as well as granting responsibilities for supervision of such operations to international authorities. The Norwegian authorities dismissed the so-called Helicopter Offshore Regulations based on having no relevance for activity on Norwegian soil, and concern that the new regulation would pose inferior to the existing one (see http://www.tv2.no/a/9148446/)

period) and the system of concession power, which ensures direct economic benefits to municipalities which provide waterfall resources to outside businesses, were established in this period.

The big expansion in hydropower capacity took place during the 1950 – 1990 period. In addition to supplying energy to the expanding heavy industry, thus driving the modernization of the nation, it also made available cheap and reliable energy for other sectors of society. This opened the way for an expansion in the use of electric equipment and appliances in these other sectors, and it resulted in a widespread use of direct electrical heating systems in the building sector. Such heating systems are inflexible in terms of energy carriers, and this dependence on electric energy has become a major issue regarding energy security in Norway. The fact that Norway is second only to Iceland in terms of per capita electricity consumption, illustrates this dependence on electric energy. Even so, the latest building regulations have, after a period of focus on alternative means of heating, resigned to a lenient stance towards direct electric heating, as it makes sense in the Norwegian market context of cheap, clean hydropower.

Through most of the 20th century the production and distribution of electric energy was mostly publicly owned, and as an effect of the strategic role of this sector in the industrial sector after WWI, it was heavily regulated through a complex of legislation. Local monopolies, differences in investment strategies, etc. had led to an inefficient energy system with an overinvestment in generation capacity. A centrally controlled and regionally administered electricity system, investment decisions and prices were decided by parliament on a yearly basis. Counties had their own electricity utility responsible for a guaranteed supply. Prices were held constant with the help of price subsidies, meaning that new generation was paid for with income from existing ones. Whenever the demand would catch up with supply, this would spur generation expansion. There was no market, and a single entity was responsible for production, transmission and sale of electricity to customers.

The work commissioned in 1980 by the government and led by Professor Einar Hope at Centre for Applied Research in combination with the ascendancy of a center-right government in 89, paved the way for a reform of the energy system with a strong focus on market economic principles (Karlstrøm 2012). Hope and his team described through more than 60 reports the system that would be implemented during the deregulation process. Production and distribution capabilities were separated, and a spot and futures market were established. The spot market would function as the mechanism for setting the prices, and the futures market allowed for insurance against fluctuations in price and quantity. Different contract schemes were introduced both in long and short-term variants, futures trading and separation of production and distribution was meant to introduce better price signaling to consumers, and thereby improve basis for investment decisions. A strict income regulation was mandated on the distribution monopolies. With the new energy law of 1991, Norway became one of the first countries in Europe to deregulate the electricity market and establish market principles as the basis for energy production, trade and investments. The new market model was soon made to include the rest of the Nordic countries, and the introduction of a common Nordic spot market for electricity.

Most low-hanging hydro resources are utilized by now, remaining potential large scale projects in general have too high environmental costs to be developed. Realistic potential new hydropower projects are therefore mostly related to smaller scale and local developments.

Oil and gas
Another main energy political area in Norway is the oil and gas sector. This industry developed from the 1970s on, primarily off the shores of southern/western Norway. During this period, the country became among the largest global exporters of oil and gas. Related supply industries and technology development followed the expansion of the offshore industry, and became important parts of the general industry structure of the country. In addition, revenues accruing from exports of oil and gas became very important in the state finances. A large proportion of this public income stream has been set aside in a designated investment fund (The Government Pension Fund Global). The political discus-

sion related to the future development of this industry reflects the uncertainties introduced with the climate issue, and the key question is whether to expand and continue developing this industry, possibly into the risky waters of the Arctic, or to downscale and leave most of the remaining resources in the ground. In the latest development, several environmental organisations have engaged in a civil suit against the government for pushing development in the far north, citing constitutionally embedded laws on the environment[2].

Other market developments

A common Swedish-Norwegian green certificate system was introduced in 2012, designed to add 28 TWh new renewable electricity into the system by 2020 (this volume represents around 10 % of the current normal year’s production in the two countries). Most projects are realized as wind and CHP projects in Sweden, and as new hydropower in Norway. A number of concessions have already been granted for onshore wind farms, but low electricity prices have yet to make such projects economically viable, and the concessions have been shelved. The short-term effect of this instrument is to increase the surplus of electricity in the Scandinavian system, and thus to maintain the low spot market price of electricity that has been observed in the last years.

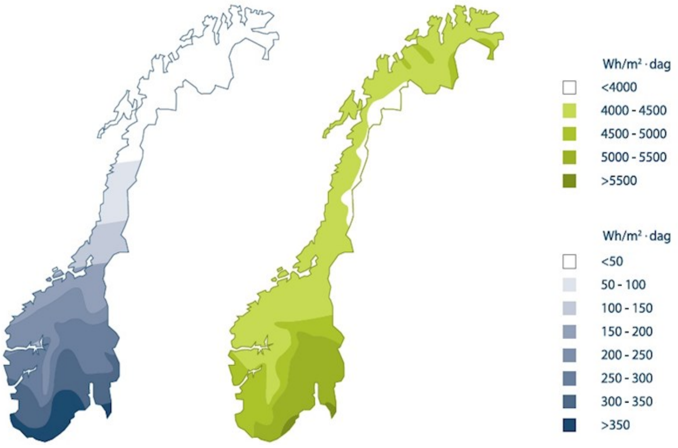

Figure 1: Solar radiation against a horizontal area in January (left) and july (right)

Solar PV has long been a common addition to Norwegian vacation homes, the cabin, typically located in sparsely populated and extremely rural areas far away from any kind of infrastructure. Traditionally, these types of solar panels have not been connected to the grid. In later years however, solar energy has become more common as prices have reduced, both in residential and industrial contexts. Once again, the reason for the low influx of solar in Norway in the past has mainly been because of low energy prices, making investments into panels economically prohibitive, compared to for instance Germany. But as of 2016, the amount of new solar installed in Norway was 11 MWp, which represented a growth of 366% compared to 2015. 10% of this was not connected to the grid. The total aggregated power capacity was increased by 75% compared to 2015 and amounts to around 27 MWp at the end of 2016. The share of this that was connected to the grid is 13,6 MWp – around 10 GWh/year. A Norwegian solar panel can usually produce around 700-950 kWh/KWp. In other words, the solar influx is higher than expected for such Northern latitudes (see figure 1), and adding to the feasibility is the relatively cold weather, which works to increase the efficiency of most panels. There are also extensive support schemes and subsidies in place to further the proliferation of solar in Norway. For instance, Enova, the Norwegian energy authorities, will typically grant £1,000 for a production rig plus €125 per kW up to a total of 15 kW, but not more than 35% of total costs. There are no other requirements.

Bioenergy resources, used as traditional firewood, in central heating systems, or as biofuels, are not utilized near their potentials today. As a broad “landscape overview”, we may therefore conclude that Norway is a country rich in energy resources. It is a large exporter of oil and gas and with a domestic energy system built around a plentiful supply of cheap and clean electric energy.

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[2] https://www.tu.no/artikler/dette-blir-konsekvensene-om-staten-taper-den-historiske-rettsaken/411646

The current structure of the Norwegian energy system

The Norwegian transmission system is divided into three levels, the central grid, the regional grid and the local, distribution grid; however, according to EU rules there is an ongoing process to merge the two lower levels. The central grid is high voltage transmission based on 300 or 420 kV, and is used to transfer electricity throughout the five Norwegian market areas as well as across national borders. The central and regional grid is operated by TSO Statnett, and some of the regional and distribution levels are served by 129 DSOs. International interconnectors are established between Norway and Sweden, Finland, Russia, Denmark, and the Netherlands, and there are interconnectors to Germany and Britain planned (Cigre, 2014). Total production in 2015 was 145 TWh, 95.8% of which was due to hydropower. Thermal power and wind generation represented 2.5% and 1.7% respectively. Norway imported about 7.4 TWh, whilst exporting 22 TWh. Gross domestic consumption was 129.8 TWh, and the net was 120 TWh. In 2015 Norway had 1065 power stations with a total output of 33 837 MW (SSB 2017b).

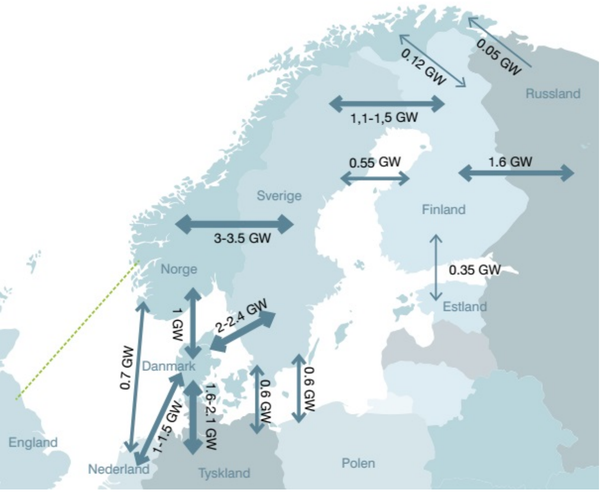

Figure 2 The Norwegian and surrounding transmission systems (Source: Statnett)

Due to the presence of huge hydropower resources in the country, it poses a rather unique case in a European or even global perspective. Half of the energy used on the mainland is based on electricity, and close to all of that is renewable. Since its deregulation in the region in the 90s, the power markets were consolidated on a common Nordic power trading market called Nordpool. Electricity is generally difficult to store, but in case of hydropower this is possible by trapping water behind a dam, in principle making it possible to turn on and off the power supply according to demand. Norway also imports power in low-price periods to conserve the stored capacity, and it will ideally be made use of only when demand is high. Low-price periods can also be used to pump water back into the magazines, however the extent to which Norway does this is not extensive (only two facilities, 640 and 56 MW). The versatility of hydropower makes it suitable for base load regulation. This makes the hydropower quite valuable in the market, and there are often talks about developing the role for Norway as a “green battery” in the European system, and provide much needed stability for a wider introduction of renewable energy and displacing coal and gas. This might however be unrealistic, mainly for two reasons: the total Norwegian foreign transfer capacity is about 4-5 GW, which represents only 10% of the load demand for solar during dinnertime in Germany. In addition, the capacity of Norwegian hydropower in total is about 33 GW. An optimistic share of this of about

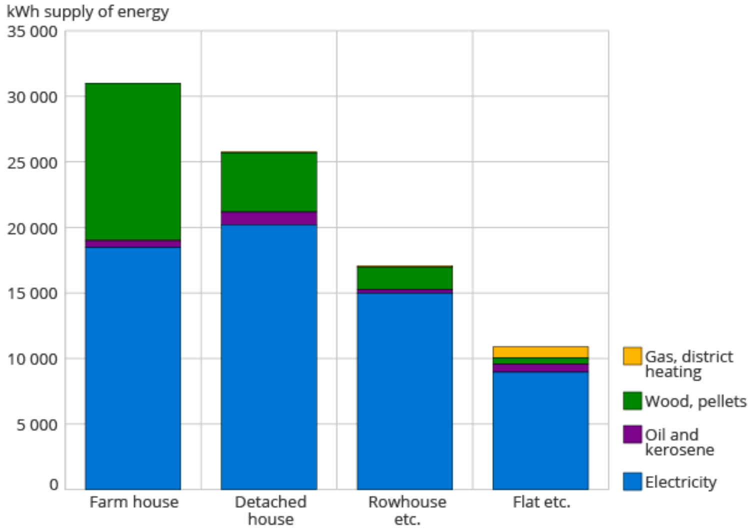

Table 1 Distribution of consumption by energy source and type of house (Source: Statistics Norway)

20-30% would still be a tiny contribution on a German scale (Bendiksen 2014). This is not to say Norway does not supply energy to the Nordpool spot market in terms of kWh over the import/export balance, which it does in large quantities as mentioned above.

When it comes to Norwegian CO2 emissions, these are often considered negligible because of the high penetration of renewable energy. This is, however, not entirely true. Emissions per capita in Norway in 2013 were 11.7 tons/year, higher than both Denmark (6.8) and Austria (7.4) (The World Bank 2013). Total emissions from Norwegian territories in 2015 were 53.9 million CO2 equivalents, a 4.2% increase since 1990. Of this, 15.1 and 11.9 come from oil and gas extraction and industries/mining respectively. The second largest culprits in the Norwegian economy is road traffic and other kinds of transport like aviation and navigation (i.e. fishing), netting 10.3 and 6.4 million CO2 equivalents respectively. Agriculture is another contributor, with 4.5 million CO2 equivalents, whereas the energy supply itself and heating in households and industry amount to 2.9 (SSB 2017c).

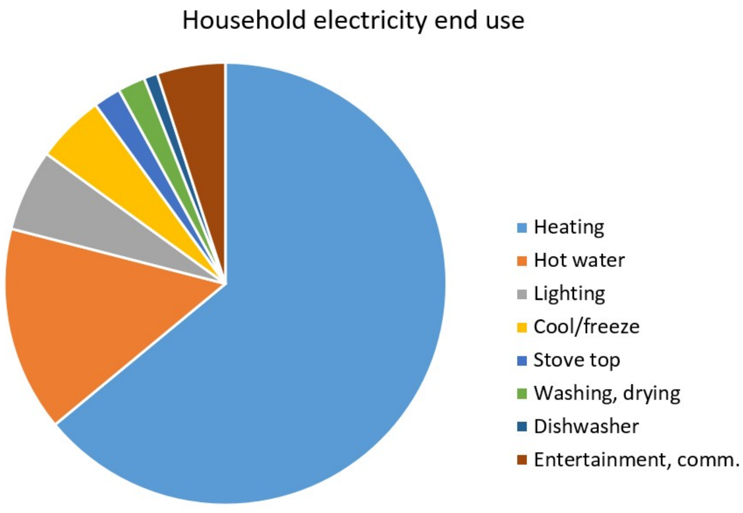

Figure 3 Electricity use based on source of consumption (Source: REMODECE)

As mentioned earlier, the prevalence of cheap, reliable, clean electricity in Norway makes it the preferred source for most anything, even heating. Even so, there is a tradition for using wood burners for space heating, as can be seen in Table 1. As shown in figure 3 (based on household measurements), space heating (64 %) represents the one dominating end use of electric energy in the household sector. This reflects both the cold Nordic climate and the characteristics of the energy system, discussed above. Addressing the use of direct electrical heating in buildings therefore is one of the priorities of Norwegian energy policy in an energy efficiency context.

1.3 Policy and regulation of the energy market

The national energy policy rests on two fundamental documents: first, there is the 2008 “Climate agreement”, a consensus document endorsed by a majority of the political parties represented in the Norwegian parliament, recognizing the challenge of climate change and specifying climate goals. Goals include reducing *global* emissions equivalent of 30% of Norwegian 1990 levels, as well as reaching carbon neutrality by 2050[3]. Second, a white paper published in 2016 on energy policy toward 2030 both reinforces and adjusts the main lines in national energy policy. The paper specifies four main goals for energy policy: (i) Enhanced security of supply, (ii) Efficient production of renewables, (iii) More efficient and climate- friendly use of energy, and (iv) Economic growth and value creation through efficient use of profitable renewable resources (Meld. St. 25, 2016).

The electricity production in the Norwegian energy system is, as mentioned, already mostly renewable. Reducing GHG emissions from electricity generation is therefore not the major motivation for energy efficiency, although exported surpluses may replace fossil fuels based electricity generation in the European market. On the other hand, development of both hydro and wind power installations will have negative local and regional

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[3] https://www.regjeringen.no/no/tema/klima-og-miljo/klima/innsiktsartikler-klima/klimaforliket/id2076645/

environmental effects, and most new projects are controversial on these grounds. Avoiding the need for some of these potential projects is therefore desirable. Energy efficiency is therefore considered a general tool for strengthening both the economic and the environmental sustainability of the energy system. The goal of enhanced security of supply reflects challenges inherent in the basic design of the Norwegian electricity system. It partly reflects an energy availability issue as determined by the reservoir filling (a factor determined by precipitation rates), as well as availability of imports.

A more pressing issue is related to the load profile of the electricity system. The locked-in dependence on electric energy, also for heating, poses a challenge in terms of power capacity. Furthermore, the typical morning and afternoon power peaks are not expected to be dampened as the number of induction tops and EVs continues to increase. In addition, in periods with cold weather, the need for electricity-based space heating causes an additional spike in demand. “Security of supply” therefore is mostly a matter of managing the power needs in this context. Energy efficiency (i.e. load reduction), load shifting with the aid of demand response measures, and conversion to non-electricity based heating systems are principal measures for improving security of supply. In other words, this is not about balancing demand and production on the grid, which can easily be handled by flexible hydro production. Rather it is a challenge of managing the load of an electricity grid with capacity limits. This is different from for instance the Danish context, where grid capacity has been “over-invested” in, and the challenge instead lies in issues of stability and large amounts of fluctuating renewable energy.

The last of the Norwegian energy-political goals poses a strategic challenge. The long-term fate of the oil and gas industry is becoming more uncertain, seen in light of the climate issue and the Paris agreement. If the large national incomes generated in this sector should be drastically reduced, and the current level of national welfare be maintained, it would be necessary to replace this income shortfall by value generated in other sectors of the economy. Given the low energy intensity in the creation of economic value in the oil and gas sector, this transition would imply a need for a substantial increase in electricity generation. The need for energy efficiency is obvious in this scenario. The built environment – existing building stock – is a large potential source of energy efficiency measures. The passive qualities of the building stock (insulation level and air tightness of climate shell) together with technical installations are keys in energy use in this sector, although the behavioral aspects of the user of the building also matters significantly.

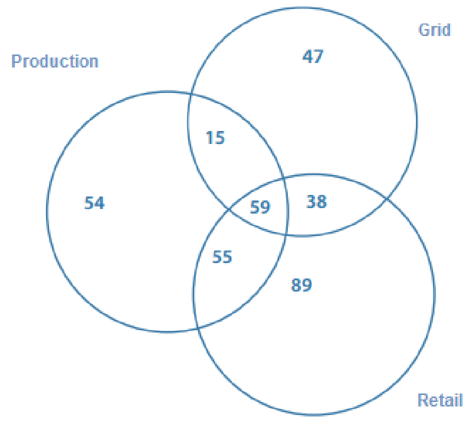
1.4 Market structure and energy consumption

The Norwegian energy grid is divided into five areas, south-eastern Norway, south-western Norway, western Norway, central Norway, northern Norway (Statnett SF 2013). This means that there are different electricity prices in different parts of the country depending on supply and demand in each area. This is of course due to the market based system of selling and buying power, which in turn produces a market based system for handling bottlenecks which arise in the grid as a result of the different elspot areas. The Norwegian Transmission System Operator, Statnett SF, is obliged by regulation to divide Norway into these five elspot areas as it is a method of handling expected energy shortage in a geographically restricted area and to handle large and prolonged bottlenecks in the regional and central grid.

Thus, the price is not regulated by authorities, but is a result of supply and demand within the specific market area, which is reported to the power exchange. Thus, the power and market situation of each area will determine which direction the power flows between the elspot areas. When the supply in a region is diminished, the price goes up, enabling electricity to flow in the direction of demand. In areas with an energy shortage, power producers usually set their prices higher than producers in areas where the energy balance is better. This will in turn mean a lower production of power in areas with energy shortages, while areas characterised by better energy balance will produce more than what is required within their own area, ensuring that power will flow from low-price areas to areas of higher prices.

In general, the prices in Norway are rather low compared to the rest of Europe. On average, the retail cost of electricity in first quarter of 2017 was 0.34 NOK/kWh, and the grid tariff was about 0.28 NOK/kWh. In addition to this came fees and taxes to the sum of 0.34 NOK/kWh. This means the average total price of a kWh in the first quarter of 2017 was only about 1 NOK, or about ten eurocents. As we have seen in table 1, the yearly consumption of electricity per household in Norway is around 10-20 000 kWh depending on the type of housing. In the third quarter of 2017 prices increased on some parts of Norway by around 30%. This is explained mainly by two things, 1) scheduled maintenance of Swedish nuclear capacity, and 2) an increase in fuel cost, affecting Norway's neighboring countries dependent on thermal capacity, increasing their demand for Norwegian power.

The system operator in Norway is Statnett, operating about 11 000km of high-voltage power lines and 150 stations all over Norway. Operations are monitored by one national control center and three regional centers. Statnett is also responsible for the connections to Sweden, Finland, Russia, Denmark, and the Netherlands. Statnett is a state enterprise, established under the Act relating to state-owned enterprises, and owned by the Norwegian state through the Ministry of Petroleum and Energy.



Source: NVE

Figure 4 Sectorial division and overlap among actors granted concession (numbers from 2013)

Around 90% of Norway's power production capacity is publicly owned. This fact, and the presence of a wide variety of actors involved in many different activities, is distinctively characteristic of the Norwegian power sector. All actors producing, transmitting, or trading electricity in Norway need a concession grant. Figure 4 provides an overview of the actors and the overlap in activity. Of 183 companies involved in production, only 54 of these are doing nothing else. Statkraft is the largest producer of electricity in Norway, and together with nine other actors, their share of production is about 75 %. In addition, there are about 159 grid companies in Norway, 47 of which are purely grid operators. Most of these are wholly or partially owned by municipalities or county administrations. There are about 241 retailers in Norway, 89 of which have this as their only activity. Norway also has a large number of vertically integrated companies (separate entities under the same parent company), or companies that deal with production, transmission and/or retail. There are 112 companies who operate in some form of competitive market (production and/or retail), and 59 of these (defined as being legal entities) are involved with all three branches. Importantly, even though these various activities often are included in so called vertically integrated companies, the activity still belongs to formally separated entities according to the unbundling principles of a liberalized market. Even so, many of these formally separated entities share office buildings, and these buildings then have sections that are separated by metaphorical bulkheads.

As briefly mentioned above, one central characteristic of the Norwegian power sector is the concession system with the reversion principle. Reversion means that the government takes over means of production compensation-free after concession time expires. This means production facilities are often sold to the public sector when the due time approaches, or otherwise is returned to the government when the concession expires. This comprises an important structuring force in the Norwegian power system. After 2008, water resources legislation was amended to allow concession for property rights to existing waterfalls and constructed facilities exclusively to public actors (OED 2015).

1.5 The Smart grids landscape in Norway

The mandatory rollout of smart metering infrastructure is to be completed by 2019, effectively putting in place a prerequisite for the diffusion of smart solutions. As mentioned in the introduction, grid bottlenecks and power limitations at different levels in the grid is the most pressing current issue regarding security of supply. Improved energy management is an alternative to investments in grid expansion in this case. It is expected that an increase in intermittent generation capacity (wind, solar), parts of it distributed, will add to the demands of smart energy management.

A central smart grids actor in Norway is the Norwegian Smart Grid Centre, which is a technology platform consisting of members from power companies, telecom, and the supply industry, as well as universities and research institutes (ETP Smartgrids 2016). The center coordinates the Norwegian Demonstration program for smart grids, or “Demo Norway”. It has “real-life” demo sites at power companies comprising more than 20 000 network customers and a national smart grid laboratory at the Norwegian University of Science and Technology/SINTEF. The center also coordinates with the European Technology Platform on smart grids and other European actors such as ERA-Net.

A survey has identified three central “smart energy” projects (GSGF 2016), all of which the Norwegian part of the MATCH project is involved with. They are Demo Steinkjer, Smart Energy Hvaler, and Demo Lyse. The Demo Steinkjer and Smart Energy Hvaler projects have a broad focus on different smart grid solutions (electricity saving, load management, micro-generation and power balancing capacity), as well as different areas of household consumption. Both projects, which are still in their initial phases, are shaped by being based within a specific geographical area (the town of Hvaler and the area of Trøndelag), giving each project unique characteristics. Both have a specific focus on smart meters and their potential use for developing smart grid solutions. Demo Steinkjer and Smart Energy Hvaler are subprojects of the DeVID (Demonstration and Verification of Intelligent Distribution grids) project, the work of which was continued in the Horizon 2020 project EMPOWER. It is a demonstration project with the aim of providing knowledge and experience for the planning of the coming rollout of smart meters in Norway.

The third project, Demo Lyse, focuses on the potential for combining smart meters with new ICT infrastructures like fiber optics and new devices such as tablets etc. Energy-related aspects like load management or energy saving are not the primary focus of this project, which instead focuses on the potential of new technologies for home automation (like controlling appliances or heating and lighting) and developing new welfare services like tele-medicine. This demo is an integral part of the Norwegian commitment to the Horizon 2020 INVADE project.

Smart grid infrastructure is slowly but steadily proliferating in Norway, as smart meters are being rolled out. The Energy and Water Resources Directorate has found that as of this summer, about 875,000 meters have been installed, which amounts to around 31% of the entire metering infrastructure. They report that grid companies estimate 57% of meters will be installed by 2018, a rate that is 6% lower than grid companies reported in January 2017[4]. In terms of structural changes in the market, the director of the Energy and Water Resources Directorate publicly expressed their plans for the future tariff structures, stating that “we want grid tariffs […] to be shaped in such a way that it will be profitable to move consumption from periods when the grid capacity is strained, to periods of less load”[5]. The purview of the mandate of the directorate includes setting this tariff, and a draft hearing on new tariff structures is expected November 2017.

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[4] https://www.nve.no/Media/5662/ams_status_juni17.pdf

[5] https://www.nrk.no/norge/vil-gjore-det-dyrere-a-lade-elbilen-pa-ettermiddagen-1.12975883

2 Norwegian case studies

The three Norwegian cases represent a variety of the smart grid landscape in Norway at the present time, each covering different aspects of the three research layers technology, actors and markets. Two of the cases target mainly household end use and both represent cutting edge attempts at creating prosumer activity in the Norwegian grid. The final case is represented by a rather large SME, and is one of the largest PV parks in the country for industrial scale power production. The first case focusing on households showcases one of two projects initiated by an energy, production and grid utility company called TrønderEnergi. In addition to its branches dealing with production and energy sale, its grid operation division is one of two DSO in the Trøndelag region. The other project included in this case is the neighbor of TrønderEnergi, which reigns in the south, Nord Trøndelag Energy, which apart from similar activity related to energy sale and production, is the DSO in the northern parts of the region. Both companies initiated a solar PV pilot project into which they enrolled end users in households in order to gather knowledge about the impacts of solar production in the grid, as the “plus customer” regulation, obliging grid companies to accept electricity from small scale production into the grid, was introduced in 2017. This effort was part of an ambition to keep their competitive edge in a changing market.

The second case studies the activities of a framework program called Smart Energi Hvaler, initiated by Smart Energy Markets (a research organization), Fredrikstad Energi (ESCO/DSO), and the municipality in Hvaler. Operating on the island of Hvaler, the project showcases a demonstration project on residential PV systems in combination with prosumer market models and novel consumption monitoring and control systems. It is also a testbed for the first power tariff in Norway, charging customers not for energy use, but peak load demands.

The third case is a study of ASKO midt-Norge, a large grocery wholesaler, and their attempt at becoming self-supplied with energy. In order to achieve this, they have installed a vast solar PV rig on their warehouses, the surplus energy of which is going to power a hydrogen production facility. The hydrogen will subsequently fuel delivery trucks which operate in the middle and low north regions of Norway. This case is also interesting because the solar power will be used to keep goods cold, and contrary to most other use scenarios which include solar power the demand curve thus follows the production curve of their PV system.

Table 1 Norwegian cases in comparison

	Case 1	**Case 2**	**Case 3**
Name	PV demo Trøndelag	Smart Energi Hvaler	ASKO midt-Norge
Main focus	Two regional solar PV projects	Test area for developing future smart grid	Transition to a post-carbon energy system
Type of consumers	Households	Households	SME
DSM	Create prosumers	Demand side management, prosumption, in-home monitoring devices, market models	Prosumption, solar powered hydrogenproduction, hydrogen fuelled transportation
Micro generation	PV systems	PV systems	Large PV system
Storage	None	(Car batteries)	Hydrogen fuel

In terms of demographics, the case studies cover a varied area of urban to suburban to rural. In the case of the northernmost prosumer pilot directed by Nord Trøndelag Energi, the setting is quite rural. The other PV pilot in Trøndelag, TrønderEnergi, is in the city of Trondheim which is the third largest city in Norway. Smart Energi Hvaler is located on the archipelago of Hvaler, close to the city of Fredrikstad, but the southernmost land-mass of this region in Norway on the border to Sweden. ASKO is located outside Trondheim but their activites cover a vast portion of the country, from central to rural, as goods and groceries are transported to and from the edges of Norway and within densely populated areas in between. The cases were thus selected not only in order to cover various regions in the country, but also in order for our study to represent some of the most cutting edge smart grid development projects in Norway.

The data gathering and analysis has been carried out by researchers at the dpt. of Interdisciplinary Studies of Culture, Norwegian University of Science and Technology. The methods used were primarily qualitative in the form of interviews (with users and experts), site visits and field trips, participation with users and experts at public meetings. The interview guides that were used were developed before the start of the data gathering, and followed largely the format used in the other countries. Interviews were recorded, transcribed and analysed by the researchers (however, at the time of writing this report, a second round of interviews has yet to be transcribed and thoroughly analysed). Some detail about each case and the data gathering process is summarised in the following:

PV demonstration Trøndelag
TrønderEnergi was initially a partner in the Centre for Sustainable Energy Studies in Norway, a Norwgian centre for environmentally friendly energy research (FME), with which the Norwegian research team was also affiliated. Collaboration with Nord Trøndelag Energi was on the basis of earlier work, mainly that which was undertaken in the IHSMAG (Integrating the Housholds in the SMArt Grid) ERA-Net project. Contact information was provided for solar PV participants and contact established in order to undertake interviews. Interviews were conducted face to face and over telephone with the participants. This case study also provided some expert interviews.

Smart Energi Hvaler
This demonstration project came into the project on the basis of our project partner in MATCH Smart Energy Markets, which had access to household participants and experts as a part of the Smart Energi Hvaler framework programme. Lists of participants were provided and contact was established in order to conduct interviews. The interviews were usually conducted in the home, with one or more household dwellers. This also provided some insight into the actual setup in the households, which were varied. Some of the households did not have solar PV at the time, offering valuable insight into the role of PV for end user engagement with smart energy technologies.

ASKO midt-Norge
This participant was selected on the basis of being one of the largest solar PV producers in the country, and contact was established without any prior connection. After contact was established, researchers were given access to several experts in the organization in order to conduct expert interviews. The research into this case was also conducted on the basis of desktop research and document analysis

2.1 Case 1: PV demonstration Trøndelag

2.1.1 Background and project characteristics

In the summer of 2016, the largest energy companies of the Trøndelag region in Norway, Trønderenergi and NTE, each initiated residential solar power demonstration projects, independently of each other. The demonstration projects are very similar in scope, size, and they were implemented during the same period. Trønderenergi is based in the city of Trondheim, and has as its main area the urban center, as well as southern part of the region. NTE is based in the northern part of the region, which is generally more rural. Both companies include grid operation of their respective areas, and both companies were motivated to engage prosumers as a part of grid trials in order to discover what kind of effects on the grid infrastructure could be expected.

Each company published a call for participants in a residential PV demo. Targeted marketing was made, aiming to recruit especially householders with a particular interest in technology. The response was positive, and the companies quickly settled on 15-20 households to participate in each of their projects. The selected households were chosen based on an estimated financial ability to participate, suitability of house and roof (house must be freestanding, roof must be big enough and the angles of the roof considered suitable in order to produce electricity, meaning that houses with roofs permanently covered by shadow due to other buildings, trees etc. were excluded). Trønderenergi further valued expressed motivation to participate when selecting their households, whereas NTE favoured an approach where the houses in question were dispersed and covered remote areas to which they cater. The projects work as a packaged deal, where the customers purchase the instalment – either outright or through regular down payments (with ensuing interest) over 15 years. The panels are all the same size and type, and the respective companies decided on this as a “standard” solution. Participants are bound to the energy provider in question for 15 years during which time the company is responsible for maintenance and any problems that may arise with regard to the instalment. Moreover, during this period, the participants sign a contract to become prosumers, or so-called “plus-customers” of the energy provider, which means that any surplus energy generated by the PV panels is sold back to the grid and the energy provider at spot price. In the spring of this year, NTE increased their purchase price by a few NOK cents.

A third party installed the PV on the roofs of the houses, and installed smart meters as well, where this was not already in place. The participants in the demonstration project are eligible for a fixed sum subsidy from ENOVA, the Norwegian environmental agency. This however, applies to all households that acquire solar power and is not managed through the demonstration projects. The first households to receive the PV did so in late autumn 2016, and the latest in January 2017.

The participants of the NTE demonstration project were given access to a website, accessible by computer, tablet, or smartphone on which they could monitor their electricity use, the production of the panels, and monitor whether they had produced any surplus energy. For the participants in the Trønderenergi demonstration, the same service was provided in a smartphone App in addition to a website. At the time of our interviews, however, not all the participants had successfully downloaded the App or familiarized themselves with the website, indicating that its content was of very varying importance or interest to the participants.

2.1.2 Socio-technical configurations applied in the project

Due to the striking similarities of the two demos (conducted at approximately the same time, including the same number of customers +/- 5, the same conditions applying in both demos, same geographical region, etc), we decided to merge the two demos into one case. This did not preclude the researcher(s) from noticing differences in the findings from each demo. Had there been consistent differences in the empirical findings from each demo, it is likely that the two would have been split once more into two separate cases. As it were, however, there were no marked differences in the findings from the two demos. Consequently, we continue to consider these one case; “PV Demonstration Trøndelag”. Our study of the Trøndelag solar panel demonstration projects has included 11 semi-structured interviews with members of households who are involved, and 4 interviews with representatives from the two companies. The interviews were conducted in person or over the phone.

Findings indicate that the companies both have initiated these demos, not primarily to test or develop a new set of technologies, but rather to expand and adapt their business to changes that are expected to come in the energy sector. As large providers with a main focus on hydropower and a traditional relationship with customers, representatives of both companies express unease with the prospect of being out competed or rendered irrelevant by new actors arriving in the energy sector that focus more on wind and solar power, and that have a stronger focus on digitalisation and service providing. The demonstration projects were therefore an attempt on the part of the two companies to familiarize themselves with a new customer relationship, testing the waters with regard to customer engagement and eagerness to adopt new renewable sources of energy, as well as to familiarize themselves with the operation of the technologies themselves.

Table 2 Sociotechnical configurations

	PV
Technical elements	PV panels Inverters Smart meter App for Smartphone Website
Social elements	30 households (15 each) Households own or lease the PVs Facebook group for participants (NTE) Subsidies by ENOVA 15 year agreement/maintenance (=no risk for homeowners) Participation in unspecified research (including workshops held by the companies themselves, as well as outside researchers)

Findings from the first of two rounds of interviews with customers, now solar energy prosumers, indicate that the environment is an important factor for many, yet not for all. Nor is it the deciding factor for most when it comes to joining such a project. An interest in owning new technology and self-identifying as a technology front-runner was the most important motivation for most. Among the participants, we identified pieces of a sociotechnical imaginary of the future, in which solar power would become increasingly important, and where energy prices would rise and become quite volatile. This motivated the acquisition of residential PV in two ways. First, wanting to be on the forefront of a development, which was considered undeniable. Secondly, keeping up with continental Europe, which is perceived to be more advanced than Norway. Thirdly, the sociotechnical imaginary of high and unpredictable variable pricing justified the investment in PV, as partially producing one's own energy could contribute to lower (future) electricity bills. Some participants express that they would like to be more self-reliant and consume more of their "own" electricity. For most however, this is not an issue as it is experienced as empirically impossible without batteries (see below). Indeed, at present, participation in the solar power demonstration is not a financially lucrative engagement due to a number of reasons. The cost of the instalment is quite high, whether payed outright or through monthly payments is much greater than what the households earn by selling electricity and much greater than what they save by using their own electricity. Furthermore, households are not able exploit most of the electricity they produce (because most are not at home during the day), the electricity sold back to the grid is purchased by the companies at such low prices that even when subtracting this from a household's electricity bill, they have spent more than they have earned. Consequently, even if the instalment had been free of charge, the households would not, at this time, profit from their PV.

Environmental concerns are in one way rather paradoxical in this context, as Norway has abundant hydropower. Both the company representatives and several of the participants in the demos pointed out this fact. However, as Norway imports energy during winters, some of which may come from coal, gas and nuclear power. Thus, the environmental concerns were part of a bigger framework, in which transnational energy-transactions were taken into consideration. The participants in these demos are not under the illusion that their ownership of residential PV will solve the problem of Norway purchasing unclean energy during the winter, nor do they think that it will directly influence the country's energy shortage during winters. They are well aware that there is little sun in Norway during the winter, and consequently that their PV will not produce much during the months in question. What our study shows is that the participants locate themselves in a larger national, international, and global context. They hope or claim to be, early adopters and frontrunners of what they think will be the future norm. Many hope that by participating in demonstration projects, they are helping companies develop services and technologies, which may, in the longer run, positively influence the Norwegian energy situation (in the shape of new technological invention, innovative solutions etc.). In short, they perceive themselves as partaking in innovation and in research, and the development of so-called new renewables therefore, was situated in a context precisely of development, of a larger shift with regard to environmental concerns. There was a desire to become more self-sufficient, to be able to visualize energy (both production and consumption) as a tool to pass on better attitudes to the younger generations (concretely, to one's children), and a feeling of being part of something *bigger than oneself.*

Our work on this case is ongoing. We have recently begun a second round of interviews with the participants. These new in-depth interviews will be conducted in the participants' homes and include as many members of the household as possible.

2.1.3 Discussion: Success and outcomes

It is not yet possible to evaluate whether the PV demonstration projects have been successful, or to what degree. The initiation of the projects certainly was a success judging by the sheer number of interested households. However, any evaluation of the overall project can only be done at a later point, and our research is still ongoing. Moreover, it seems pertinent to ask; whose success is in question? As we have seen, the companies themselves have a long-term, complex motivation behind the demonstrations. This complex motivation importantly consists in wanting to remain relevant in the national context, to continuously develop their services, and not to be outcompeted or rendered irrelevant by newer actors in the Norwegian electricity market. The companies do not refer much to the international context. Consequently, it is likely that any definitive "result" of the demonstration projects will materialize in other branches of the companies (e.g. innovation) or in different business strategies, in time. With regard to the participants too, more research needs to be conducted, preferably over time and we are currently arranging follow-up interviews.

We see that motivations behind the initiation and the participation in demonstration projects such as these, illustrate well the ways in which the social and the technical are intertwined and never function independently of one another.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: The demonstration projects showed that there is considerable interest in the existing residential customer base to engage in pilot projects and install solar PV on their roof. The technology related to this was however somewhat immature, e.g. monitoring devices and facilities were not widely adopted by the users. The very early state of these projects must be taken into consideration however.
- Actors: The energy companies engaged in this seem to be motivated by an anxiety for lagging behind in a market environment that seems to be developing quickly with steadily increasing digitalisation and novel energy service provision. Judging from the customers, there is a large demand for this development as well.
- Markets: Markets for prosumer activity is not well developed with respect to the view of customers, and selling back energy to the grid does not nearly provide sufficient economic incentives for investing in rooftop solar PV for end users. However, many have stated other concerns as sufficient, for instance a desire to reduce carbon footprints (even in context of Norwegian hydropower, which, as many point out, gets exchange with continental brown power). Many were also keen on the idea of market independence and self-sufficiency, though at current the size of installations and continued grid dependence (solar PV does not work during power outages) makes this hypothetical.

2.2 Case 2: Smart Energi Hvaler

2.2.1 Background and project characteristics

Smart Energi Hvaler (SEH) is a framework program that has been running for 7 years, meaning it is a collaborative project between the local energy utility Fredrikstad Energi AS (FEAS), the local municipality, and the Norwegian Centre of Excellence for Smart Energy Markets that is situated at the nearby Østfold University College. As such, coordinating activity in what we could consider a triple helix arrangement, the program has undertaken a self-proclaimed mission to shape “the energy markets of the future”. A part of this includes employing demo technology and solutions in the small island municipality of Hvaler, a small archipelago on the border to Sweden including five islands covering 86 km^2, with a total of 4000 vacation homes, 2700 domiciles, and some commercial properties. A main focus of the demo, which has been studied here, has been smart metering with solar photo voltaic (PV) panels with the aim of making customers into prosumers.

Currently there are also plans to make use of local battery storage on the neighborhood scale, and there are burgeoning results from a newly placed micro windmill in conjunction with a waste recycling facility. In parallel, there is also a plan to roll out a good number of public charging stations for EVs on the island in addition to the ones already there. The island is a holiday destination for many EV owning vacationists, as well as being a thirty-kilometer deep cul de sac; a trip from the nearest city to Hvaler’s southernmost point would consume a quarter of the ideal capacity of a Nissan Leaf.

The island community of Hvaler municipality lies in the south east of Norway, located outside the larger city of Fredrikstad. It has around 5,000 permanent residents. During summer however, the number of seasonal visitors can reach as high as 30,000, due to the island being the location of many summerhouses.

In a Norwegian context, Hvaler is an ideal location to implement solar PV, because it is one of the places in Norway with the most days of sun – which also coincides with high tourist demand. However, there are some concrete challenges that has made Hvaler attractive as a demo site for distributed microgeneration in the form of solar PV. For instance, the island only has a single power line connecting it to the mainland. This means that if it should be interrupted, any part of the community downstream from the breaking point will be without power until the situation is resolved.

Throughout the years, this has been happening infrequently. Two years ago, half the community was without power several hours during the day as an unlucky bird had flown into a switch. Only this summer there were two incidents of private sailboats shorted the main line by navigating into it with its mast, resulting in the entire archipelago losing power. Power fluctuations pertaining to grid balancing issues has also been a problem, and many incidents of ruined home appliances on the customer side has been reported.

These events have led to the local citizen’s action group, among others, to demand the commissioning of an underwater cable to service the islands, in an argument with the grid company that is still ongoing. One grocery store owner – claiming losses during tourist season in the hundreds of thousands of kroner because of each of these commonly 4-5 hour long outages – upgraded his store with a diesel generator. He claimed the investment quickly paid off[6]. With local municipal council seated ambitions regarding environmental goals that include the roll out of more EV chargers, as well as the influx of ever more EV driving visitors, the redundancy of the island’s electricity system is going to

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[6] https://www.f-b.no/nyheter/norgesnett/hvaler/stromstans-satte-sinnene-i-kok-pa-hvaler/s/5-59-820761

be tested further. Last but not least, these developments are contentious in a public perspective due to the issue of security of supply.

SEH started out in 2010 as an attempt at delaying a refitting that was due of about 2000 failing electricity meters. This was at a time in which it was clear that new smart metering was about to be introduced, as it was scheduled in a revision of the regulation in the two years earlier. The entire project was thus premised on an ambition of avoiding newly refitted metering infrastructure becoming obsolete immediately after installation. This revelation encouraged the stakeholders, which would later form the framework program, to use the upcoming revision of regulation to delay refitting in order to make sure they could properly exploit any future advantages of an obligatory smart meter roll out. In other words, instead of simply rolling out new meters, they wanted to make sure the meters were an investment that would support hypothetical future gains in the smart grid.

The main activity soon involved rolling out private PV installations with 3 or 5 kW capacity, capable of producing around 3-5000 kWh/year. After having introduced the panels, it became evident based on customer demand that it was necessary to introduce monitoring capabilities. Thus, Smart Energi (a subsidiary of the local energy company) was established, and it started work on an Internet portal for keeping track of production, consumption, and selling of energy to the grid. The portal was introduced soon after, together with smart plugs that had the ability to monitor consumption in the home based on appliances, and provide data of this to the user via the internet portal. The focus for the utility and grid operator has been on rolling out remote control abilities to some customer, which based on the data from the plugs would be able to orchestrate household loads for network benefits. These control modules were not accessible for the end user, however. Demand side management is important in Hvaler due to the redundancy issues mentioned above, as it is a way of increasing grid robustness without costly grid expansion – costly in terms of money, but also in other terms, such as interfering in nature. Large parts of Hvaler has national park status defined as protected.

The efforts of Smart Energi has garnered quite a lot of positive attention on Hvaler, as efforts that deal with the issue of security of supply is warmly welcomed by the population. This is in addition to the environmental aspect, which has appeal to many of the quite well off citizens of the largely suburban parts of Hvaler. The project also benefitted by its close collaboration with the municipality. This has made it possible to fast-track paper work necessary for the fitting of PV installations, as well as providing increased public trust through public meetings with the attendance of local community leaders, like the mayor. In addition to the face-to-face aspect of the framework (according to an informant from our interviews 85% of solar panel customers knew the project leaders by name, and would call them directly with questions), SEH benefited from rather strong neighborhood effects, and in turn the project managers talked warmly of the most «forward leaning» energy customers in Norway. Something of the truth in this is indicated by an Enova competition that elected the domicile of a customer in Hvaler “Norway’s smartest house”. Having a close relationship to the people in this way also benefitted customer research undertaken by the utility, which provided information on cost benefit analysis like price sensitivity and down payment duration tolerance. The triple helix configuration has also been widely successful in establishing international EU projects on their own. SEH are in the process of finishing up their first large Horizon 2020 project, EMPOWER (Local Electricity retail Markets for Prosumer smart grid pOWER services), which is set to end this year. This project is already set to be followed by the new H2020 project INVADE (Smart system of renewable energy storage based on INtegrated EVs and bAtteries to empower mobile, Distributed and centralised Energy storage in the distribution grid), which is the largest smart energy project in Norwegian to date and which SEH is also a part.

As one of the first areas in Norway, the grid operator in Hvaler has also introduced power tariffs in Hvaler. At the time of the study SHE had rolled out PV to about 100 houses, which have provided this case study with 17 interviews, 15 with households conducted in the home and two with experts working within the SEH framework. The total number of respondents were 22. At the time of writing this report, 8 interviews has yet to be transcribed and fully analysed. Their contribution to this chapter is thus preliminary.

Of experience, the most interested customers were older segments. The area had the largest buyer group of solar panels in the country in 2015 which was the year the solar roll-out started, and the average age was 60 (oldest 87). This could relate to cost: the cheapest PV setup at Hvaler was around €2000 (average €5000, most expensive €12 500). PVs in seem to appeal to a rather grown up, mature buyer group that have a stable economic situation, characterized by having a decent amount of disposable income. Additionally, many of this generation still remember the ‘over consumption meter’, which was a gauge usually placed in the kitchen and that would assert a maximum limit on load demand in the household. It has long since lost its relevance after power tariffs were abandoned.

2.2.2 Socio-technical configurations applied in the project.

With the re-introduction of the power tariff in Hvaler, there is some reference to the tariff structures of the past, constituting a motivation to reduce peak loads in the home. This is in contrast to what is seen in younger participants. In general, participants with PV rigs state that they are concerned about contributing towards handing over the planet in a decent condition to their kids, and tend not to carry concern only about economic incentives. In a few cases participants were not greatly aware of their own production, and one household reported not having used the web portal to get an overview of consumption, use, and production. In this case the only indication participants had of the panels even functioning as they were promised was by checking the display on the inverter itself.

A tailored and ready-made solar PV setup in a packet solution, is something that is very difficult to acquire independently by users in the current market for PV. Thus, some reported being engaged in the project simply because it was a good deal on solar panels, which some had already read up on quite extensively. As for those who had not invested in solar panels a few reported cost, one reported that the technology was not good enough (they wanted solar roof tiles), others reported joining to learn more about smart energy monitoring because of its relation to the persons work. Apart from PV, the households included in this case exhibited other socio-technical elements as well, the most relevant of which are listed in table 1.

Table 2 Sociotechnical configuration

	SEH participant with solar PV (11/15)	SEH participant without solar PV (4/15)
Technical elements	Smart meter eWave monitor (2) Web Portal PHEV / EV (6) Households appliances Smart plugs Demand side management unit Heat pump (6) PV panels Inverter	Smart meter eWave monitor (0) Web Portal PHEV / EV (3) Households appliances Smart plugs Demand side management unit Heat pump (3)
Social elements	11 households Town meetings Participation in R&D Grid power tariff Feed-in tariff (PV) Subsidies by ENOVA Identity marker	4 households Town meetings Participation in R&D Grid power tariff

The solar PV consisted in most cases of 12 panels over an area of 18 square meters, amounting to a 3.2 kW output at peak production. The production of such a setup in a representative household was around 3600 kWh/year (of which 1000 kWh were sold), which amounted to around a quarter of total consumption. A 3.2 kW setup cost around €5000, but participants were eligible for Enova support in the range of €1500, making the total one-time cost for the panels including installation around €3500. The prosumer aspect of the panels, and what makes them competitive on the market, is the feed in tariff. The price of one kWh of electricity delivered to a Norwegian household averages at around €0.10, or one krone. This, the total purchase price, is an aggregate of grid tariff, electricity price, and taxes. The pure market price for electricity in this cost and tax bundle is only around €0.02, or 20 Norwegian øre.

This means there is in general very little money to be made selling electricity back to the grid, as the market will usually only give the market price. Thus, in a normal case without a feed-in tariff, the obvious choice for the prosumer would be to attempt using most of the produced electricity on site rather than selling it. In our case however, due to a feed in tariff that sets the selling price at a flat €0.10, a kWh bought and a kWh sold makes no difference. This increases the incentive for buying a solar PV rig, giving it at return on investment of about 10 years (3500 kWh per year for 10 years at one krone per kWh), but it does reduce incentives for load shifting. The future of the feed in tariff was uncertain, though, and it is not guaranteed to last for 10 years. A short return on investment time in the future is dependent either on rising prices (which is relatively likely due to the increased export capacity planned for Norway), or on a customer's ability to spend own production to shed loads to reduce the impact of a grid tariff (not easy without a battery, as the sun shines during periods of low demand).

Other ways of incentivizing the acquisition and operation of a PV are being planned. A type of tariff structure that was under testing was called Smart Neighborhood. It made it possible for neighbors to purchase electricity at a 30% discount if there was a surplus of locally produced solar power anywhere in the neighborhood. This was proven very difficult to achieve however, because at this time the structure and organization of the billing service which was used. The billing systems were simply not able to cope with the amount of flexibility this kind of account settling would require. This points to a weak link in the service chain, making evident the need for smart grid innovation in areas which have previously not been closely associated with it.

From a perspective of the electricity system, the locally produced electricity and demand side management relieves the connector supplying the islands and the local grid. This is where the power tariff comes into play. Previously, the part of the electricity bill made out by the grid tariff was determined in the same way as the retail part, namely in accumulated kWhs. Since the introduction of smart meters, however, the all residents in Hvaler have received a power based structure on their grid tariff, meaning that the cost of electricity delivery is measured by peak load. To be specific, it is based on the average of the three largest consumption peaks (peak is per day) within each month divided by 3, multiplied by 65 kroner (~€7), with an additional flat charge of 600 kroner (~€65). The math ends up looking like this:

$$((p1+p2+p3)/3)\text{kW} \times 65$$

Or, if we insert numbers that are representative:

$$((5.1+5.3+6.1)/3)\text{kW} \times 65 = 357 \text{ kroner}$$

This means the customer is greatly incentivized towards reducing the operation of many appliances at one time, thus reducing the share of their households' strain on the distribution grid. A not uncommon peak among representative dwellings would be in the range of 4-7 kW, and one household in the sample (with solar power) had managed to consistently reduce their usual peak to less than 2 kW. The activities related to this was avoiding the simultaneous use of power hungry appliances, like PHEV charging, dishwasher, tumbler; and alternative means of heating, like wood burners and solar thermal for water heating. Some of the customers were also mindful to consume necessary services when the sun was shining in order to reduce load; however, this was really only doable for those staying at home during the day (home-workers, seniors, etc.). At the time of the study, the project was in the process of installing controllers that would automate shut down of slow loads like water heaters, but had yet to make it operational. This would greatly benefit the usefulness of panels, as automated water heaters is a viable way to shift or replace load demand by storing power in low-peak hours or when the sun is shining.

When it comes to visualization techniques in the households of Hvaler, some of the project participants had two years prior received a small pad-like screen that monitored energy consumption in real time, the eWave. Many of the respondents reported having very positive experiences with the little box that would smile at them when they were treading lightly on the grid, and a newspaper reporting on a competition spurred between users of eWaves maintained that many households had managed to reduce electricity cost by 15% simply by avoiding peaking their load. The eWave was a rather simple means to improve the understanding by residents of the consequences of energy consumption in the households, paving the way for a more knowledgeable relationship with the solar panels two years later.

The other means of visualization, the web portal keeping track of produced, consumed, and sold electricity was necessary for giving people a chance to make sense of the relation between their consumption and the PV panels. The way this worked in practice was by connecting a small antenna via a TP-link to the inverter that – in addition to converting the solar power into usable 230 V – collects data, even though it does not have a proper user interface beyond a simple digital display. The antenna thus functions as a means of placing the inverter on the internet, and the data it generates ends up in a cloud based interface operated by the utility. This was proven crucial in order to aggregate timely and relevant data about consumption and production to the participants. The idea of delivering another type of pad instead of just an internet portal was dismissed due to cost.

The majority of customers claimed they were informing themselves with the web portal, and some reported energy savings in addition to an added overview of consumption and an increase in general energy knowledge and awareness. Even so, there were a number of participants who reported little interest in the portal. In one case the solar PV investment was mainly to ensure private environmental gain, and the actual profitability was not interesting. In most cases there seemed to be a correlation between solar panels and web portal use. In the case where participants had not installed PV, the reported use of the monitoring portal was still quite high.

This is because along with the launch of the portal, participants were given a number of smart plugs that could be installed between appliances and sockets, reading and sending information about consumption to a hub which then communicated with the web portal. Thus it was interesting for customers even without PVs to follow up on their own consumption by using the portal. This portal also provides a view of the three largest peaks which the participant has accumulated at any given time, and even without solar panels many customers reported using the portal to learn how to avoid peaks and monitor peak production to keep them low. This was true even for those without solar PV. The portal was lacking according to some, however. The automated demand side management system was completely black boxed, and one customer noticed it did not avoid running the water heater and heat pump at the same time. Other problems were related to the communication protocol of the plugs. Using radio mesh signals which are very weak, many plugs were out of reach from each other and the hub, making them useless in the house. This can only be solved by increasing the number of nodes in the mesh or by installing boosters, or using different communication protocols, like WiFi. This however has other drawbacks, like high energy use.

2.2.3 Discussion: Success and outcomes

The socio-technical element that perhaps caused the greatest impact in this case was without doubt the power tariff. Power tariff was introduced with public meetings, and also quite manageable in the web portal. In general, households in our sample reported having become more concerned with shedding and shifting load, even if the size of the monthly bill had remained more or less the same as in the previous scheme. A clear majority of respondents elicited a clear understanding of how to reduce loads, but found it difficult to avoid ruining a low load peak streak within each month. As the bill is made up of these three peaks a customer only has to “forget” about them three times in order for a whole month to be ruined. After producing large peaks in moments of stress or when there is little room for planning, the rest of the month it no longer becomes necessary to reduce peak consumption. A feeling of despondency was created, and motivation to reduce peaks would diminish. In both the opinion of the user and SEH, some level of automation in combination with the power tariff was much needed, as people often found themselves lacking tools to load shed easily. Even so, income levels are high enough that the financial penalty is quite weak. The customers engaged in load shifting did it more on principle, and found simply just not running appliances simultaneously a most achievable challenge.

The main ambition of the SEH project seems to be to incentivize people to buy and install local means of power production, in this case solar PV, and having them actively shift or shave their loads as a close secondary goal. This makes sense from the system perspective, where the goal on Hvaler is to reduce the strain on the local grid by increasing local production capacity at the end user and making consumption flexible on a neighborhood scale. But the Smart Neighborhood strategy – trading surplus energy among neighbors with some production capacity among themselves at a discount – also shows it is possible to allocate benefit to singular households as well in this manner, if still only in theory. But shared production facilities and individual book keeping by the smart meter of the amounts produced and consumed per participant is at this point not all that is necessary to start “load-pooling” among neighbors. As we have seen, the account settling technologies and organization are a clear area in which smart grid technologies need to catch up for this to be possible.

What is perhaps most interesting to note as well, is how the motivation of SEH and the local population, represented here by our case, is aligned when it comes to security of supply for the community as a whole. The feeling of living with a strained and weak power supply was a strong part of the collective consciousness of the people in Hvaler. The feeling that the grid was something tender that must not be strained too much was evident in many aspects, for instance skepticism to the roll out of EV charging infrastructure at a town meeting and subtle resentment for vacationers taking with them to Hvaler a carefree energy attitude from the mainland. The main success of the 'forward leaning' energy customer in Hvaler relates to their shared experience of the acuteness of energy shortage, and a common interest in increasing the robustness of their grid. This ties in with the reported motivation of many of the respondents in participating not for the sake of personal economic gain, but in order to take part in and contribute economically to a research project that they endorse. In this regard, the social value of placing a solar PV rig on the roof of ones' house or garage in a place like Hvaler should not be underestimated.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: The framework program which is Smart Energi has been successful in proliferating their demo site with various novel smart grid technologies, many of which have proven quite useful but some of which are hampered by the relative immaturity of some of the components, such as in the case of portal and smart plugs. Prosumers are producing energy and delivering back to grid however, and power tariffs are in place which incentivise load shifting. A necessary component in this configuration is the web portal.
- Actors: The triple helix configuration has been beneficial for the project, and contributed to enrolling many of the users. The participants were interested in and the project allowed for engaging with local political as well as environmental issues.
- Markets: Users are able to sell own produced energy, or use it themselves in order to save money or energy, and there is a return on investment. The panels are as of now quite heavily subsidies, and there are feed-in tariffs which may not last forever. Account settling between ESCO and customers presents as a reverse salient, a part of the smart grid front line that has fallen behind.

2.3 Case 3: – ASKO midt-Norge

2.3.1 Background and project characteristics

ASKO is a large Norwegian grocery wholesaler. Its core activity is to sell and distribute groceries to stores, retailers and the catering industry across the country. The corporation has 13 regional branches, all with their own storage facilities. In total, the company has around 600 trucks to do the delivery of goods.[7] In MATCH, we have studied a project undertaken by a regional ASKO branch located in the middle of Norway (ASKO Midt-Norge)[8], a project that is a collaboration between ASKO, the research institute SINTEF and the car manufacturer Scania.

ASCO Midt-Norge have around 280 employees. The company has 27,000m^2 of storage, which are located in an area called Tiller, roughly ten kilometers south of the city Centre in Trondheim. The storage is energy intensive, in part because much of it is used for keeping food frozen. In the Norwegian context, such space cooling as well as space heat-

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[7] https://asko.no/om-oss/

[8] https://asko.no/kontakt-oss/vare-asko-selskap/asko-midt-norge-as/

ing has traditionally been provided by hydroelectricity, which means that the electricity provision is already close to 100% renewable.

The storage at Tiller distributes goods to more than 1,700 stores and restaurants. They deliver goods to customers in three counties, covering a distance of more than 800 kilometers. To do this, ASKO Midt-Norge have around 50 distribution trucks. Inside the storage facility, they have around 20 forklifts, used to load the trucks. While the company covers a large area in their work, many of their deliveries consist of relatively short-range trips within and around the city of Trondheim.

Over the last years, the parent company ASKO Norge has branded themselves as one of the most environmentally ambitious corporations in Norway. This can largely be attributed to the engagement of a key group of individuals amongst ASKO's owners in the mid 2000's, a period when the focus on climate and environmental issues generally increased in the Norwegian public sphere (Haugseth, Blix-Huseby & Skjølsvold 2016). The corporation aims at being 100% renewable and carbon neutral by 2020. Since the use of electricity is already green, much of what the corporation is doing deals either with offsetting carbon emissions from transportation, or by actually decarbonizing their transport, e.g. through things like biofuels. A more in-depth discussion of this topic is forthcoming[9].

2.3.2 Socio-technical configurations applied in the project

The relationship between the parent company ASKO Norge and ASKO Midt-Norge is an important element in the studied socio-technical configuration. While ASKO Midt-Norge is a stand-alone unit with its own budget, the corporation and its owners have fixed requirements for return on investments. However, the board of directors have made a clear exemption from this rule when it comes to environmentally oriented technology. Here, they are ready to accept medium-term losses, and long-term break-even.

At a corporate level, ASKO has invested in a wind park in Rogaland with a production capacity of 60GWH. This covers roughly 70-75% of the corporation's total energy consumption. With this as a backdrop, ASKO Norge has challenged its regional branches to come up with new "cases", new ways of covering the last 25-30% to make all of ASKO self-sufficient in terms of electricity.

ASKO midt-Norge have responded to this in two ways. First, they have become prosumers in a relatively straightforward way. They have built 3,000 square meters of solar cells on their roof at Tiller, and by the end of 2017 this will increase to 12,000 square meters. Solar radiation conditions in Norway have been measured to be better than one might intuitively think for such a dark country. As an example, the solar radiation in Oslo is very similar to the measured solar radiation in Bremen,[10] and the entire region of the south and east resembles central Germany, where PV has become very important.[11] That said, there are some distinct Norwegian challenges. Located at 63 degrees North, Trondheim is relatively dark in the winter, which means that PV production decreases. At the same time, electricity demand peaks for most actors in the winter, since electricity for space heating is so important.

For ASKO midt-Norge, the situation is the other way around. They mainly use electricity for cooling and freezing, for which the need peaks during the summer months, when solar production is at its highest. Currently, ASKO midt-Norge feeds electricity back into the grid. During much of the summer, however, they produce more than they can feed back. While they have been contemplating microgrid solutions, they have not yet moved in this direction. Compared to buying hydroelectricity, the costs of producing electricity from the solar power facility has been described as relatively expensive. However, ASKO midt-

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[9] An article discussing this case in-depth in a sustainability transitions and social acceptance perspective is currently under review in *Environmental innovations and sustainable transitions.*

[10] https://www.nve.no/energiforsyning-og-konsesjon/solenergi/

[11] The norwegian solar organization, https://www.solenergi.no/norske-solforhold/ (accessed 15-11-2017)

Norge expects that with time, electricity prices in Norway will increase, and solar power production will make good sense also economically.

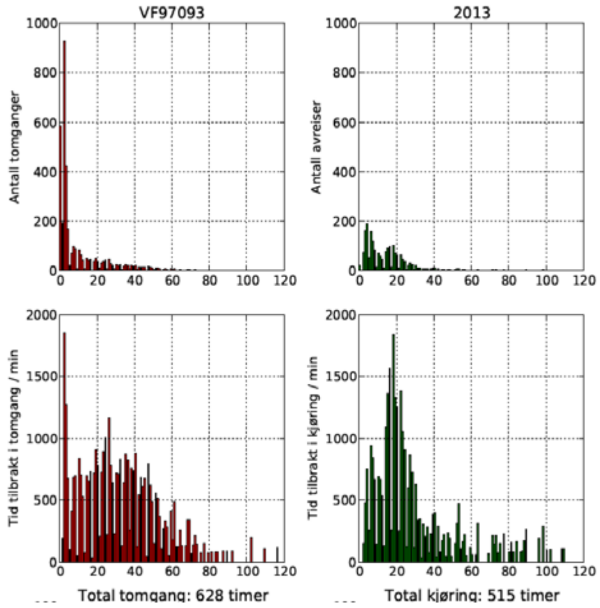

Figure 5 Hours of idling

This set-up is relatively straight-forward, even if what ASKO midt-Norge has built is a large solar park in the Norwegian context. The focus on solar production has been combined with promotion of pro-environmental behaviour amongst employees, in an attempt to nurture a sort of environmentally oriented habitus. An annual environmental fund of roughly €1 million has been established. This funds electric bikes, environmentally and energy efficient home renovations, or tickets for collective transport for employees. On-site, ASKO midt-Norge also has established electric vehicle chargers, which employees use freely. This appears to have been relatively successful, several of our respondents talked about a “sense of pride” in working for a company that was doing something important, and that it produced a sense of participating in something larger than themselves.

However, what makes ASKO midt-Norge particularly interesting in the MATCH context is their work to think about new modes of storing excess electricity production from the PV facility and decarbonizing their fleet of heavy-duty delivery trucks. To tell the story about how these ideas came about, we need to take one step back, and look at a parallel project that ASKO Midt-Norge has been involved in.

Together with a group of researchers from the research institute SINTEF, ASKO Midt-Norge has since around 2012 been looking into ways of reducing idling when doing urban deliveries. The story began in a quite unexpected way. SINTEF was working on a hydrogen reformer that produced hydrogen fuel cells from diesel. The idea was to use the fuel cell to power the lifts of distribution trucks. The rationale behind this was that on a typical route, trucks spent a considerable amount of time idling, in order to keep the battery for the lifts charged. By close study of three ASKO trucks, the scientists were able to determine driving a delivery truck for 515 hours in an urban setting, required 628 hours of idling (as illustrated by fig 5). Hence, there were enormous fuel expenses and emissions that could be cut. A report from the scientists concluded: *“The fuel cell system can remove the need for idling at delivery, and reduce the annual CO2 emissions per car with 4500 kg. If implemented across ASKO, 1350 ton of CO2 emissions can be avoided per year”*[12]

Through participation in this project, ASKO Midt-Norge reduced their emissions from this particular type of urban short-range delivery of goods with about 85% CO2 emissions. Figure 6 shows deliveries in and around Trondheim city centre on a typical Monday, which serves to illustrate why the small fuel cell could have such effects. In 2016 a similar system have been tested in another type of truck, where idling is caused by the need to power mobile refrigeration.[13] The technology is still a prototype,[14] but according to

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[12] https://brage.bibsys.no/xmlui/handle/11250/2378808

[13] For more technical detail, consult: http://www.powercell.se/asko

[14] http://www.powercell.se/wp-content/uploads/2016/04/PowerCell-Datasheet-PowerPac.pdf

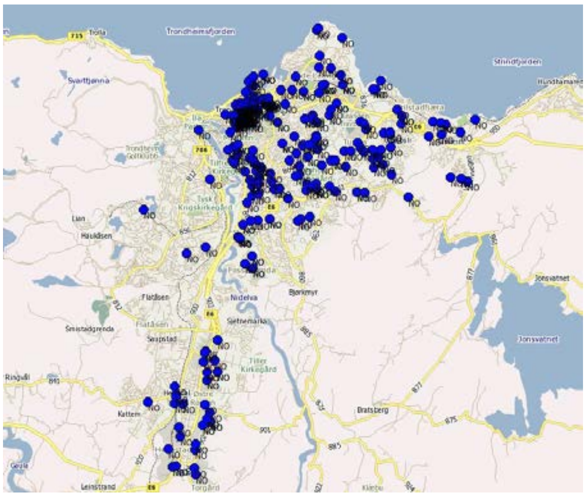

Figure 6 Deliveries in and around Trondheim on a typical Monday

statements made by executives, investments in this technology would pay off within three years.[15]

The fuel cell is not part of the configuration we have studied, but it is a technical add-on, which could make sense for delivery companies especially in urban settings under certain conditions. However, it is important for the configuration we study, because it sparked an interest for ASKO nidt-Norge for converting and storing energy in the form of hydrogen using fuel cells.

The ASKO management became convinced of the potential practical qualities of hydrogen fuel cells. Hydrogen, they were convinced, was an option to pursue in the strategy to decarbonize their fleet of heavy-duty transport trucks and forklifts. This was not only a result of being newly convinced of the qualities of hydrogen itself. The move was further motivated by the prospects of surplus electricity production from their PV installation. Thus, what was originally a move to engage in energy generating practices was suddenly an essential ingredient in a shift towards producing their own fuels, and decarbonizing their transport fleet through hydrogen.

Hence, ASKO started a pilot project where the goal is to produce hydrogen from excess solar power. They have invested 23 million NOK (around 2.3 million €) in an off-the-shelf hydrogen production facility which is installed on-site. The production will officially start on December 6th 2017.[16] The system is a containerized hydrogen production unit, an electrolyser that has a production capacity of more than 300kg of hydrogen per day. ASKO Midt-Norge has also commissioned a hydrogen filling station, to be installed on-site at Tiller. It will be installed with three separate dispensers, two dispensers at 350 bar dedicated for forklifts and trucks, and one dispenser at 700 bar dedicated to private cars[17].

The filling station for cars will be the first of its kind in the region, also making it possible for citizens to fill hydrogen. However, the hydrogen will first be used in three new 27-tonne trucks where the internal combustion engine in the powertrain will be replaced by an electric engine powered by electricity from fuel cells and hydrogen gas on board the vehicle.[18] A fuel cell creates electricity by an electro-chemical process using hydrogen and oxygen. The electricity generated by the fuel cells powers the electric powertrain. The system has an integrated battery buffer, and the only emissions are pure water. Figure 7 illustrates the vehicle.[19]

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[15] http://www.bequoted.com/bolag/powercell/pressmeddelande/genomforda-falttester-av-powercell-powerpac-har-natt-projekt-52082

[16] http://www.hydrogen.no/hva-skjer/aktuelt/steffen-moller-holst-har-kjopt-hydrogenbil-far-ikke-fylt-drivstoff

[17] http://nelhydrogen.com/news/nel-asa-awarded-contract-with-asko-for-hydrogen-production-and-fueling-solution-in-trondheim/

[18] https://www.scania.com/group/en/scania-and-asko-test-hydrogen-gas-propulsion/

[19] The image is taken from Scania's news item about the collaboration, and is available under a CC 3.0 lisence https://www.scania.com/group/en/hydrogen-a-fuel-of-the-future/

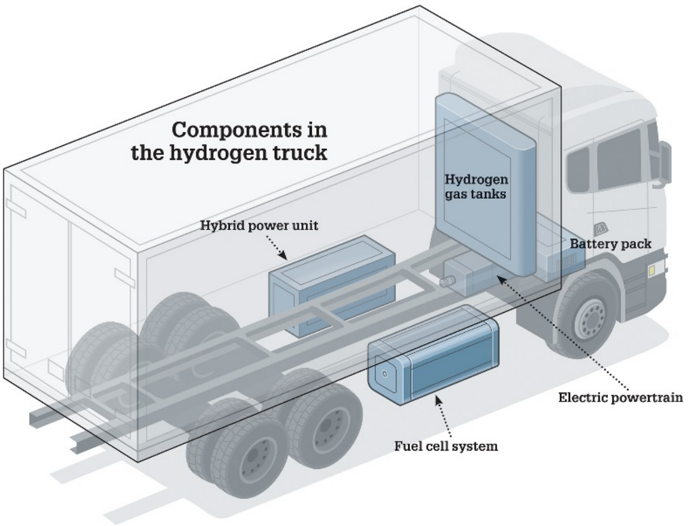

Figure 7 Hydrogen fuelled delivery truck

However, acquiring a contract for the purchase of such a heavy-duty vehicle was not straight-forward. ASKO negotiated with every car manufacturer that delivered trucks in Norway, but no-one believed that ASKO's plans were realistic. In the end, they were able to set up a project involving staff from ASKO, Scania (a long-time provider of vehicles for ASKO) and Sintef, who are now in the process of developing the truck. Furthermore, ASKO midt-Norges forklifts are being replaced with hydrogen powered forklifts. The project have received around 19 million Norwegian kroner (ca €1.9M) from the government enterprise ENOVA to realize the project[20]. In describing the process that resulted in this agreement, our interviewees highlighted long-term relationships of personal and organizational trust which had been built through working together for close to a decade as essential.

ASKO midt-Norge is an interesting case, because it represents a different way of thinking about how to deal with the intermittency of new renewable energy production. Whereas many "smart" solutions try to do this through matching supply and demand in the grid, the production of hydrogen matches the surplus production of solar power to another kind of demand than that for stationary electricity, namely that of heavy duty transport. Hence, it is a sort of internal demand management as opposed to within a system of electricity consumers and producers.

An important aspect of the socio-technical configuration, is ASKO midt-Norges expectations related to future framework conditions for their kind of company. They are convinced that electricity prices will increase, that environmentally oriented regulations will become stricter locally and nationally, and that the kinds of changes they are now implementing in their company will be vital in order to survive in the future. As an example, interviewees have shown how they think delivering goods with heavy diesel trucks in urban settings will likely become illegal. It is worth noting that they also work actively to create this future, lobbying for strict environmental regulations, nurturing pro-environmental attitudes, trying to persuade traditional electricity providers to begin producing hydrogen etc.

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[20] Info from ENOVA: https://www.enova.no/bedrift/transport/transporthistorier/asko-satser-pa-hydrogen-og-el/ (accessed 20-08-2017)

Table 3 Sociotechnical configurations

	PV	PV + hydrogen production + hydrogen trucks
Technical elements	Low-voltage grid 3,000 square meters of PV panels Large roofs Electric vehicle chargers On-site cooling systems Annual cycle of winter/summer solar radiation paired with pattern of electricity demand	12,000 square meters of PV panels containerized electrolyzer Hydrogen filling station (350 + 700 bar) 3 Hydrogen powered trucks 10 hydrogen powered forklifts
Social elements	Corporate structure and normative orientation, decreased demand for return on environmental investments Patterns of electricity demand during sumer/winter Practical and behavioural programs targeting employees. Sense of "pride" amongst employees Tariff schemes/contract with grid company?	Corporate structure with decreased demand for return on environmental investments History of cooperation between car manufacturer, research institute and company and trusting relationships. Company target to decarbonize by 2020 Expectations for future green society, and radically different framework conditions Active lobbying, targeting policy makers, other companies and individuals aiming to produce favourable framework conditions.

2.3.3 Discussion: Success and outcomes

The first configuration of this case mainly involves electric power production through PV and appears relatively successful. It is technically non-complicated and it does not represent a direct monetary loss for the company currently. There are now discussions in Norway concerning whether or not such facilities should be included in the Norwegian-Swedish renewable electricity certificate scheme. Currently, they are not, but Asko has managed to get dispensation for another similar facility in the east of Norway[21] could make their solar power production more profitable. As actors like ASKO begins to produce electricity on relatively large scales, they also cause controversy amongst traditional electricity providers and grid companies, because of their disruptive potential. Hence, the choices ASKO make over the coming years will be under close scrutiny by many actors. The company has managed to make a strong environmentally oriented brand, and it appears as if many employees see the "greenness" as part of the package of being an ASKO employee.

It is too early to say if the pilot project on hydrogen will be a success, or what the outcome will be. So far, however, it represents an interesting encounter between actors and technologies which come from traditionally relatively separated domains. The electricity system and the mobility system is increasingly merging in the Norwegian context due to the influx of electric vehicles, and hydrogen represents an interesting option for electrifi-

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[21] Asko Vestby has installed 19 000 m2 of PV. https://www.tu.no/artikler/na-er-norges-storste-solcelle-anlegg-blitt-nesten-tre-ganger-sa-stort/346914

cation of heavy duty transport. It also represents a potentially new way of matching excess production of electricity with demand in other spheres, such as the demand for heavy duty mobility and transport. For solar power the production is likely to vary according to season. ASKO is currently in dialogue with other actors such as wind farm operators, about using wind power to produce hydrogen e.g. at night, when the wind still is strong, but electricity demand low. As some of our respondents have told us, producing hydrogen from solar power is unlikely to be technologically “optimal” in the strictest sense of the word, but currently the alternative is that excess electricity production goes to waste when the production is beyond what can be delivered to the grid. As it stands, however, the current project would probably not have been possible without economic support from Enova.

In summary, and with reference to the MATCH framework, the main findings of the case study in relation to technology, markets and actors are:

- Technology: ASKO midt-Norge has successfully become one of the region’s largest solar power producers. Their venture into hydrogen represents a novel way to think about storing electricity and matching production and consumption across infrastructures, sectors and seasons. The case also illustrates the advantages of considering technologies in relation to each other, with the possibility of constructing new constellations.
- Actors: The case illustrates how the boundaries of the traditional electricity system is increasingly becoming blurry. ASKO is a grocery wholesaler, and have not traditionally been part of this system as anything but a large actor on the “demand side”. Now they produce electricity and are venturing into fuel production, hence illustrating potential for disruption. This was enabled by the close cooperation between ASKO, a commercial company and SINTEF, primarily a research actor. Further, the case illustrates the importance of trust built over time between actors when trying to establish unconventional solutions.
- Markets: Similarly, the case illustrates how new combinations of actors and technologies might open new market opportunities e.g. in hydrogen. So far, the pilot project relies on economic support, and it is difficult to predict if framework conditions will change enough to make this economically feasible. ASKO however, are prepared to take some losses.

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Determining factors for integrated smart energy solutions

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About ERA-Net Smart Energy Systems and MATCH

ERA-Net Smart Energy Systems (ERA-Net SES) – formerly ERA-Net Smart Grids Plus – is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programs along the innovation chain provides a sustainable and service oriented joint programming platform to finance projects in thematic areas like Smart Power Grids, Regional and Local Energy Systems, Heating and Cooling Networks, Digital Energy and Smart Services, etc.

Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

www.eranet-smartenergysystems.eu

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https://www.match-project.eu

Improving energy efficiency and replacing fossil fuels with renewable energy are among the most important measures on the road to a sustainable energy system. This implies new ways of generating and consuming energy as well as new forms of relations between the energy producers and consumers. The MATCH project contributes to the shift to a carbon-neutral energy system by zooming in on the changing roles of small consumers in the future electricity system (the “smart grids”).

The overall objective of MATCH is to expand our knowledge on how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. The study is cross-disciplinary and based on detailed studies of current smart grid demonstrations in Norway, Austria and Denmark. Through comparative analysis across cases and countries, the study identifies key factors related to technology, market and actor involvement in developing integrated solutions that “work in practice”. This is addressed in this report.

1 Introduction

The aim of this WP is to identify and discuss critical factors related to market, technology and actor-involvement that are decisive for designing integrated smart grid solutions for small consumers that work under real-life settings. The comparative analysis is based on the findings of WP2 and involves additional data analysis where necessary.

Identifying critical factors in real-life constellations help to better define and understand the success of 'working solutions' across cases and national contexts. In the three country case studies, presented in WP2, we describe and explain various solutions for integrated smart energy systems in a comprehensive way. In each of the nine projects we were able to identify a number of different solutions and described them as socio-technical configurations. These configurations had been developed within different national, regional and project specific contexts. They 'work' – at least – within these specific local contexts and the applied case study research attempted to understand the working of the various solutions as integrated parts of these different framings and frameworks. In generic terms, these socio-technical solutions work successfully, because relevant actor groups – through interaction between actors in local-situated networks – to a certain degree have been able to define, set up and test these solutions in real-life settings.

Based on the detailed but hitherto separate isolated analysis we now aim to go beyond these findings and try to compare cases, projects and configurations across countries. Although the analysis aims to find general patterns, the results are sensitive to the local context of smart energy systems solutions.

Comparison in the social sciences is a highly contested approach, located between two radically different epistemological positions. On the one hand, we have methodological positivism, assuming that the comparative method will help us to uncover universal (social) laws. On the other hand, there is methodological relativism, stressing the importance of local contexts in understanding the meaning of particular human beliefs and activities (Deville et al. 2016).

However, as the new term 'comparative relativism' indicates, there indeed are efforts to deal with this seemingly paradox in a productively way (Jensen 2011). Picking up this discussion, Krause (2016) has argued that the social sciences should be more open to less restrictive forms of comparisons. Comparative approaches have more to offer when they aim for other than the traditional linear-causal forms of explanation as postulated by positivistic positions. Krause assumes that the rule to only compare 'like with like' does not longer hold "when all things can be described in terms of both similarities and differences" (Krause, 2016: 57). From this point of view description takes on a central role in any comparative study. With such a concept of social scientific comparison approach, we aim to contribute with comprehensive description, concept development, and critique, and thus attempt to provide comprehensions that distinguish from conventional explanations. As a consequence, research strategies may imply the use of different kinds of comparison, ranging from what Krause calls 'like with unlike comparisons', to 'asymmetrical comparisons', to 'hypothetical comparisons', or even to 'undigested comparisons'.

Informed by those description-oriented forms of comparison this report aims in the first place to provide a brief overview of the nine case studies and their respective national contexts. What problems are addressed by the studied projects? What kinds of solutions have been developed? What differences and similarities between countries, projects and solutions do we see? What kind of patterns can we observe? And finally: How was success framed and configured on the project level and what can we learn when we analyse and compare different constellations of context-depended cases? These and other questions will help us to identify clusters of solutions and critical factors that are relevant for further in-depth analysis. The following section will give an overview of the cases' national contexts: Austria, Denmark, and Norway and will discuss relevant national characteristics in direct comparison.

2 Three national contexts in comparison: Austria, Denmark and Norway

Austria, Denmark, and Norway are all three countries that are heavily influenced by regulation set in the European Union; either as members (Austria and Denmark) or as an associated country (Norway). Especially, common market and environmental protection regulation influence national laws and regulations with regard to smart grids. Nevertheless, the three countries differ on significant contextual determining factors such as e.g. geography and social conditions (Table 1). For instance, when it comes to area-size, Norway is by far the largest of the three countries. Both, Austria and Norway are very mountainous and can therefore profit from the use of hydropower. Further, in opposition to Austria, Denmark and Norway have long coastlines. Also, especially Norway has – due to its location in the northern hemisphere – longer days with a lot of daylight during summer and considerable shorter days in winter. In Austria, due to the more southern location, the variations are less intensive. Also differences according to dwellings are substantial. While Austria has a strong renting tradition, which makes only half of its population live in self-owned houses, more citizens in Denmark live in their own detached houses, and this is by far the dominant form of living in Norway.

Table 1. Country specific factors

	Austria	**Denmark**	**Norway**
Size	83,879 km^2	43,000 km^2	323,802 km^2
Population (Million)	8.77	5.73	5.26
Density (pop/km$^{2)}$	104.6	132.6	16.2
Geographic Profile	Mountainous/forests	Long coastline & many islands	Mountainous/long coastline
Daylight	8.5 h (winter) 16 h (summer)	7 h (winter) 17 ½ (summer)	In northern parts: neglectable in winter, plenty in summer. Southern parts: similar to Denmark
Housing Situation	55 % homeownership	62.7 % homeownership	82.8 % homeownership
Mean and median income by household in € 2016	23,694	28,659	39,569
Total Government debt/ GDP 2016	84 %	40 %	33 %
Industry share of GDP	26.87 % (2005) 27.74 % (2016)	30.54 % (2005) 23.48 % (2016)	44.48 % (2005) 31.96 % (2016)

Economically, Norwegian households have a considerable larger median income than both Danish and Austrian ones. Similarly, Norway has the smallest debt/GDP ratio, followed by Denmark and then (being double of the Danish one) Austria. In Norway, industry plays a large role for its economy, although it is declining. In Austria this importance is slightly less, but still considerable. In Denmark, industry has the smallest role amongst the three countries. Both Denmark and Norway experienced loss of importance of industry in the last 20 years, while industry-importance slightly increased in Austria.

Notably, the different geography of the three countries influences their choice of energy use substantially (Table 2). Noteworthy are here Norway's **fossil energy resources** that are one of the cornerstones for its wealth. In Denmark, fossil energy resources (oil and natural gas) are also playing an important role both for export and for domestic consumption, while in Austria fossil energy resources are neglectable. While Norway has vast amounts of fossil resources it does not consume them as energy, but exports them as a product. Conversely, Norway produces electricity through hydropower and exports some to neighbouring countries. While Denmark is more or less self-sufficient, Austria is a clear energy importer. In Austria, the expansion of wind power has already reached a relevant level. Both Austria and Norway profit from their mountainous landscape, which allows them to use pumped hydro storage. Hence, Denmark uses indirectly the Norwegian storage capacity.

Table 2. Energy regulation: sources, production and consumption etc.

	Austria	**Denmark**	**Norway**
Fossil energy resources	No	Yes, but decreasing	Yes
Energy Importer/ Exporter	Importer	Almost self-sufficient	Exporter
Total electricity production 2017	70.100 GWh	33.716 GWh	148.400 GWh
Solar in electricity production	1.5 % (2015)	2.1 % (2015)	0 % (2015)
Wind in electricity production	7.4 % (2015)	42.1 % (2015)	1.7 % (2015)
Storage	Pumped hydro	Miscellaneous	Pumped hydro
Household heating sources	30 % wood and pellets, 21.5 % gas, 20.7 % oil	64 % district, 25 % oil or natural gas	Electric, supplemented by biomass/stoves
CO_2 Emissions per capita	7.4 t/y	6.7 t/y	11.7 t/y
Share of passenger cars being electric vehicles	0.3 % (2017)	0.4 % (2017)	20.8 % (2017)

Electricity plays an important role in all three countries. However, in Norway electricity production is considerably larger than in Austria, which simultaneously is twice as large as in Denmark. The influence of renewables, however, varies significantly. Electricity based on wind is the dominant form in Denmark, followed by Austria and with almost negligible quantities in Norway – even though it is increasing. Wind-based electricity plays a substantial role for the Danish electricity production, accounting for 43 % of the total energy supply (in 2017).

Households in Austria and Denmark use mostly central **heating**, and with regard to source of heat, households in Denmark rely mostly on district heating. In Austria, the main source of heating is wood and pellets followed by gas and oil; district heating accounts only for 21 %. In Norway, electric heating plays a major role, which is also visible in Norway's electricity production. CO_2 emissions in Norway are also slightly larger than in both other countries. With regard to **electric vehicles**, Norway has by far the largest share of newly registered electric vehicles, followed with some distance by Austria and with a neglectable uptake in Denmark. In Norway, regulation and subsidies favours heavily the purchase of electric over conventional vehicles.

In Austria central **policy actors** are federal and regional agencies together with small and medium sized companies and transnational corporations (Table 3). In Denmark central policy actors are mainly on the national level. The Ministry of Energy, Utilities and Climate is the main policy actor, while funding in research and development is mainly provided by national funding programs (e.g. the Energy Technology Development and Demonstration Programme, EUDP, and the Innovation Fund) and supported by SMEs and transnational corporations.

In Austria, the research policy and related programs are the main drivers for Austrian smart grid initiatives (e.g. e!MISSION.at – Energy Mission Austria). Conversely in Denmark, the driving policy papers are Danish Smart Grid Strategy and, more broadly, the Energy Strategy 2050. Both strategies are addressing climate change and energy independence based primarily on domestic renewable energy. In Norway the driving policy for smart grids is both research and energy policy.

Climate policy has a central influence on Danish and Norwegian smart grid initiatives and is binding through agreement on European Economic area. In Austria however, although also bound to the same climate agreements, they do not have substantial practical influence over local political decision-making.

Local government and municipalities play a crucial role for the success of Austrian and Norwegian projects. In Denmark, the local governments are not in general playing a central role, except in relation to district heating, although some municipalities have developed specific strategies to achieve climate neutrality etc. within the coming 10-20 years – and in some of these municipalities, the activities also include smart grid related activities (in addition to traditional measures such as energy savings and/or installing new RE capacity).

For all the three countries, **research actors** are a combination of PPP, universities, research institutes, and industry companies, and public funding agencies.

The **smart metering** landscape differs between the three countries. While all three have specific targets for 2019 that include an almost fully complete cover of smart meters (in 2020 in Denmark), the actual roll out differs significantly. Denmark's rollout is well on the way, while Austria lags behind in reaching the set target. The progress reported by mid-2017 in Norway was 6 % slower than expected at the beginning of the year. The Norwegian plan is highly ambitious, as it demands for a complete smart metering rollout in households by 2019. Also, the Water and Resources and Energy Directorate has made smart meters obligatory.

Table 3. Overall policies and regulation and local initiatives supporting the national smart grid landscapes

	Austria	**Denmark**	**Norway**
Central Policy Actor for Smart Grid	Infrastructure Ministry and regions provide major funding together with SMEs and TNCs	Ministry of Energy, Utilities and Climate, national funding programs and SMEs and TNCs	The Norwegian Water Resources and Energy Directorate has made smart meters obligatory.
Driving National Smart Grid Policy	Research Policy	Climate and Energy Policy	Research and Energy policy
Binding Climate strategy	Binding through agreement on EU Area, no legal implementation at national level	Binding through agreement on EU Area (distribution by countries)	Binding through agreement on European Economic Area
Local Government	Municipalities and regions play central role	Municipalities and regions play a limited role	Municipalities and regions are central
Research Actors	Platform with industry and research institutes	Universities, institutes and industry in both classical energy and ICT central	Universities, institutes and industry in both classical energy and ICT central
Smart metering target	Infrastructure by 2019 of 95 %	Infrastructure by 2020 of 100 %	Infrastructure by 2019 of 100 %
Meters Installed 2016	8.5 %	More than 50 %	(Mid 2017) 31 %, 57 % before end of 2018 (exp.)

The market structure shows strong differences between household electricity prices (including taxes) in the three countries (Table 4). Noteworthy is hereby the much higher price for Danish households in comparison for those in the other countries. In contrast, electricity prices for non-households are similar in all three countries and notably lesser than prices for households.

All three countries show a high share of public ownership of the **power production** capacity and grid operation, which ensures a high level of control by public actors. However, in Denmark, the ownership of the power production capacity is divided between two major private companies (the Danish Ørsted and the Swedish Vattenfall) owning the large coal or gas-fired CHP plants and much of the wind power capacity, on the one side, and about 250 decentral CHP plants typically owned by local municipalities or as co-operatives owned by local customers (on the other side).

In all three countries **distribution system operators** are a mix of public-owned, co-ops and private companies, with a predominance of municipal actors in Denmark and Norway.

Austria's **energy market** is generally liberalized, but still dominated by incumbent, partially public, regional utilities, which still divide their commercial area amongst themselves. Similarly in Norway, while it was one of the first countries to fully liberalize electricity markets, it is still dominated by partially municipally owned utilities and long-standing relationships with local customers. In Denmark, the market has also been liberalized, but with a low entrance of new companies and the incumbent companies (partly municipal-owned, partly co-ops and private companies) still being the main actors and maintaining their local customer-base (established historically).

Table 4. Overview of the energy market structure

	Austria	**Denmark**	**Norway**
Electricity prices HH 2017s1 first of half year	0.195 €/kWh	0.305 €/kWh	0.164 €/kWh
Electricity prices non-HH 2017s1 first of half year	0.093 €/kWh	0.082 €/kWh	0.071 €/kWh
Public Ownership of power production capacity	high	Partly public (state and municipalities) or local co-ops.	high (around 90 %)
Distribution system Operators	Mix of state-, federal, municipal-owned and private companies	Mix of municipal-owned, co-ops and private companies	Mostly (partially) owned by municipalities, regulated by government regulator
Liberalization of energy market	Liberalized, but utilities are traditionally regional bound through partial regional government ownership and local customer base	Liberalized, traditionally regional bound through local customer base	One of the first countries to fully liberalize Electricity markets

In summary, this brief comparison shows that the three case study countries differ in many ways and in some respects quite considerably from each other. There are clear differences regarding demography, economic conditions, natural resources, geography and climate. Existing energy systems and the legal and political framework conditions for the development of smart energy systems are at least as diverse. As we will see in the following section, these clearly different contextual conditions also have a significant influence on the type and actual design of the solutions investigated in more detail in the MATCH project.

3 Projects and solutions in comparison

This chapter provides a brief overview of the nine projects and all studied ‘solutions’. The aim is to show differences and similarities in our total ‘sample’, and based on this overview, we hope to find a number of possible ‘clusters’ of solutions which are suitable for comparison. At least some of the characteristics of the selected solutions should be similar (e.g. similar target group, similar technology, similar project aim).

The cross-national sample of projects to some extent represent the great variety we actually see in field of smart energy systems innovation in Europe (Table 5). Our nine projects differ regarding the phase of the innovation process, which technologies are used predominantly and also which key actors are involved in the activities. However, projects usually focus on more than one topic as innovation activities in all our cases are inspired by the idea of combining technologies, services and sectors in new constellations.

Table 5. Overview of projects: Description, key actors and innovation phase

Country/ Project	Description	Key Actors	Phase of Innovation
Austria			
Köstendorf	Pilot and demonstration project with smart distribution grid field test	Regional DSO&ESCO, research institute, industrial group	R&D
Rosa Zukunft	Pilot and demonstration project with Building-to-grid solution and DSM field test	Regional DSO&ESCO, research institute, housing association	R&D
VLOTTE	E-mobility business implementation	Regional DSO&ESCO	R&D, Product development
Denmark			
Innovation Fur	Piloting and demonstration of balancing local energy exchange at the community micro grid level	DSO & Municipality	R&D
ProjectZero	Promote and facilitate energy efficient measures and local renewable energy to decarbonize consumption	DSO, regional Bank-Fund, Municipality	Local energy transition
Samso Energy Academy	Community participation project to increase energy autonomy of the island	Dedicated Organization for project implementation	Local energy transition
Norway			
PV demo Trondelag	Two related regional PV demonstration projects	Two regional DSOs	R&D
Smart Energy Hvaler	Testing the potential for balancing the local grid	Regional DSO, Municipality, University	R&D
ASKO midt-Norge	Business implementation using PV excess for decarbonisation of fleet and for on-site electricity use	Large grocery wholesaler	Technology/ product development

1.1 Phase and type of the innovation

The projects are situated in different innovation stages. Some are mainly organized around R&D activities, some apply a company specific innovation and development focus (closer to working business cases), and others, however, manly focus on the implementation and dissemination of already proven and available solutions. In our sample there are essentially three groups:

Projects with a main focus on R&D: Some projects focus mainly on R&D (Köstendorf, Rosa Zukunft, Innovation Fur, PV demo Trøndelag, Smart Energy Hvaler). They run test trials, set-up pilot projects, test new configurations, and aim at technology learning (new knowledge, practical know-how, e.g. to improve or complement their own product portfolio).

Projects with a main focus on technology and/or product development: Two projects belong to this category (VLOTTE and ASKO midt-Norge). Although these two projects differ regarding their history, today they focus mainly on the development of new solutions in the mobility sector (smart e-mobility infrastructure, hydrogen company fleet).

Projects with a main focus on a local energy transition: Two projects mainly aim at driving a local transition process towards a low carbon society (ProjectZero, Samso Energy Academy). In these examples a strong local actor develops a kind of holistic strategy to initiate change in a wide variety of sectors to achieve ambitious environmental and climate targets. Here the focus is on implementation and dissemination of effective solutions; why technology development, learning and knowledge production is less important.

1.2 Applied technologies

Except for one case all projects in our sample deal with PV systems. Some of them focus on the integration into the local grid (Köstendorf, Innovation Fur, PV demo Trøndelag, Smart Energy Hvaler). Some others try to learn more about the combination of PV systems, heat pumps and batteries on the household level (Köstendorf, VLOTTE, Innovation Fur). Another focus is on the combination of PV systems and e-vehicles (Köstendorf, VLOTTE). And a few projects use PV systems in an already tried and tested manner without a special research focus (Rosa Zukunft, VLOTTE, ProjectZero, ASKO midt-Norge).

Smart grid infrastructure technologies are involved and tested in several projects (e.g. Köstendorf, Rosa Zukunft, VLOTTE, Innovation Fur, PV demo Trøndelag). ICT systems, smart meters and similar information technologies are used to balance loads or to reduce the cost for infrastructure investments. Demand response and energy feedback on the household level, as an additional example of this area, was part of the test trial in the city of Salzburg (Rosa Zukunft), in Hvaler (Smart Energy Hvaler) and on Fur (Innovation Fur).

In several projects heat pump technology is used to consume surplus electricity from renewable sources (e.g. Rosa Zukunft, Innovation Fur) and store it in form of heat energy for later use.

E-vehicles are involved in three projects (Köstendorf, VLOTTE, Smart Energy Hvaler) and one project each deals with hydrogen technology for vehicles.

1.3 Key actors and main target groups

Main project owners in most cases are local or regional DSOs/ESCOs. Two projects are led by dedicated organisations created specifically for the implementation local energy transitions (ProjectZero, Samsø Energy Academy), and, in one particular case, the project is led by a company from outside the energy sector (ASKO midt-Norge). In addition to these main actors, several other partners and clients are involved in the implementation of the various solutions of the projects (e.g. research partner, local companies, municipalities).

In four out of nine cases, private households are the main target group of the activities. In these cases, householders are addressed in several roles, as consumers, end-users, prosumers, and field-test participants. Three projects deal with mixed target groups, usually addressing private households, local companies and public authorities as customers. In two cases the main target group are SMEs and their own staff (VLOTTE, ASKO).

For a detailed analysis of the success of the applied solutions, however, it is necessary to identify several 'clusters of solutions'. This is the aim of the following section.

Table 6. Overview of projects: Applied technology and main target groups

Country/ Project	**Applied Technologies**	**Main Target Group**
Austria		
Köstendorf	Local grid PV integration, combination of PV systems and batteries, PV systems and e-vehicles, testing smart grid Infrastructure	Households, SMEs, public authorities
Rosa Zukunft	PV systems without research focus, testing smart grid infrastructure, household level DR and energy feedback, heat-pumps, CHPs	Households
VLOTTE	Combination of PV systems and batteries, PV systems and e-vehicles, PV systems without research focus, testing smart grid infrastructure	SMEs & employees
Denmark		
Innovation Fur	Local grid PV integration, combination of PV systems with heat pumps or/and batteries, testing smart grid infrastructure	Households
ProjectZero	PV systems without research focus, EVs and heat pumps as well as "smart" building energy renovations to achieve higher energy efficiency	Households and SMEs
Samsø Energy Academy	Testing potentials for reduce energy demand by regulate temperature and install energy efficient equipment (energy efficiency measures)	Households and SMEs
Norway		
PV demo Trøndelag	Local grid PV integration, testing smart grid Infrastructure	Households
Smart Energy Hvaler	Local grid PV integration testing demand response and impact of smart technologies as PVs and e-vehicles	Households
ASKO midt-Norge	PV systems without research focus, hydrogen generation, hydrogen driven trucks	SMEs & employees

1.4 Clusters of solutions

A ‘cluster of solution’ consists of at least two working socio-technical configurations applied in two different projects (see tables 5, 6 & 7). At least some of the characteristics of the selected solutions should be similar (e.g. similar phase of innovation, similar target group, similar function, or similar project aim). These similarities should provide for a more stable basis for comparison and allow for the discussion of aspects and patterns that help to better understand the success across projects and solutions.

Table 7. Overview of studied socio-technical configurations (solutions)

Country/ Project	Solution 1	Solution 2	Solution 3
Austria			
Köstendorf	Smart distribution grid with vast PV generation	PV, EV & home battery	100 % renewable household
Rosa Zukunft	Building-to-grid	Energy feedback & DR	EV sharing
VLOTTE	PV & EV car park	Company e-fleet & fast charging point	PV, EV & home battery
Denmark			
Innovation Fur	PV & home battery	PV & heat pump	No other configuration
ProjectZero	Households (Zerobolig)	Sport centres (ZERO sport)	Shops (ZERObutik)
Samsø Energy Academy	Energy savings in local business	No other configuration	No other configuration
Norway			
PV demo Trøndelag	PV in private homes	No other configuration	No other configuration
Smart Energy Hvaler	SEH participant with solar PV (11/15)	SEH participant without solar PV (4/15)	No other configuration
ASKO midt-Norge	Large on-site PV system	PV, hydrogen production & hydrogen trucks	No other configuration

Combining main functions of the studied solutions and similarities regarding target groups and organizational set-ups, we were able to identify the following clusters, which will be analysed in more detail below (chapter 4):

- **Balancing generation and demand:** The main focus here is to better deal with variable renewable generation. The more renewable energies that are being developed, the greater demand for such solutions. The studied projects applied and tested several strategies for matching supply and demand, ranging from energy feedback & DSM (Rosa Zukunft) to smart charging (VLOTTE), the use of heat pumps and batteries at the household level (Innovation Fur) and the use for cooling or hydrogen production (ASKO).

- **Renewable powered company fleets:** In two of our cases the activities focus on the development of solutions that aim to convert vehicle fleets to renewable energy sources. In both cases these activities are in-house developments aiming first of all at the companies' own needs. In the VLOTTE project a regional DSO develops a smart e-car park; in the ASKO case a large grocery wholesaler establishes a hydrogen infrastructure for hydrogen-powered commercial vehicles.
- **Comprehensive energy concepts:** The aim of the approaches in this cluster is to provide complete solutions to achieve a maximum in terms of energy saving and use of renewables. The focus of our examples is on households (100% renewable household in Köstendorf), apartment buildings (Rosa Zukunft), supermarkets (Samsø, ZERObutik), and sports facilities (ZERO sport) – in some examples as part of a regional energy transition plan (Samsø and ProjectZero). In all these cases a number of technologies, rules and practices work together in a custom-made manner to achieve ambitious energy targets. In addition to various technologies, precise planning and consulting are of great importance in this cluster.

An additional topic for cross-country, cross-project and cross-solution comparison is user integration. We may assume that users are of great importance in all our cases. A cross-case analysis should therefore offer an additional perspective on the success of the solutions. This issue will be addressed in a separate analysis (chapter 4.4).

4 Successful solutions in comparison

In this chapter we aim to analyse a couple of selected solutions in comparison. The aim is to better understand the 'success' of solutions. This part of the report should provide a more detailed discussion what success means in the projects of a selected cluster, how it is defined and by whom. So far, success was defined as 'the working' of solutions in practical settings. A working solution provides a service making value for e.g. the grid, customers, and environment. In the following we attempt to broaden this definition a bit, as some of the solutions do work well as part of a research project, but did not end up as a (marketable) product or a working business case. Other solutions are better characterized as a successful experiment rather than a solution. In those cases 'success' means that actors were able to keep the development running (keep the building of the configuration running) and coming up with useful conclusions. Thus, while the socio-technical configuration of the solution might not be transferable, other elements of the innovation processes might be.

There are a several characteristics that seem necessary, but not sufficient to make the success of a solution. For example, the solutions in the project fulfil the aimed function for a project at its innovation stage. They are adapted to country conditions such as geography, market conditions, policies and regulatory frameworks. In addition, the specific solutions meet local conditions. Also, the involved actors such as project partners work well together and customers or other stakeholder are successfully addressed by the socio-technical configuration.

According to this, chapter 4 is a compilation of four cross-case comparisons. Each of these comparisons follows a similar structure, including (1) a short description of selected solutions (including arguments why a comparison make sense), (2) a discussion of how success is defined (by whom) in each of the selected solutions, and (3) a discussion of patterns (factors) that help to understand success across cases and solutions.

4.1 Balancing generation and demand using solar PV and storage

4.1.1 Introduction

The underlying assumption for solutions in this section is that installing production capacities at sites of consumption can contribute to reductions in peak demand, thus providing grid operators with leverage capabilities in balancing the grid. In some cases herein, distributed generation is a customer driven phenomenon and has driven grid operators to organize trials to gauge the effects of the introduction of local generation on the grid. Various solutions that have proven capable of balancing generation and demand will be presented. In short, they are characterized by utilizing residential rooftop solar PV panels and, in some cases, storage capacity in terms of a battery and/or the use of thermal capacity (heat pumps and boilers). As several of the studied solutions included economic incentives to support active demand response (i.e. time shifting loads), this will also be commented on in the following analysis.

The socio-technical constellations having to do with balancing generation and demand examined in the MATCH-project were comprised of four solutions with similar characteristics. The solutions are summarized as follows:

1. Households with solar PV (Trøndelag PV).
2. Households with solar PV & heat pumps (Smart Energi Hvaler, Innovation Fur/GreenCom).
3. Households with solar PV & battery (Innovation Fur/GreenCom, Köstendorf, VLOTTE).
4. Large scale solar PV & storage/heat pumps (Rosa Zukunft)

Solutions 1-3 are centred on private customers, or households, with small-scale (~3-5 kWp) solar PV panels, which can be utilized during peak production to charge in-house batteries, heat water, and run heat pumps. Load shifting these appliances can contribute to reducing capacity peak demand or local aggregated energy demand in general. The fourth solution described in this chapter is focused on the same goals but deployed on the scale of large housing complexes. All solutions introduced a form of visualized feedback mechanism, such as in-home displays or a web application, providing real time information on production and consumption, as well as cost variation. However, these were implemented and utilized to widely varying degrees across cases.

The first solution, involving households with rooftop solar PV, is covered in one of the Norwegian cases, Trøndelag PV. This is an example of a “bare minimum” case, in which simply installing and testing the PVs in the grid was the main goal. The motivation of the energy companies in charge was to drive business development processes regarding solar PV for the private market, and to gather experience in this area for all parts of the corporation (both were integrated energy companies). From the perspective of the grid operator, the aim was to meet changes in market demand constituted by increased shares of small-scale renewables and the necessary digitalized capabilities associated with handling such developments. From a market and business point of view, the company aimed to develop market models associated with micro-generation, which were thought to become more relevant in the future. In other words, this case was predominantly customer driven. The costumers’ motivation for participating was most of all characterized by an environmental concern and self-identification as taking part in a technological vanguard for solving those concerns.

The second solution, including households with PV and heat pumps, was found in the case of the Smart Energi Hvaler (SEH) energy technology pilot in Norway and in the case of Innovation Fur (GreenCom) Denmark. Compared to solution 1, the cases employing solution 2 show an added level of sophistication in a variety of ways. More effort was devoted to adding visualized feedback mechanisms and some degree of automation capability, which contributed to making localized PV production more useful than in cases where there is no automation linking production with consumption. Automation can aid customers to practice load shifting by linking local production with consumption, making sure they happen at the most fortuitous times for grid balance purposes and for the customer, in relation to overall demand and market prices.

The third solution, featuring batteries in conjunction with PV production, was found in three cases, the GreenCom demo in Denmark, in the Austrian projects Model Village Köstendorf, and VLOTTE. In the case of GreenCom, batteries were operated in tandem with PV production aided by an intelligent storage system. Taking into consideration possible future low-voltage grid capacity problems, the aim of the project was to explore new methods of balancing exchange of energy at the local micro-grid level (e.g. by increasing self-sufficiency) in order to increase regulation capacity and reserve power. However, even though promising results in terms of load-shifting of some energy consuming practices in the households, the trial showed that the already existing grid capacity in the area is already more than ample to accommodate future increases in electricity demand and fluctuation from electric vehicles and more heat pumps. Secondly, The DG DemoNet Smart Low Voltage Grid project, situated in Köstendorf together with the LEAF project, implemented battery storage in a wide range of field tests involving already existing configurations of households with rooftop PVs. The aim of this project was to explore new tools for grid stabilization and learning about systemic implications of prosumer households for the grid. Finally, the VLOTTE project, though mainly focused on company fleet scale e-mobility, also feature a smart energy trial household consisting of a two-family home with rooftop PV panels and a battery (10 kWh). The battery installation has shown promise, as the families increased their PV self-consumption from 15 % to 40 % (and even up to 98 % in summer).

The fourth solution is technically similar to the three previous but differ in terms of scale, scope, and configuration. The HiT (“houses as interactive parts of the grid”) Rosa Zukunft project features 8 apartment complexes with 129 units and an ambition to implement a scenario where entire buildings can be intelligent actors in the grid. It showcased a central Building Energy Agent (BEA) interoperating with the large-scale rooftop PV (72 kWp). This part of the project was highly automated in nature and relied to a large degree on end-users being entirely passive, while the building (and, not to forget, the building operators) intelligently maintained operational aspects of the system. In addition, 33 of the 129 apartments participated in a one-year demand response test trial. In this case a variable tariff was introduced under special approval by the regulator and the variability was communicated to the users via the in-home displays.

4.1.2 Outstanding qualities of the selected solutions

Solution 1 - Households with PV

As mentioned, solution 1 was found in two demonstration projects in Trøndelag, Norway, both of which were solar PV trials undertaken by the region's two leading energy company/DSOs, TrønderEnergi and Nord Trøndelag Energi (NTE). Due to the similar characteristics of these two projects, these two demo projects were merged into a single case within the MATCH study.

In both cases, a marketing campaign advertised for prospective solar PV end users, and in both cases, the response from interested households was massive. This resulted in a total of 30 households selected to trial based on how suitable their characteristics were for solar PV production. 11 of these were interviewed for this study, all of which had been provided smart meters, rooftop PVs, and access to data about production and consumption through a web and mobile application. The PVs were provided as a packaged deal, where the households purchased the installation – either outright or through regular down payments (with ensuing interest) over 15 years. Participants are contractually obligated to the energy company's energy provider for 15 years, during which time the company is responsible for service and maintenance. Moreover, for this period the participants signed a contract to become prosumers, or so-called "plus-customers", and any surplus energy generated by the PV panels would be sold back to the grid and the electricity provider at spot price.

In the spring of 2017, NTE introduced a small feed-in-tariff of a few NOK cents in addition to the spot price. However, this amount was a rather insignificant addition to the already insubstantial Norwegian spot price (The spot price hovered around €0.05.). Additional subsidies for the PV installation itself were available upon submitting an application after they have been purchased through the Norwegian energy agency, ENOVA. (The current support program is available for anyone with a new solar PV installation. The support provides a flat sum of about €1,000 and €125 per kW capacity installed.)

From the perspective of the grid operator, the project has thus far been quite successful. Finding participants and recruiting them was unproblematic, as there was ample interest among the general populace for joining such a project. For the purpose of testing for grid implications of micro-generation, that goal was met; although what exactly was learned by this demo was too early to say at the time of study. At any rate, it was established that the grid would accommodate micro-generation capacity and the operator had few large problems from this new and intermittent source of energy. From the view of the end users, participation in the project was experienced as mildly successful, but bore signs of constituting a surplus project for the ones involved. This means that participation is probably dependent on a relatively stable life and economy, being a home-owner at the very least, as the immediate financial gains of being a plus customer without a feed-in-tariff are not very large. However, end users achieved success in fulfilling personal ambitions related to environmental concerns and early technology adoption, concerns that seemed to have an important role alongside monetary remuneration upon making the investment decision.

In summary of Solution 1, from an economical perspective this scenario lacked a substantial feed-in tariff. Selling energy back to the grid would return earnings close to the spot price, whereas self-consumption would provide customers a saving per kWh of about 70%. In this case, a strong incentive to self-consume was prevalent, though this was to a large degree impractical in everyday life, even though respondents reported that they sometimes engaged in manual load shifting, and that they were "using when the sun was shining". In terms of having the appropriate overview and information about production and consumption, not all participants had successfully downloaded the app or familiarized themselves with the information web-portal. This indicated that information about electricity produced, sold, and consumed was of varying importance or interest to the participants.

In summary, from the standpoint of the grid operator, the somewhat modest ambitions to test equipment and learn about the impact on the grid was achieved, as they gained experience with PVs in the grid and learned that they would be able to manage it. From the point of view of the households, a full return on investment through self-consumption or sale of energy is not expected. This made the project mostly interesting for individuals who have motivations other than of the monetary kind (environmental, technical vanguard, etc.). Even so, the project managed to recruit a sufficient amount of people focusing on these motivations, and the demand for project participation was high.

Solution 2 – Household PV & Heat Pumps

Solution 2 was encountered in two of the MATCH cases. In the Smart Energi Hvaler (SEH) case, a collaboration involving the municipality, the local university college, and the energy company/DSO, had successfully deployed 3 kWp rooftop solar PV panels to about 100 households. 15 of them were interviewed for this study. A comprehensive marketing strategy involving strong elements of social interaction such as town hall meetings, information campaigns, and municipal as well as energy agency (ENOVA) funding led to a massive interest among the general population for acquiring solar PV, and subsequently aided recruitment strongly. Another factor was that the archipelago of Hvaler, where the demo was situated, had a rather weak connector to the mainland and a less than robust distribution grid, leading to a conceptual interest in self-reliance and localized production. This was effectively exploited in the recruitment effort. In addition, Hvaler is one of the first municipalities in Norway that have introduced capacity based tariffs (consumption is still based on monthly net energy metering), adding weight to the concept of keeping peak loads down by employing local micro-generation and self-consumption.

Households were provided access to a web application where production, consumption, sales of surplus, and peak loads could be monitored. Using smart plugs, consumption of individual appliances could be monitored in real-time. At the time of the study, intelligent demand-side management equipment was installed and had just started trial. This equipment added automated flexibility to boilers, heat pumps, and cooking stoves, to allow these appliances not to run concurrently on a neighbourhood scale (boilers), as well as within households (boilers, heat-pumps, and cooking stove). Unfortunately, the results of these efforts were not yet available at the time of this study, but initial findings suggested this would provide increased flexibility for the grid operator without having a large impact in the daily life of households. Even so, some end users reported they were already managing demand response manually, and some with systems integrated in their heat pumps or connected to panel ovens. This was due to the capacity-based grid tariff providing a strong incentive for avoiding large peak loads in the household. The data indicates rather strongly that most of the respondents have paid closer attention to their capacity outtake, and have engaged more strongly in time shifting practices. This is especially the case for laundry, cooking and – where applicable – car charging.

In addition to the support from ENOVA and the municipality (the latter on a limited, 30 person, first come, first serve basis), a feed-in tariff of about 80 øre (€0.08) made the deal for solar PV that was offered to households very lucrative. One kWh sold back to the grid was in rough market parity with a purchased kWh. A feed-in-tariff this strong is an expensive subsidy. As this study showed, the result gained with market parity of sold and purchased kWhs is that the market can function for the household as a form of storage; the funds received for selling a kWh can, with stable prices, be used to buy it back at a later time with no added cost. From the point of view of the customer, this is a great benefit. However, for the project owner it can be expensive to maintain. Furthermore, there is some indication that it dis-incentivises load-shifting. The tariff is guaranteed to be maintained throughout 2018, but are likely discontinued in the future. Consequences of such an action have not been examined in this project. Likely, it may make time shifting consumption practices more interesting and investing in solar panels slightly less interesting.

The Innovation Fur/GreenCom project also contained solutions configured by a combination of solar PV and heat pumps and, like SEH, the original Innovation Fur initiative gained much of its momentum from a strong and timely focus on face to face meetings with the public. This involved e.g. free energy consultation, involving local craft businesses, free courses on the pros and cons of different energy technologies and solutions, and several kinds of subsidies. In sum, the project was very much bottom up, rooted as it was in a local, citizen-led project called Branding Fur. GreenCom, part of Innovation Fur, is an EU-funded demonstration project using Fur as an international test area for smart grid development, aiming at balancing the local exchange of energy at the community micro grid level. The configurations relating to solution 2 in this project came from a pool of 33 households, 19 of which had home monitoring. 20 households had PVs installed and 11 of them were equipped with heat pumps, the sum total of households in this project with this specific solution (PV+heat pump). Heat pumps were equipped with HaaS-capability (Heat as a Service) and could be remotely controlled by the grid operator for gaining flexibility to the grid.

The home monitoring systems were largely ignored by households due to technical issues and ensuing disinterest. The HaaS capability had at the time of study only been taken for a calibration test run, which according to GreenCom successfully proved it could be used for load shaving to the amount of 1 kW of demand per household. However, due to the more than ample grid capacity already developed in the region, this load shaving was not implemented at the time of study. Measured in R&D goals from the point of view of the project owner (the local DSO), the solution combining solar PV and heat pumps was successful and more profitable than PV combined with batteries, due to their current cost. The households were happy with the solution, and reported they felt they had benefitted. Notably, many of the technologies they received were subsidized by the project. More general, the interviews with households with PVs on Fur (with/without heat pumps) showed that several households attempted to time shift some of their electricity consumption in order increase self-consumption (and save money); energy intensive appliances like dishwashers and washing machines were shifted to daylight hours, a shift which was connected to the hourly net metering scheme that households were subject to. Specifically, this was not related to the PV and heat pump combination, but to the PVs and the hourly net metering combination alone.

In summary of solution 2, evidence shows that applying automation for shifting demand of heavy use appliances so they avoid consuming at the same time seems providential, and this can also be used for having consumption concur with PV production. However, the incentive for time shifting and self-consumption can be lost if there is market parity of purchased and sold kWh. In a sense, this allows the market to function as “storage” capacity to the households, since revenue from sold surplus production could provide funds to purchase energy whenever it was in demand. However, the grid power tariffs and time-of-use pricing such as hourly net metering, incentivize load-shifting and makes households strive to keep peak loads lower than they otherwise would. The GreenCom case combined PVs with heat pumps as part of a Heat as a Service (HaaS) business model, remote controlling heat pumps to increase flexibility within present parameters. This solution was not ready at the time of study, but calibration data suggested this could prove quite successful seen from the perspective of the DSO.

Solution 3 – Household PV & Battery Storage

Solution 3 was encountered in Innovation Fur/GreenCom, Model Village Köstendorf, and the VLOTTE project. First of all, the GreenCom project had success with this solution, since the pilot showed that it was able to foster self-consumption greatly and reduce peak loads significantly (35-70%). However, because of batteries being expensive at this time, the solution was not profitable for either households or the DSO, nor for optimizing PV as a strategy for load management in general. Further, the interviews indicated that households with battery storage felt less engaged in time shifting their electricity consumption to optimize self-consumption; in this way, load shifting appears to be delegated to the battery storage.

Model Village Köstendorf was another venue in this study that included solution 3. Even though much of this project's success was associated with high levels of social interaction as well as strong public awareness efforts, the 43 buildings in this cluster provided with PVs notably also received subsidies from the federal state of Salzburg. Of these, 40 houses had PVs, a central Building Energy Agent, and smart meters installed. At a later stage, some of the houses were fitted with batteries. One house, the 100 % renewable case, had batteries and heat pumps in addition to PVs. One goal of the project was to manage the intermittent loads caused by such configurations, and to evaluate a newly installed controllable transformer. The hypothesis was that the old transformer could not handle the intermittency, and so, part of this project was to gauge if other areas in Salzburg with increased shares of local micro-generation needed to be upgraded with a phase controllable transformer as well. Rated as a success, the project revealed it was not necessary to have expensive, transformer-based phase shifting control as the localized inverters of every PV equipped household could take measures to make sure phase shifting at transformer level would not be necessary for stability in the grid. The success proved viable enough to work as regional grid standard for the entirety of Salzburg, proving it was ready for more PV in the future.

Success in terms of the householders were achieved partially due to strong social interactive elements as well as subsidies. Household time shifting appeared more as a side effect, with positive results for the grid. The project concluded, based on these findings, that it would be possible to double the local grid capacity at half the cost. In general, the project provided Köstendorf with much positive publicity, and the village could even reopen the local pub as there was a significant increase in energy-related visits to learn from the pilot. In Köstendorf, people appreciated that they were producing and using their own energy. Their reduced energy bill, due to self-consumption of the generated electricity, gave them a sense of self-reliance and autonomy, even if they were still dependent on a grid connection.

The VLOTTE project, while focused mainly on E-mobility, featured solution 3 in a two-family smart energy trial household. The test user in this case was an affiliated user, as the man in charge of this two-house smart energy trial was employed by the project owner at the time. The main goal was to gain practical experience with a PV system (5.1 kWp), a battery (10 kWh), and an EV in a realistic use environment. The results indicated a strong increase in own electricity consumption. Before batteries were installed, households consumed 15% of PV production. After installing batteries, this number was increased to 40%, while measurements in summer periods were as high as 98%. These numbers were achieved without any significant focus on practice change in terms of load shifting.

In summary, incorporating PV in the grid on a vast scale is achievable without the need for voltage control at transformer level, as this can be managed by solar PV inverters at the level of households. Furthermore, in the cases featuring PV and batteries, the results proved that batteries are extremely helpful for increasing capacity in the grid and helping households consume own production without adding a burden of manually shifting away loads from peak hours. However, as in the case of GreenCom, even though batteries are useful for increasing household flexibility, the cost of batteries at this time makes them an expensive way of achieving this goal.

Solution 4 – Large scale PV & Storage/Heat Pumps

Solution 4 was encountered in the Rosa Zukunft project. It is one of the more prominent projects of its kind in Austria and has a status as a pioneer in the building and scientific communities. In the context of this study, the findings reveal both successes and some failures with what was tested. The relevant configuration to this solution found in the project is the building-to-grid element, consisting of 8 buildings with a total of 129 apartment units, a rooftop PV system (72 kWp), a large water boiler (90 m^3), a heat pump, and a biogas-powered CHP unit. The system is managed by a central control system called the Building Energy Agent (BEA) which, aided by smart meter and data aggregation, undertakes demand side management and system optimization to reduce load peaks. This system was highly successful, but also very cost intensive, since it required a high level of electrical engineering and IT competencies.

Notably, the building operators necessary for the operation of this system is an example of the category of affiliated users. Conversely, the system has no conditions for involving any kind of active user apart from the affiliated ones, as all aspects are fully automated. With regard to the generation through PV, some users showed a sense of ownership to the “home-grown” energy produced on the projects premises. Although the PV installation and its production were solely owned by the ESCO, users felt betrayed that they did not share the earnings from “their” energy. In that sense, the users did not feel self-reliant with regard to their energy use, but were clearly aware that they were dependent upon the involved energy company. The integration of generation and storage was very successful from a technical point of view and provided the involved initiators of the trial with useful information for future development. Conversely, users felt disconnected from the installed capabilities that they perceived as only beneficial to the ESCO, due to a lack of ownership.

However, 33 of the 129 apartments were chosen to be included in a demand response program, and given special displays, gauges and switches. One way of conveying information about conditions in the grid to end users were by a so called “traffic light” system, which indicated at which times consumption would occur off peak. On top of this, a variable tariff was introduced, incentivizing load shifting. This part of the project would test a hypothesis that active participation from end users could be expected with favourable conditions (i.e. financial remunerations for time shifting). These expectations were not met as most people were unable to time shift any of their activities. This was made particularly difficult by the dynamic and unpredictable nature of this Time-of-Use pricing scheme. The ones that did time shift thought of the resulting savings at the end of the year as not sufficient enough to weight up for the added effort of time shifting. In the end, most of the end users wanted the project owner to remove the in-home display solutions altogether at the end of the project. The trials were instructive about the potential for time shifting in the case of apartment time shifting and the use of energy advice, which were also applied in this context and which did prove to be successful.

4.1.3 Discussion of critical factors and common patterns

Characteristic of all solutions described in this chapter has been the importance of anchoring of project in local context. Solutions 1 showcased a simple PV roll out, and its success was largely the result of a rather strong demand from local customers to make it possible for the grid operator to accommodate solar PV in the grid. The pilots of both companies were customer driven to begin with, and the projects were started in due to the necessity perceived by the energy companies/DSOs in question to gather knowledge about the impact of increased local micro-generation on the grid.

In the case of solution 2, featuring the Hvaler case and the GreenCom case, both projects had committed to a strong local anchoring of the project, involving a broad set of varied actors on the local level. Hvaler had an issue relating to its weak distribution grid, posing special challenges which was successfully leveraged in enrolling the public. In the case of GreenCom the grid was strong, but the project successfully borrowed driving force from the already ongoing Branding Fur project, which later turned into the Innovation Fur project. In both cases, local people, craftsmen, political leadership, key people in the municipality organization, and knowledge institutions were involved, in addition to the local energy industry actors.

Solution 3 featured VLOTTE and Köstendorf in addition to GreenCom. Similarly to GreenCom, Köstendorf had its renewable energy projects spring out of an effort to counter a trend of depopulation and economic stagnation. Rebranding and attracting renewable energy business was successful enough to among other things re-open the local pub and proves that local anchoring of a project does not necessarily need to connect directly to energy related issues. Even so, much of the success was due to energy consciousness of the local public, which lent itself to being translated into positive action, contributing enthusiasm and to the good will existing towards the project. The VLOTTE case was less dependent on local contextual support, since it was a company and could rely on line management to ensure participant engagement in the project. Even so, the efforts they made were met with enthusiasm by local clients and customers, as well as employees.

For solution 4, at Rosa Zukunft, the overall project was well connected to the already established programs within the region of Salzburg. Here, many policy makers and connected stakeholders showed long-term commitment to co-creating and designing new energy solutions. However, the community of residents in the housing complex did not grow organically over time, but came together through the creation of the project. Thus, ready-made solutions were inserted, which left users with limited agency over the scope of the project, leading to a perceived lack of ownership. Nonetheless, their participation in the trial was only temporarily required and yielded valuable information on smart grids for the involved stakeholder institutions.

Another critical factor seems to relate to subsidies and monetary remuneration, both of which undoubtedly govern the choices of pilot end use participation. In the case of solution 1 and the PV projects in Trøndelag, all households were given subsidies by the Norwegian Energy Authorities (ENOVA) for purchase of solar PV. Another example is the plus customer agreement, which the government has mandated grid operators to provide, making it possible to sell own production back to grid at spot prices. Furthermore, there was in the case of solution 2 and SEH the effects of feed-in-tariffs, which were effective but expensive.

In the case of GreenCom (solution 2 and 3), the participants acquired the tested technologies (PVs, heat pump and home battery) with a significant subsidy from the project, which was funded by EU (FP7) and a national energy R&D program. Also, the households got an indirect subsidy through the Danish hourly net metering schemes for prosumers, which means that electricity customers will not pay tax, VAT or net tariff of the electricity the household consumes within the hour of production. This represents about 24 eurocents/kWh of the total customer electricity price of about 28 eurocents/kWh. Finally, households get a fixed price (feed-in tariff) of 5 eurocent/kWh for surplus electricity supplied to the grid, which is about twice the market price of electricity.

In the case of the model Village Köstendorf and the Rosa Zukunft Project, both are part of the Smart Grid Energy Region Salzburg (SGMS) and received direct funding from several federal governmental (e.g. Neue Energien 2020 program of the Climate and Energy Fund) sources. They are co-created with several stakeholders from the sectors energy, housing, and industry, accompanied by consulting and research partners. In addition, the model village Köstendorf received direct funding from the state of Salzburg. The project Rosa Zukunft received indirect funding by the state through adjustment of public housing support schemes to fit the project.

Economic incentives through different types of Time-of-Use (ToU) pricing and capacity-based tariffs are present in many of the cases, except solution 1 where there was monthly net metering. In the case of Solution 2, Smart Energy Hvaler had ToU pricing and capacity-based grid tariffs, whereas GreenCom presented hourly net metering (making it economically attractive to increase self-consumption). Solutions 3 and 4, consisting of PV, storage and heat pumps, also had hourly net metering schemes. In all events, ToU-pricing proved somewhat effective for incentivizing time shifting of (in particular semi-automated) energy-intensive practices like laundering, dish washing, and car charging. In the case of Rosa Zukunft, however, ToU-incentives were experienced as inadequate to efforts made towards load shifting. This was indicated by the fact that even those most eagerly attempting to load shift were rewarded with very small savings. The reason for this might be the general fact that apartments often have few appliances installed and offer little leverage to load shift.

Based on the comparison of the ToU solutions, several analytical observations can be made regarding the role of economic incentives (price) in promoting load shifting in households. First, ToU pricing (including capacity-based tariffs) does have a positive influence on households' engagement in time shifting consumption, and the size of the price spread between lowest and highest price is important. However, the specific impact of price-incentives on households' active engagement in load shifting is dependent on a wide range of other (non-economic) elements in the socio-technical configuration, in particular: a) micro-generation appears to help make the local power production more "visible" to households and in this way promote engagement in load shifting; b) dynamic ToU pricing schemes with unpredictable prices are in general refused by households as too difficult to adapt to; c) trust in and the framing of the schemes are important (e.g. distrust in the energy company disengaged participants in Rosa Zukunft, while the local anchoring appeared as a productive framing in SEH and GreenCom; d) because of physical proximity to neighbours, households in apartment buildings have difficulties with time shifting consumption to night hours due to problems of noise.

4.1.4 Conclusion

In general, a high degree of social interaction, learning, and exploitation of issues in local context contributed to the viability of piloting the solutions described in the above. The projects that were most successful were the ones having made extensive and varied recruitment efforts consistent with aspects of social learning. Town hall meetings, involving different user groups (households, craftspeople, businesses, etc), education and information campaigns were all useful for both recruitment and teaching people about the benefits of time shifting (and how to avoid expensive peak loads!). Active participation and a positive judgment of the overall project could be seen in projects like model Village Köstendorf, GreenCom and SEH, where users felt a sense of ownership with the project. They identified with the project aim or the larger vision of energy transition behind it. Coming from a different angle, the results from Rosa Zukunft show that a sense of ownership was still felt even if the direct identification with the project was missing. In this case, users felt left out by the ESCO.

4.2 Renewable powered company fleet as a smart energy solution

4.2.1 Introduction

In this chapter, we compare two company driven projects with a focus on the development of solutions to convert vehicle fleets to renewable energy sources. In both cases the activities are in-house developments aiming first of all at the companies' own needs. However, at the same time both activities can be characterized as mission-oriented innovation, as they aim to contribute to a decarbonized transport sector in general. In the VLOTTE project a regional Austrian ESCO together with an associated DSO develops a smart e-car park as part of their own e-vehicle fleet; in the ASKO case a large grocery wholesaler from Norway establishes a hydrogen infrastructure for a hydrogen-powered fleet of heavy-duty delivery trucks and fork lifts. In addition to a similar thematic mission of the projects, there is another interesting common feature: In both cases, we are dealing with companies that have transformed their relation to and participation in the transport system as an outcome of the project.

In the case of ASKO, the current development is part of a broadly stated mission from the company and company owners to reduce the CO_2-imprint of the grocery sector at large. Additionally, being able to deliver groceries without emitting CO_2 is arguably a competitive advantage. The project we study started with a large rooftop PV-system that led to the idea for an economically and ecologically meaningful use of the excess energy from abundant sunlight during the summer season. The idea of using hydrogen came from a parallel small-scale project with positive experiences. Not only may the conversion of excess solar power into hydrogen fuel solve the problem of seasonal PV production fluctuations, but by producing their own emission free fuel ASKO are transforming their role in the transport system as well as the grocery sector. Similarly, in the VLOTTE project the concept for a smart e-car park is well embedded in the larger VLOTTE context of building a model region for e-mobility in the whole province. The main challenge in this case was the integration of a rooftop photovoltaic system and to develop the car park without additional investment in the expansion of the grid connection – a restriction set by the project owner to provide for realistic framework conditions form the outset.

In this cluster of solutions our main focus of analysis is on innovation processes, the various activities leading to working solutions. While the e-car park is already in use and vehicles are partly replaced by electric ones, the process to establish a company internal hydrogen infrastructure is still in a much earlier phase of development. Nevertheless, these two solutions are well-suited for a direct comparison as they deal with similar objectives and apply similar innovation strategies.

4.2.2 Outstanding qualities of the selected solutions

In this section we briefly recapitulate the specific features for the selected solutions. We address the question of why and by whom these solutions are described as a ‘success’, what the solution is contributing to and what actually works and for whom. In the first part, a short characterization of each solution is presented. In the second part, we directly compare both solutions and discuss critical factors, similarities and differences.

VLOTTE – e-car park

The smart e-car park started as a demo project and was already in regular operation at the time of our interviews. It is owned, operated and used by the company and continuously further developed. The technological elements are a multi-storey car park with rooftop PV, a converter, a stationary battery, smart wall boxes, a standard grid connection and an electronic reservation system. The project started in 2016 – at that time only the car park and the PV system existed. Since 2017 every employee can book a car online. Today, short distances are almost exclusively driven with e-vehicles. The mobility department of the company manages 600 car registration numbers. At two of their sites they have 60 vehicles at their disposal of which 18 vehicles are electric. By now, the amount of bookings of e-vehicles is similar to the bookings of standard vehicles. The range of the e-vehicles in use is roughly 250 km and this is sufficient for 80 % of the routes taken. When an e-vehicle is returned, it gets charged immediately. If several vehicles are charged simultaneously, the available power is distributed among them.

A well-working reservation system is key to the practicability of the solution. The now used booking system is the result of a longer development process. It is a significant improvement compared to the previous system as it makes the booking process transparent. Earlier, a standard software calendar with limited functionality was used. In this early phase, when a vehicle was not used it still was blocked if no one cancelled the reservation. The added transparency in the new system contributed to the reduction of range anxiety among the users as well. The latest solution is well accepted among the employees according to interviewees, though so far the cars in the system are mostly used for short distances. In the beginning, there were some minor software issues, which were solved within the first year of operation, but besides that no difficulties have been reported. The e-vehicles are sufficiently charged when needed, no vehicle shortages were reported, and no one has complained about range problems or the like. The overall goal was described by one of the interviewees as aiming at providing an easy-going solution for everyone. In their opinion, there is no need to be an electrician or to know how the systems actually work. E-mobility in the VLOTTE project means simply getting into the car and driving.

The solution is 'smart' which means it is energy efficient, infrastructure efficient and it uses renewable power from the rooftop PV. The rooftop PV was installed during an earlier VLOTTE project phase and is now embedded in the daily business, which means that the generated energy is used for the car park and excess energy is stored in the stationary battery or supplied to the grid. Also, the configuration is economically efficient as no additional grid investments were needed (providing for a stronger connection to the transformer). The internal load management using the smart wall boxes works well, ensuring the fair distribution of power among the e-vehicles while charged. This made the use of the existing infrastructure possible without the threat of short circuits, and the costs of the system operation can be maintained at a low level. In addition, it helps to charge a large number of EVs efficiently. 18 e-vehicles are charged in the car park and only if they are being charged simultaneously, the capacity of the supply cable would be exceeded. As the current car battery status is fed in the booking system, the load management can lower the power at which the e-vehicle is charged. In practice this means that the software is telling the e-vehicle that charging with 22kW is unnecessary and for instance 20kW or less should be enough. So, in this middle range car park a limited supply of power is fairly distributed, which is a remarkable achievement. For the future, the project managers plan to prioritize the loading processes in line with reservations already received. This should lead to an even better utilization of the existing infrastructure as certain vehicles can be addressed specifically.

The solution is comprehensive as it involves several technical and social elements that fit together well. In 2016, the head of the car park department decided to switch to an online booking system, which made the implementation of e-mobility easier. On the one hand, the booking of vehicles then became transparent while on the other hand the booking system could assign e-vehicles for short distances automatically. When an employee is booking a vehicle for a short distance, the system automatically assigns an e-vehicle. In the beginning, educational work had to be carried out as some employees did not feel comfortable using an e-vehicle. For the car park department leader it was a personal matter to convince the employees of the usability of e-mobility. Also, the positive reputation of the VLOTTE project in the federal state supported the action of the car park department as the positive responses from the public and the overall success of the pilot project convinced the employees of the applicability of e-mobility in daily life and business.

The solution is still in development but already used as a showcase and part of the consulting portfolio of the company. The head of the mobility department maintained that they were planning to increase the variety of e-vehicles. At the time of the interview in 2017, only Renault Zoes were part of the fleet. If other EV models will be integrated in the fleet, the load management is faced with new challenges as every vehicle model is charged differently. The person responsible for the IT solutions of the car park and load management said, that they are working on integrating different vehicle models in the charging system. Also, the booking system optimises the fleet with a CO_2-factor of the standard vehicles, so only the most efficient vehicles are in regular use. The vehicles with the highest CO_2-factor are exchanged for electric ones. The car park is used as a testing site, but is already in daily use. Besides that it also works as a showcase for potential customers. One interviewee said that there are more such sites in planning. The ESCO often develops unique solutions for customers (in other areas), so a potential customer can call the ESCO, tell them their demands and then a solution is developed. The solution developed for the company's own needs then serves as a reference model and know-how carrier.

ASKO – hydrogen-powered fleet

A 9000 m^2 rooftop PV system was installed and operates at a peak production of 1 MW. An electrolyser was acquired for the production of hydrogen fuel cells from solar power. The interest of the company in hydrogen production emerged from a pilot project where small fuel cells were tested to power distribution truck cooling systems and lifts, reducing the need for idling during urban grocery deliveries. The development of an on-site hydrogen production and distribution infrastructure was accomplished together with the research institute SINTEF, and a production and filling station was recently opened and works as planned. Ten hydrogen forklifts and one hydrogen truck will be delivered later this year (2018) and the plan is to have 30 hydrogen fuelled distribution trucks by 2023. The main technical elements are the large rooftop PV, the electrolyser (off-the shelf), two filling stations (350 + 700 bar), the hydrogen powered trucks, and hydrogen powered forklifts. The solution has the following main qualities:

The first quality of the solution is that it works in a real world context. The case is still unfolding and under development, but the aspects of the project that have materialised are working. While this is a pilot project – similar to the VLOTTE case – it is also part of the real ASKO corporate economy; and ASKO expects to invest at least €7 million in the project. The solar panels currently produce an equivalent of 20-25 % of the electricity used at ASKO Midt-Norge’s storage facilities. The electrolyser and hydrogen filling station have been opened, but as we write this report, the first delivery truck has not yet been received from Scania. However, Scania is an actor from the traditional car-manufacturing regime, which has been described in the past as conservative and difficult to change (Geels et al. 2011). Their involvement here can be interpreted as an incremental innovation step, primarily driven by ASKOs work. Company employees seem to have accepted and embraced the solution, and they are proud of working for a company that acts with a technological impetus on environmental challenges. Since we conducted our fieldwork, it has also become clear that the solution has become part of the ‘real world’ as it was reported on extensively in local, national and, to a certain extent, international media. Through this, the pilot has become somewhat of a showcase and is part of producing new expectations for renewables and hydrogen, highlighted as important in sustainability transitions literature (e.g. Bakker, Maat and van Wee 2014).

The second quality of the solution is that it is both renewable and ‘smart’. Renewable electricity is generated from solar panels. ASKO has a high demand for electricity because of their large cold storage facilities. The ‘smartness’ in this case, lies in combining solar power production with electrolysis to produce hydrogen, and fuel cells to cater for the company’s main expenditure, its transportation demand. Thus, the solution brings a relatively new element to the notion of balancing supply and demand, as it does not only provide balance to the electricity grid but also leverages the demand for transportation services to balance the production of electricity. These dynamics of balancing across time and sectors is strengthened by the fact that solar production is high in Norway during summer months, and lower during the dark winter months.

This suggests that, as in the VLOTTE case, the solution is comprehensive. It involves implementing and shifting technologies across domains (trucks, forklifts, solar cells, electrolysis), which means that the solution 'produces' a series of new technology users (drivers, operators, maintenance personnel, the company itself), and re-configures work processes and modes of organization, in grocery wholesales, transportation, fuel supply and electricity generation. Beyond this, the solution feeds into an even more comprehensive strategy where ASKO works broadly to advance a sustainable agenda.

Table 8. Main characteristics of the two solutions

	VLOTTE	**ASKO**
Renewable	Uses renewable power from rooftop PV	Renewable electricity is generated from solar panels
Smart	Energy & infrastructure efficient	Combines solar power production with electrolysis to produce hydrogen
Comprehensive	Involves several technical & social elements that fit together well	Involves implementing & shifting technologies across domains & produces a series of new technology users
Development status	Still in development, but already used as a showcase	Works in real world context, but still unfolding & under development. Used as a showcase

4.2.3 Discussion of critical factors and common patterns

The ASKO and the VLOTTE solutions were arguably enabled by a set of critical factors. Some of these enabled the start-up of the project, while others have been more important for sustaining momentum within the project and to ensure that the solution continues to 'work' under real-life conditions. The discussion below does not entail a ranking of the factors in terms of importance and not all characteristics apply to every solution.

Supportive political context

The sustainability transition literature has long recognized the importance of political context for innovation endeavours (e.g. Smith, Stirling and Berkhout 2005), and for ensuring that solutions are accepted and promoted by political actors and market actors (e.g. Wüstenhagen et al. 2007). Both studies strengthen such assertions, highlighting the importance of a supportive political context. In the VLOTTE project, the idea to bring e-mobility to Vorarlberg was developed by a local consulting company, but illwerke vkw handed the project proposal in. The origin of the idea goes back to 2007 when the consulting company had the idea to bring 100 e-vehicles on the streets of Vorarlberg. In 2008 this was picked up again when the first call of the e-mobility model region program of the energy and climate fund provided the perfect opportunity for the project. The federal government and the ESCO commissioned the consulting company to write the proposal, but the responsibility was with the ESCO. This was due to the limited opportunities for action of the consulting company. The ESCO and DSO are to 95.5 % in public hand and as renewable energy was a major part of the call, it was decided that the ESCO handled the project. Vorarlberg pursues the strategy to become energy autonomous by 2050. For the relevant stakeholders in the federal state, renewable energy and e-mobility go hand in hand. Therefore e-mobility is an essential aspect of the state's energy strategy. As the experiences with the e-mobility model region and the VLOTTE project were positive, the government wants to build on that with further development of e-mobility. One of the respondents named the energy strategy also as an important aspect of the ESCO's engagement in the VLOTTE project.

In comparison, the ASKO solution also has been part of a supportive regime, in which both the political and organizational context has been vital for realizing the project. In terms of funding, the project received around €1.8 million from the Norwegian energy authorities, ENOVA, which is substantial in the context of a €7 million investment. Further, Norwegian regulations state that if an electricity production facility produces more than 100 kW at any time, it is legally defined as a power plant. This opens the door to a series of potential regulatory and bureaucratic issues dealing with fees and taxes on the power production, but due to special circumstances, ASKO was exempt from this rule, allowing them to exceed the production limit and still be considered and treated as a plus-customer in the grid. Just as important as these considerations is the sort of protection that this and similar projects receive within the corporate structure of ASKO itself, by benefitting of its ownership and the comprehensive strategy of promoting sustainability as discussed earlier in this report. The board of managers has explicitly stated they expect a significantly lower and slower return on investments in the case of environmentally or climate oriented projects, indicating a long-term position on this project. Thus, the development of solar panels, electrolysis and the hydrogen trucks and lorries have been subject to economic care and nurture both from external and internal sources.

In sum, this discussion points to the importance of a supportive socio-political context. On the one hand, this is related to the shielding or nurturing provided by formal political bodies external to the companies, which allows the project operators to take on risks that they might otherwise not have done. On the other hand, the discussion highlights the need to consider politics and policies as broader phenomena than those provided by such external bodies, also keeping an eye on the political work of the involved entrepreneurs and organizations.

Pre-existing resources/competence building in the region

There have been calls in the sustainability transitions literature for a better understanding of the role of space in transitions oriented innovation (STRN 2017). Our two cases analysed here, provide insights about the importance of pre-existing, locally embedded competence. After the VLOTTE project phase ended in 2011 the ESCO participated in several research projects as well as EU projects. In one of these projects the *"Mobilitätszentrale"* (mobility centre) was developed. The *Mobilitätszentrale* was funded in the 2012 e-mobility model region call of the Climate and Energy Fund of Austria. It is part of VLOTTE and an e-mobility information hub which serves as a service provider for potential customers interested in e-mobility. Before the *Mobilitätszentrale* was established, there were still reservations towards e-mobility and the *Mobilitätszentrale* is seen as a tool to reduce those reservations. Due to the success of this centre, illwerke vkw was invited to participate in two EU research projects. The establishment of the *Mobilitätszentrale* can be seen as the implementation of services that vkw had been offering before, but are now being offered centrally. This means, people interested in e-mobility only need to contact the *Mobilitätszentrale* and get services from different actors such as car dealers, electricians and others that are needed when switching to e-mobility. It functions as a central network node, maintaining contact with other actors is crucial. Therefore car dealers, electricians and other important people are contacted regularly. With the *Mobilitätszentrale* the complexity of the topic e-mobility is bundled in one place. By 2017, VLOTTE cooperates with research centres such as the Technical University of Vienna or the FH Vorarlberg. At the FH Vorarlberg an endowed chair is sponsored by illwerke vkw. Students from colleges and universities get the chance to round out their theoretical knowledge with work experience through summer or part time jobs. There is also the opportunity to write a bachelor or master thesis at the ESCO.

Similarly to VLOTTE, the geographical and organizational position of the company ASKO in knowledge and technology intensive networks of innovation and manufacturing is important. ASKO Midt-Norge is located in the same town as the key Norwegian research and innovation community that has been researching and promoting the hydrogen economy for a long time, arguably through what Callon (1986) has called translation (see Arnøy 2012 for an extensive analysis). These researchers convinced ASKO to become part of a small-scale project where hydrogen was tested to operate lifts and cooling systems on trucks, and thus replace the need to idle diesel engines in urban areas during deliveries. These small-scale hydrogen tests were essential in convincing ASKO that hydrogen could provide a potentially viable innovation pathway in a broader way. Once ASKO had been convinced of this, other elements of their pre-existing network enabled the project to unfold. At first, it was quite difficult for ASKO to convince any of the traditional car manufacturing companies that hydrogen powered trucks were viable in the short term. In the end, this was enabled by a long-term and trusting customer relationship with Scania, with whom they had previously worked on customization of other low-emission vehicles for close to a decade. Thus, networks of competence and trust, which on the one hand worked to pull ASKO in one direction, and on the other hand, ASKO could push in one direction, were critical factors enabling and sustaining the project. The case also illustrates the importance of geographical location to innovation and transition dynamics, for which the literature has called for more focus (STRN 2017).

Seen together, our two cases illustrate that knowledge intensive innovation benefits from being closely located in space and time to related initiatives, projects and communities. At the same time, they illustrate that closeness in itself is not sufficient to advance innovation, but that the success of the projects depend on their ability to become part of it.

Corporate culture as innovation driver

Tellis et al. (2009) have identified corporate culture as a significant driver of innovation within firms. In the innovation department attitudes and practices are different to other departments. In both cases analysed here, this appears as a central enabler of transformative action. We see VLOTTE and the *Mobilitätszentrale*, which is the locality of VLOTTE, as the innovation department of the ESCO. In corporate culture three mindsets are crucial for innovation: the willingness to sacrifice profit, foresight, and toleration of ventures (ibid.). These three mindsets can be found in the e-mobility department of the ESCO. The ESCO is taking the risk of venturing into an unknown business field such as e-mobility. The ESCO started investing in e-mobility when it was in an experimental phase and no production vehicles were available. The ESCO is acting long term as e-mobility is seen as the future and decentralised energy generation will become more important. The setup of new small hydroelectric power plants was an essential part of the first call of the e-mobility model region. What is also contributing to the success is the size of the team, which is small and tight knit. The e-mobility department has five employees and several interns. Before the VLOTTE and the EU project no one really knew how e-mobility worked and what kind of implications it will have regarding the electricity grid or how potential customers will react towards e-mobility, if they would accept or reject the new technology. Even though the employees of the e-mobility department were optimistic, the project results exceeded their expectations. On one hand, more people were interested in switching to e-mobility than was expected and on the other the development of the technology accelerated. One interviewee said that in 2008, when the proposal was written, there were only converted e-vehicles. These vehicles were Fiat 500 and Think C!ty models, that used to be combustion vehicles but were transformed to e-vehicles with ZEBRA batteries. By 2017, different production vehicles and e-mobility was about to become mainstream. In general, every member of the team is dedicated to e-mobility, uses it privately and knows what kind of issues are being faced by customers on a day to day basis. Flat hierarchies are an important part of the success and the creativity that is used when developing new products. Also, in the VLOTTE team staff from both the DSO and the ESCO works together in this informal cooperation.

In extension of the first point made, is the importance of the culture within ASKO and Norgesgruppen (the owner of ASKO) when it comes to promoting environmental solutions more broadly. Their role can be understood as that of an intermediary, or 'middle actor' (e.g. Janda 2014), that actively works not only to adopt and implement new technologies, but also to promote changes in the framework conditions for these socio-technical solutions. Both ASKO and Norgesgruppen do this by promoting environmentally oriented lifestyle choices amongst employees, and among other things lobbying the government for stricter procurement rules and for beneficial conditions promoting a hydrogen fuelled transport sector. Hence, one might also argue that they are part of co-producing (Jasanoff 2005) both projects and favourable conditions for these projects in Norway. A different way of looking at this factor could be to highlight that what we observed here is actually an instance of the kind of 'social acceptance' that some scholars have called (e.g. Wüstenhagen et al. 2007; Wolsink 2012; Devine-Wright et al. 2017) market acceptance. This concept suggests that 'social acceptance' (of solutions to the climate challenge) is not something that should be limited to the study of 'end users', but that the acceptance of political actors and market actors is an equally important factor explaining the proliferation of working solutions. These points can also be found in the VLOTTE solution as several interviewees stressed the importance of becoming a "green company". The educational programmes carried out by the transport department also includes telling new employees about alternative transport modes for daily commute such as cycling.

Both companies are innovation-friendly and actively support environmentally oriented lifestyle choices among their employees but foremost see it as a leading culture of the firm. Social acceptance is key and with ensuring that employees accept the changes the companies are fostering their credibility to the outside.

External know-how and expertise to solve certain bottlenecks

For overcoming certain bottlenecks external know-how was employed. Illwerke vkw does not develop hardware or software, but buys necessary tools from external service contractors. The software solution for the wallboxes and the load management is external. Also, the wallboxes are bought from certain product developers. There are different kinds of wallboxes on the market and the ESCO buys the model that is best for their needs. One of the interviewees said that biddings are announced on a regular basis for different kinds of needs and products. Furthermore, the existing cooperation with universities and colleges is used to experiment and to solve specific problems. One such case was the experiment with old ZEBRA batteries that are now in use as a stationary battery in the car park. At the time of the interview in 2017 the battery did not have a significant impact, but the experiment is a first stage of further development.

The company as user-innovator

Recent developments in the sustainability transition literature have argued strongly that one should consider the role of technology users in new ways. Users, however, do not only passively 'accept' solutions produced by others; they sometimes innovate on their own by producing solutions that they will use themselves (Schot et al 2016; Chilvers, Pallett and Hargreaves 2018). This is the situation in both our cases, where industrial users act as both a developer of the solution and user of the solution (although there is a division of labour within the company). In the VLOTTE case, the demand for the development of the concept of the car park was ordered by the fleet management department of the company and therefore was an internal order. Here, the company functions as a 'user-innovator' and benefits directly by using their own product. In the case of illwerke vkw it is the need of lowering the CO_2-emissions of the fleet and also the need of charging the electric fleet without having to expand the supply cable. The ESCO innovates a smart car park that makes the efficient charging of the e-fleet possible, involves the rooftop PV, which is also a prototype for a product.

In the ASKO-case, the user innovation mainly consisted of assembling ready-made technologies in a new way on their own property. Solar PV, the electrolyser and the filling station are all existing technologies; the novelty lies in assembling them around and within ASKO as a user of the newly assembled solution.

Real use-case with real end-users

A key debate in the transitions literature deals with how one can move solutions out of demonstration and pilot settings, how to scale up to broader societal settings (e.g. Naber, Raven and Kouw 2017). Our cases are already active, beyond pure pilot, embedded in broader societal processes. The staff of the e-mobility department of the ESCO uses e-mobility in daily business and some of them, such as the product manager, also in their private life. Therefore immediate feedback is available. Furthermore, when an employee returns the e-vehicle to the car park, difficulties have to be communicated immediately, and users do so via the booking system. This makes dealing with problems easier as there is no need to manually handle these problems as they are centrally processed via the booking system. That the staff of the e-mobility department are users also helps with the development of products and new product developments are discussed in the team. Sometimes aspects such as the price or certain conditions that present themselves are a matter of discussion as the developers are also private users and not just employees that use e-mobility in a business context. Also, this private use makes it possible to realise needs or difficulties. This means that team members get the opportunity to voice their needs or difficulties, and solutions are found with the help of the team. These solutions can later present themselves as beneficial for customers. This innovative process only works because employees are given liberties by the company to be creative in their job.

In a similar way, the ASKO solution works, in part because ASKO is a real-world technology user, who, as noted, works as a user-innovator' (Schot et al. 2016). ASKO does not produce any new technologies, their innovation mainly lies in assembling existing and ready-made technologies which have traditionally catered for different domains (electricity production and transport), and to put them together in a new context. ASKO is a company for which the demand for transportation services is high, since transportation is in effect what they do. Thus, they assemble technologies in a new way, with the intention of using these technologies themselves.

Table 9. Critical factors and common patterns

	VLOTTE	**ASKO**
Supportive political context	ESCO & DSO are to 95.5% in public hand. Public funding by federal government	ENOVA funded the project ASKO is treated as a plus-customer in the grid
Pre-existing resources and competence building in the region	Establishment & further development of the *Mobilitätszentrale*	Close connection to Norwegian research & innovation community
Corporate culture as innovation driver	Foresight, willing to sacrifice profit & toleration of venture	Promote environmentally oriented lifestyle choices Promote changes in the framework conditions
External know-how & expertise to solve certain bottlenecks	Necessary tools are bought from external service contractors	Cooperation with Scania
The company as user-innovator	Industrial user acts as developer & user of innovation	Industrial user acts as developer & user of innovation
Real use-case with real end-users	Part of daily business & also used as showcase	Assemble technology in a new way with intention of using themselves

4.2.4 Conclusion

This analysis had the main purpose of working out certain factors and patterns of the solutions that enabled their success. Here, the similarities of the solutions shall be summarised to stress the important factors of this cluster. The supportive political context was crucial for both solutions and the company's politics are also numbered among this point. Pre-existing resources and competence building in the region likewise contributed in both cases. For VLOTTE it was on one side the early success of the project, but also the network of research and university institutes. For ASKO it was the intensive networks of innovation and manufacturing that helped. Another point that was already touched on lightly in the first paragraph was the corporate culture that functioned as an innovation driver. The ESCO of VLOTTE did not shy away from venturing in an unknown business field as well as ASKO sees the promotion of an environmental solution and wants to promote changes in the framework conditions for such socio-technical solutions. Furthermore, both are real cases with real end-users, which is a key factor. In VLOTTE real life conditions helped to validate first ideas and to check if employees personally would be willing to accept prices and/or conditions. Also, this point works together with the companies both being user-innovators who benefit of their own inventions.

4.3 Comprehensive energy concepts

4.3.1 Introduction

This cluster includes solutions that are part of comprehensive and often community-based energy concepts with the overall attempt of achieving energy savings and/or increase the use of local renewable energy production through integrating several and diverse energy solutions (renewable energy, energy savings, demand-side management etc.). Although the individual characteristics of the studied solutions (cases) are strongly dependent on the local contexts, the analysis aims at identifying key similarities and differences between the individual cases and solutions. Even though to various degrees, all solutions in this cluster share the characteristic that they are elements in ambitious community-led transition strategies covering a specific locality (e.g. an island, a village or a region). In addition, the transition strategies typically involve a wide range of different initiatives as well as multiple actors and technologies that interconnect within the different contextual settings.

The selected cases and socio-technical configurations are: Model Village Köstendorf (focusing on homeowners in small residential buildings, including single-family homes), Rosa Zukunft (solutions targeted apartment buildings), Renewable Energy Island Samsø (in this study with a specific focus on initiatives targeted local businesses, including supermarkets), and Project Zero (in this study focusing on initiatives targeted homes, sport centres and supermarkets). In other words, the selected cases and socio-technical configurations all focus on creating a comprehensive energy transition within a specific geographical locality or region, but differ with regard to the type of users in focus (homeowners, residents in apartment buildings, local business/shops and sports centres) as well as to the specific mix of energy solutions applied.

Both the Model Village Köstendorf and Rosa Zukunft are situated within the Austrian Bundesland Salzburg, and both cases were originally part of the Smart Grids Model Region Salzburg (SGMS) initiative. The SGMS initiative – and thereby the specific cases of Köstendorf and Rosa Zukunft – reflects the ambitious climate policy targets of the federate state of Salzburg, which according to the Salzburg's Agenda 2050 aims for 30 % emissions reduction and 50 % renewable by 2020 and climate neutrality and energy autonomy by 2050 within the region of Salzburg. In this way, Model Village Köstendorf and Rosa Zukunft are inscribed within the region-wide climate change and energy transition policy. However, compared to Rosa Zukunft, the village of Köstendorf stands out by being, first, a small village community (compared to the city of Salzburg), and by having, second, an affinity towards energy conservation and local energy production that dates long back in time.

The studied solutions in the Model Village Köstendorf include three socio-technical configurations: (1) A field test focusing on the integration of a large number of small PV systems and electric vehicles to the local grid (testing the capacity of the local distribution network); (2) the single field-test households and their "internal" configurations within the home (typically combining rooftop PV, stationary battery and EVs); and, finally, (3) a single household experimenting with covering the energy need (almost) entirely by renewable energy produced on the premise. The two former configurations are part of the project called DG DemoNet Smart Low Voltage Grid, while the third is an independent initiative that originally goes back to the 1990s and is run by the male owner of the "100% renewable household" home. Even though the third solution was initiated by a single homeowner, the specific context of Köstendorf with regard to the area's long history of local energy production and conservation is obviously a significant key driver when it comes to such private initiatives.

Rosa Zukunft focuses on the testing and implementation of residential energy and mobility solutions; specifically, the incorporation of smart grid technologies (demand response) in new-built residential buildings (eight apartment buildings, including 129 dwelling units). Although being part of a “smart energy” agenda, an accompanying goal for the Rosa Zukunft development was social; the idea was to support local community building across different generations and income groups through offering organised social activities to the residents and other community building offers. Three configurations were studied in relation to Rosa Zukunft: (1) A building-to-grid configuration aimed at reducing load peaks through combining micro-CHP with a heat pump and a large energy storage tank to store surplus energy, all controlled with a Building Energy Agent; (2) energy feedback to residents via tablets and smart phone apps in order to motivate residents to shift energy consumption away from load-peak hours (partly through information about current grid load, partly through a variable tariff); and, finally, (3) EV sharing of a number of EVs with controlled recharging.

Project Zero is the name of a strategy of making the Danish city and municipality of Sønderborg climate neutral by 2029 as well as the name of a public-private partnership founded in 2007 with the aim of promoting and facilitating the energy and climate transition in Sønderborg. The Project Zero Secretariat facilitates this transition through a wide range of initiatives and in close collaboration with the municipality and other local actors. This project has studied the following three configurations: (1) ZEROhome (focusing on promoting energy efficiency and renewable energy in homes, e.g. by offering independent enegy-consultancy), (2) ZEROsport (focusing on promoting more energy efficient sports centres); and (3) ZEROshop (focusing on energy savings in local shops, such as supermarkets).

The Renewable Energy Island Samsø has a long history dating back to the late 1990s. The island (having 3,700 inhabitants) originally aimed at becoming self-sufficient with renewable energy, which was realized by 2008 (if measured by the annual net energy consumption and renewable energy production). Now, the goal is to get entirely rid of using fossil fuels by 2030; in particular by replacing fossil fuels for transport with renewable alternatives. Along with this, the Samsø Energy Academy continues activities focused on achieving energy reductions and higher energy efficiency. The MATCH-project has studied the activities of this key local actor targeted increasing energy efficiency in local businesses (including supermarkets, a hotel and restaurant and the local community center). The energy reductions have been facilitated by the Energy Academy through regular visits to and in close collaboration with the owners and staff of local businesses on the island. Activities include monitoring existing consumption and promoting conventional energy saving solutions such as replacing halogen spots with LED lights, etc.

The following analysis focuses on identifying the context-related conditions and features related to the specific design of the local initiatives that help to explain the relative successfulness of the individual cases/solutions.

4.3.2 Outstanding qualities of the selected solutions

Model Village Köstendorf

Overall, the three solutions tested are considered as successful in several respects and from different stakeholder perspectives (R&D objectives, planning objectives of the utilities provider Salzburg AG, the local community has profited from both direct subsidies and the technological momentum, etc.). The studied activities can be seen in continuation of previous energy and sustainability-aligned (e.g. Local Agenda 21) initiatives in Köstendorf. The configurations are still in place (upon end of trial period) and further initiatives are expected in the future. Thus, the studied solutions represent a significant element in a longer list of initiatives that together form a successive progression towards future climate neutrality and energy autonomy, which corresponds with the aim of the regional climate neutrality plan. A process in which technical manifestations form the basis for social alignments and new decisions for further technical implementations usually referred to as socio-technical production or co-evolution.

The following highlights the main qualities of the solutions implemented in the comprehensive energy concept of Model Village Köstendorf.

Firstly, the different solutions work well in real-world contexts of "real" users, and are therefore in general characterised as socially accepted and technically feasible solutions. The local energy provider Salzburg AG plays a central role in the two solutions that both are parts of the DG DemoNet Smart Low Voltage Grid trial. Here, Salzburg AG acts as a locally-anchored "key actor" within an otherwise diverse network of actors involved in these configurations. Thus, the provider is an important mediator between local actors (including residents/users) and national/international actors (e.g. Siemens). Further, the key role of Salzburg AG was facilitated by one particular community member employed by the company, even though this person was not professionally involved in the project. The community member was selected as the local mayor, after the solutions were initiated.

Secondly, these solutions gained strong local support and anchoring because the participants strongly identify with the objectives of the trial and hence were proud of playing an active part in the energy transitions. Also, the solutions were strongly supported by other related actors in the community, which helped with disseminating knowledge about the successes and challenges connected to the projects. In addition to early involvement of key actors, users, and local stakeholders, attractive subsidies, owing to the funded projects, seem to play a significant role for the great satisfaction about participation among the variety of actors.

Thirdly, the general success, positive reception and local support of the solutions are a result of the long history of energy transition initiatives in Köstendorf. The energy transition initiatives are partly institutionalised in the local energy group called "e5". The solutions have achieved much (international) attention from smart energy researchers and developers. The activities have also helped attract further energy projects and R&D funding. In this way, the initiatives served to enforce local economic investment and development in the area. In terms of that, national funding and the variety of projects and programmes worked as making a valuable energy "test bed" for both research and industry, and consequently contributed to a long-term development in the region.

Finally, the 100 % household is comprehensive in terms of installing the patchwork of several advanced technical technologies by integrating them into the everyday life. By testing new technologies, the household control the usability of the solution by fitting the overall vision of 100 % self-sufficiency, and become a driving force for progressing development of prosumers interplay with the energy system. This actor exemplifies how an active energy citizen becomes a "role model" for a sustainable energy transition in the area.

Rosa Zukunft

This section highlights the main qualities and lessons-learned from Rosa Zukunft. Rosa Zukunft are comprehensive because of the involvement of several technological and social elements, which are mutually coordinated and jointly contribute to the functioning of the solutions.

Of the three studied solutions, the building-to-grid configuration turned out as particular successful. This configuration did not contradict (or even interact) with the daily routines of the residents and was regarded as financially viable (even without external funding). Also, this solution has been replicated in similar residential projects in Salzburg (although in a less sophisticated and hence economically more feasible version). While the building-to-grid configuration was highly automatized and did not involve active participation of the residents, the other two configurations were based on a much more direct user engagement. The engagement consisted either in adapting daily energy-consuming practices to variable prices and information about the current grid load or by taking part in the EV sharing scheme.

The other two configurations were never really adopted by the users. They could not profit economically from taking part in the time shifting, even if they tried hard. This lead to a feeling of deception and a decreased sense of ownership and identification with the project. The combination of several goals in one project to some extent explains the lack of active participation by the residents in the two configurations that called for active engagement. On the other hand, the latter two configurations were successful in the sense of providing knowledge about important factors for the success of demand response and EV sharing solutions.

Both Salzburg Wohnbau and Diakoniewerk Salzburg were important actors due to their roles as main contact for the participants (with Salzburg Wohnbau being the key actor as coordinator of the trial), and thus responsible for the primary communication with the residents about the smart energy initiative. These actors appear to focus mainly on the social dimension of the Rosa Zukunft development. Salzburg Wohnbau participated due to the initiative of other successful regional companies such as Salzburg AG and Diakoniewerk Salzburg. They trusted those, due to longstanding connections.

Project Zero

The three solutions are comprehensive, since they involve several technological and social elements that fit well together. Overall, the three configurations have been successful in the view of both Project Zero and the targeted users (households, shops and sports centres). Substantial energy reductions have been realized in local supermarkets and sport centres (resulting in financial savings), and the households in general find it meaningful to be actively engaged in the energy transition initiatives. Also, the individual configurations contribute to the overall aim of making the Sønderborg area CO_2 neutral by 2029. Finally, Project Zero has succeeded in making the vision of CO_2-neutrality by 2029 an active and visible element in the local community and is thus successful in aligning local activities and actors in relation to fulfilling this vision. Following findings are the main qualities to be highlighted with regard to the efforts initiated by Project Zero.

All three constellations of solutions work well in real-world contexts (real users, socially acceptable, feasible). According to the annual monitoring accomplished by the Project Zero secretary, the area's CO_2 emissions were 25 % lower in 2015 than in 2007. This reduction has been achieved through significantly more efficient energy consumption and increasing energy supply from the area's own renewable energy sources. Correspondingly, substantial energy savings are gained through the energy efficiency strategies in focus in the configurations of ZEROhome and ZEROshop.

Characteristically for the configurations is that they are facilitated by community-led initiatives as part of a greater, local-based transition initiative (developed and maintained by Project Zero). More generally, Project Zero is a key actor in promoting the local CO_2-neutrality vision and in aligning activities and creating networks of actors (including transferring knowledge and ideas among local actors). Regarding this, the configurations contribute to maintain and develop the local energy transition vision. Also, the solutions contribute to a national and international "branding" of Sønderborg, which helps – among other things – attract investments and public funding in further energy transition initiatives (including EU Horizon 2020 projects).

Common for the solutions promoting energy saving are the involvement of many actors/local stakeholders. Local companies are among the involved actors, sometimes in the role as providing and testing new technical solutions, as it was the case with the waste heat recovering system in the studied Supermarket. In this way, Project Zero activities contributes to substitute existing equipment with more efficient technologies in local companies as well.

External funding plays an important role in some of the cases in the ZEROsport configuration (particularly in the case of Diamanten), but appears to have a limited influence in the other two configurations which indicates that the solutions chosen are economically competitive even under today's conditions. Significantly, national (tax) regulation plays a pivotal role in making investment in renewable energy generation feasible (or not) for many households taking part in ZEROhome (especially with regard to installing PV panels). This also relates to the purchase of EVs.

Renewable Energy Island Samsø

The initiatives targeted energy savings in local shops appear successful as the shops have realized substantial energy savings through rather conventional measures such as adjusting room temperatures or replacing inefficient light bulbs with efficient alternatives. In this way, the innovative element of this configuration (solution) is mainly related to the approach and methods applied by the Energy Academy and thus less to new technical equipment as such. The energy savings are realized on basis of close monitoring of energy consumption and frequent visits to the shops carried out by the same staff members from the Academy. This includes continued dialogue with the shop owners or shop staff members about their daily routines (in order to find solutions that fit well with these) as well as in order to identify possible energy saving options. Compared to all other solutions in our sample, this configuration works most strongly through social elements. The following summarises the main qualities to be highlighted with regard to Renewable Energy Island Samsø.

The solution works well in a real-world context among real users due to high social acceptance and not least due to the substantial energy savings achieved. That said, the activities carried out by the Energy Academy depend very much on external funding, which makes it difficult to evaluate the economic feasibility of the solution.

The Energy Academy’s approach gained strong local support and anchoring, and all the involved shops express great satisfaction about participation. The approach is characterised by close and continued involvement of users (shops) established through persistently follow-up visits accomplished by the same (one or two) staff members from the Energy Academy. In terms of that, the Academy is the key actor in the solution studied (as well as the broader energy transition of the island).

Overall, energy transition initiatives has a long history on the island of Samsø, which may partly explain the positive reception and local support by the shops. The Energy Academy is well known on the island and has an established reputation as the local authority on energy-related themes and energy saving initiatives. This, combined with the informal relations between the Academy and local citizens, implies that the Academy generally is met with trust engendered by the Academy’s well-established and extensive network of relations.

The energy transition vision of Samsø combines the idea of decarbonizing the local energy consumption with the vision of revitalising the local community with regard to settlement and economic development. In this way, the transition initiatives are inscribed in a broader vision (narrative) for the future economic and social development of the island. The solution is part of promoting the local community and the Renewable Energy vision, which has achieved much (international) attention from smart energy researchers and developers. The activities have also helped attract further energy projects and R&D funding.

4.3.3 Discussion of critical factors and common patterns

Across the studied cases, the existence of local visions or strategies for a comprehensive energy transition appear to play a key role in aligning activities and actors within the specific configurations and solutions. This was in particular evident in Project Zero, Renewable Energy Island Samsø and Köstendorf, but less in the case of Rosa Zukunft. Summarising the success of the variety of the community-driven solutions critically depends on the productive role of local/regional energy transition visions.

With regard to this, the reason why Rosa Zukunft seems to differ from the other cases might be related to the critical importance of the long history embedded in locally anchored energy transition activities. In Köstendorf, Sønderborg and on Samsø, the studied configurations (solutions) are only single elements in an otherwise wide spectrum of energy transition initiatives. Thus, the studied configurations can be interpreted as continuations of previous initiatives and their material and semiotic manifestations. Significantly, the degree of the solutions' success often build on pre-existing networks of actors. The only exception from this anchoring of solutions in pre-existing energy transition activities and networks seems to be the case of Rosa Zukunft.

Framing the energy transition within a broader vision of local (community) development is essential. In several cases, the local/regional energy transition visions were framed within a broader vision of supporting general economic and social development (e.g. promoting settlement and economic development on the island of Samsø). This goes for Project Zero and Renewable Energy Island Samsø, and also Köstendorf. This framing appears to be particularly productive, if a local key actor (like Samsø Energy Academy) is taking on the responsibility of facilitating dialogues and processes through what has been termed (in the case of Samsø Energy Academy) "hope management", which "focuses … on the careful building of a process taking individual or group stakeholders' interests and worries as a starting point of situated negotiations" (Papazu 2015: 157).

Furthermore, the fact that one primary key actor with relations (often informal) to a wide range of local actors can be identified seems to play an important role. Across most of the cases, one actor can be identified as the key actor that takes on the leading role of communicating (mediating) between the network of actors related to the individual configurations. This is the Energy Academy on Samsø, Project Zero in Sønderborg and Salzburg AG in Köstendorf. In the case of Rosa Zukunft, Salzburg Wohnbau and Diakoniewerk Salzburg appear as accompanying actors. In addition to facilitating and supporting the communication within the network of actors, these key actors also play a key role of more direct involvement in developing the specific design of the solutions (as in the case of Salzburg AG in Köstendorf and Samsø Energy Academy on Samsø). Especially Samsø Energy Academy exemplifies an actor with a highly continued and frequent interaction with the actors involved in the studied configuration in particular at the sites (e.g. the supermarket). In comparison, the role of other key actors, such as Project Zero, appears to be primarily focused on network building and supporting the alignment of local actors and activities in relation to the energy transition vision through communication (and less direct involvement in the realisation of initiatives).

Moreover, competitions and rewards in several ways played a key role in two of the configurations related to Project Zero (ZEROshop and ZEROsport), which indicate that competitions, recognition and general publicity can motivate organisations like shops and sport centres to take part in energy saving initiatives. Such initiatives require a degree of rules setting and developing certification schemes, which also crucially depend on broader management of such programmes facilitated by one primary key actor.

4.3.4 Conclusion

The solutions outlined in this cluster analysis are all, though to a different level, part of comprehensive and often community-based energy transition strategies and visions attempting to reduce carbon emission through energy savings and increased local renewable energy production in the area. Despite the solutions are strongly dependent on specific localities and vary in terms of technologies, actors and networks, all the individual solutions are enrolled and embedded within ambitious community-led transition strategies that involve a wide range of different interconnecting initiatives, technologies and multiple actors. Commonly across these socio-technological configurations, the productive role of comprehensive community-driven local strategies and visions, typically established through a long history of anchored energy transition initiatives, appear essential for establishing and anchoring solutions. Successful solutions are part of longer history with previous experiments, implementations and initiatives. Hence, these solutions represent single elements in a much wider spectrum of energy transition initiatives. With exception of Rosa Zukunft, these solutions often build on pre-existing networks of actors, though one local key actor seem of particular importance in order to be the 'leading' responsible for designing the solutions as well as driving and facilitating the processes and initiatives of cooperation, network-building and communication. Furthermore, central key actors' performance of persistent continued and frequent interaction with the users appear as a valuable approach in order to create support and joint-responsibility, which are crucial for anchoring the workable solutions in real-life on a longer term.

4.4 The role of users in emerging socio-technical configurations

4.4.1 Introduction

A central idea of the MATCH project is to identify and describe smart energy solutions as socio-technical configurations. The studied solutions work, is one of our main arguments, because social and technical, semiotic and material elements are interlinked and enacted in a meaningful way. However, in this chapter we will focus on one specific aspect of energy solutions as socio-technical configurations: the various roles users play across the studied configurations. The aim is to better understand how users are configured, involved and actively engaged in these solutions and how users contribute to the development of solutions through social learning and the creation and stabilisation of new symbolic meanings and use patterns.

It is obvious that users matter in all of our cases. They play an integral part in the various field-tests and pilot-projects and are even, in some cases, almost completely responsible for the working of the solutions in place. However, as most of our solutions still are in an early phase of development – clearly before a significant market uptake – we have to direct our attention to the role of users in early phases of energy innovation processes, in particular.

Once a technical artefact (or a set of technical elements) leaves the limited context of research, engineering and design, contexts and ways of using the technology are normally far from clear. The range and character of possible roles of users can vary widely. From being restricted to what Williams and Edge (1996) have called 'veto power', meaning that consumers have no opportunity to engage with the design of technology other than deciding whether to adopt it or not, to being deeply involved in the design process or even becoming the main source of 'user innovation' (von Hippel 1986). This makes the role of users somewhat ambivalent: they can be considered as both active and able to shape the design and meanings of an artefact, or passive and reconfigured and shaped by technology. Put differently, users can be conceptually located within a field of tension, and thus being both passively configured by other actors or technologies and actively appropriating technologies at the same time (Shove 2001).

In our context, the focus is on the ability of users to actively shape the meaning and design of technology and through this, contribute to the successful working of the studied solutions. Early users always play an active part in meanings and practices related to an artefact (Mackay and Gillespie 1992), as artefacts only acquire social meaning in use contexts. The process behind this is what is sometimes called 'appropriation' or 'domestication' of a technological object, which refer to how technology is 'incorporated into the routines and rituals of everyday life, the way it is used, and the ways it becomes functional' (Vestby 1996: 68). In their role as users, consumers can be active, creative and expressive (Mackay and Gillespie 1992).

In the case of early and active first-users, the appropriation of technology becomes a broad and transcending activity, obviously 'blurring the boundaries between production and consumption' (Oudshoorn and Pinch 2008: 554). Users may become 'prosumers', as Toffler has called them already many years ago (Toffler 1980), which means that they are producers of technology, but nevertheless well grounded in the knowledge and the day-to-day experiences of ordinary users.

To what extent users are able to become active designers of technology is indeed dependent on a variety of different factors (we will discuss some of them below), covering socio-economic and demographic characteristics, personal skills, structural and cultural conditions, as well as properties of the technology itself. Therefore, it is important to bear in mind that there are different groups of users, which vary in their power to choose the technology, to acquire skills and authority to use it in different ways, to adapt or modify it, to fix problems, override functions or bypass its outputs, or perhaps to subvert or reject it (Russell and Williams 2002). In a similar way, Klein and Kleinman (2002) have stressed the power or capacity of users and other social actors in this context. They argue that the ability of users to shape technology depends largely on structural characteristics, such as economic, political, and cultural resources and assume that among different groups we may find systematic asymmetries of power, and that these differences are rooted in structural conditions of social life. It is very likely that such structural conditions also play an important role in our examples, as most solutions are still embedded in well-protected innovation niches.

Within innovation studies there is quite a long tradition of analysing users as an important source of innovation-related knowledge (see e.g. Rosenberg 1982, von Hippel 1986). Drawing on a number of empirical cases from different industrial sectors, von Hippel (1986) has shown that up to 90 percent of all innovations in a field were developed by product users. Of course, in these cases most users had not been individual end-users but firms or organisations. Nonetheless, the point is that these industrial users did act in their 'functional role' as users, rather than as manufacturers or suppliers of products. They provided solutions for their own needs, which eventually became successful innovations. In the contexts of the MATCH project the earlier studied cases of ASKO and VLOTTE are excellent examples for this kind of corporate users taking on the challenge to develop new solutions by themselves.

Von Hippel (1998) has shown that users have specific local knowledge that could be highly relevant for defining and solving problems (with their own interests as priority) and eventually lead to technological innovations and new market opportunities. Collins and Evans (2002) point out that so-called 'specialist uncertified expertise' know-how from users is integral to the development of the technology, especially in cases of public-use technologies such as cars, bicycles, and personal computers. But users could also contribute as 'narrow specialists', broadening the knowledge base, as users or active non-users. This second form of expertise based on experiences from users or non-users of technology is acknowledged as an integral part in establishing meaning and success for new technical artefacts.

So, there are different users, with different abilities, ambitions, skills, stocks of knowledge, etc. as well as different structural conditions and local settings. In the context of smart grid developments Goulden et al. (2014) compare two contrasting models of energy consumers with energy citizens (Devine-Wright 2007). These two user types deploy different personas and play different roles in energy innovation and it can be expected that they perform differently. While in the context of smart grids, energy consumers appear to perform 'managed demand side', energy citizens are likely to become managers in the process of consumption and (micro-)generation. With a focus on the relation between providers and consumers, van Vliet (2012) suggests to consider three different types of technology users: consumers, citizen-consumers, and co-providers.

From a sustainability transition perspective, Schot et al. (2016) have recently argued that consumers should be reconceptualised as users in the innovation process shaping new routines and enacting system change. Based on the existing scholarly work on the role of technology users in innovation processes the authors develop a new typology of users trying to link these user roles conceptually to the timely dynamic of transition processes. In the start-up phase of a transition process, they argue, user-producers and user-legitimators – users who are also committed to the political legitimation of alternative technical visions – help to create technological and symbolic variety. In the acceleration phase, user-intermediaries (e.g. user organisations) align various actors, user-consumers creatively embed new technologies in their everyday practices while user-citizens mobilize against the existing regime. In the last phase, called stabilization phase, a larger number of user-consumers switch over to the emerging regime with its re-defined practices. As most solutions studied in the MATCH project represent early manifestations of possible socio-technical pathways our focus in particular should be on the role of user as producers, legitimators, intermediaries, and consumers.

Based on this short literature review we may conclude that different types of users engage with socio-technical innovation on three interrelated levels: (1) the functionality/performance of the solution; (2) the development of the solution; and (3) the socio-political context of the solution. Users play a crucial role in any emerging socio-technical configuration. Users link elements together in meaningful ways, they perform practices integrating these new configurations and are involved in ensuring that certain outcomes are achieved. However, the importance of users goes far beyond the practical functioning of the studied configurations. Users are involved in shaping the symbolic meaning of novel solutions, provide practical knowledge, articulate individual preferences or directly fix technical problems. In sum, users are active drivers of innovation and can help to build up and stabilize social networks, improve the political meaning and legitimization of smart energy solutions.

4.4.2 Different user roles in comparison

A general overview shows that the collection of solutions studied in the MATCH project involves a number of different types of users. Users appear as:

Research partners and citizen scientists: An example of this type of users are the residents of the so-called monitoring households in the DSM-trial in the Rosa Zukunft residential building in the city of Salzburg (33 units with DSM equipment, 33 without equipment). Information and advice has been available to users in these households and they were provided with special equipment to test for one year. The users' experiences were documented and scientifically analysed. The households in Köstendorf also took part in (two different) research projects. In the second case, however, users were more deeply involved through own financial investments made in the process, and the involvement went beyond the research project period. However, the main contribution of users as field-test participants is the production of knowledge. To a certain extent, users in this case are ‘research objects’ who participate in the project through a mutual agreement and supported by benefits for a certain period of time. In the case of the Norwegian project in Hvaler and the Danish case of Innovation Fur, however, users play a more active role as citizen scientists; some of them are quite offensively involved in the production of new knowledge.

Traditional or ordinary users: The Rosa Zukunft residential building is also a case that involves ordinary consumers. All residents without monitoring equipment (around 100 units) belong to this type of users. Here, consumers obligatory have to be customers of Salzburg AG, as heat and hot water are exclusively produced by the implemented building-to-grid solution. Consumers share two interfaces with the utility, technically (through a small transfer station in each apartment) and legally (through supply contract, billing and customer service). In the first months of operation, the technical performance was improved on the basis of consumer feedback. In their role as consumers some of our interview partners complained about the quasi-monopoly status of the utility, but are generally satisfied with the heat-supply. Overall, the consumers in this case were able to stick with their existing habits and respond to the solution based on these preferences.

Prosumers: In Köstendorf, Trøndelag and Hvaler, private households act as users and producers of electricity. In all three cases, the associated financial risks for private investors were reduced through subsidies, but this does not change the fact that these users sell electricity to the grid operator and, in doing so, that they take a certain amount of entrepreneurial risk. In these households, energy becomes visible through technical equipment and smart meters that show the daily production and allow for different forms of data processing and energy visualisations. Even more, this is the case in prosumer-households equipped with stationary batteries and/or EVs (like in Innovation Fur and ZEROhome). However, in the Hvaler case the technological configuration along with the tariffs structures are set up in such a way that it demand little activity on behalf of the prosumers. For instance, whether the prosumers consume their own energy when production from PV is high, or sell it back to the grid have no consequences for them. Some of the users in the Trøndelag case also represent a weak form of prosumer; here, households technically and contractually sell electricity to the grid, but the energy provider owns and takes care of the equipment.

Energy citizens: The term energy citizenship assumes that the general public is a politically engaged stakeholder in the transition of the energy system towards greater sustainability (Devine-Wright 2007, Ryghaug et al. 2018). We find those politically active users in our cases in all three countries. In Austria, the person who created the (now) 100% renewable household over the last 25 years is a typical example. The decision to switch completely to renewable energy sources in this case is closely linked to a political agenda (ecological movement, climate change mitigation) and the actions taken in the home are part of the mission to show the public that it is possible to rely almost exclusively on renewable sources. The energy agenda clearly became an integral part of his personal identity. The same type of energy citizen can be found in Norway, in particular among the participants of the smart energy project on the island of Hvaler; people whose commitment to energy issues goes far beyond their participation in the on-going field trials, as evidenced, for example, by the fact that they give public lectures on their activities or generously guide groups of visitors through their home and share their experiences with the tested smart energy solutions. To some of these users their engagement is rooted in feelings of taking social responsibility for the developments of society.

'Affiliated users': In some configurations employees of the project owner take on the role as early end-users and test the solutions under development in real-world contexts. We may call this type of users 'affiliated users' as they are in an employment relationship with the project owner. This makes it relatively easy to actively enrol them as part of the applied configurations, enables direct and immediate feedback, allows for mutual learning processes and guarantees unrestricted access to data. At the same time this arrangement limits possible risks because the solution is tested within the own company only. Examples are the end-users in the VLOTTE project. In this project, in all three analysed configurations affiliated users do play an important role; they use e-vehicles and the electronic reservation system of the smart e-car park, and serve as a private test-household with PV panels and stationary batteries to learn more about economic and technical aspects of higher levels of self-consumption. Similar cases also exist in the Trøndelag case, where employees of the project owner act as test households.

User innovators or user-producers: The last type of user we could identify in our sample is the user as driver of innovation. Here, mainly a user develops a smart energy solution, according to own needs and mainly based on own resources and capacities. In this constellation the user acts as a producer, as a technology developer. This is the case with the VLOTTE project, where a regional energy service provider is developing a smart e-car park solution, as well as in the ASKO case, where a large Norwegian grocery wholesaler is developing a hydrogen infrastructure for hydrogen-powered fleet of heavy-duty delivery trucks. The innovation activities in both cases first of all aim to serve needs and goals that these companies have set for them, and, as there was no suitable offer available on the market, they decided to tackle the task by oneself. User innovators may not be experts in the new field they entered, but they have a lot of local knowledge and are very much aware of how the new solutions should work. User producers also could be found in the Danish ZEROhome, in particular in one household in which the male find it highly interesting and meaningful to 'tinker' with the technical energy systems on a continuous basis and who built his own advanced energy provision system combining and optimizing the dynamic interplay between solar panels, solar PV and a biomass oven.

In all our case study configurations, users take on (or are enrolled to take on) several roles. In the private test-household in the VLOTTE project, for example, the responsible person acts as prosumer and at the same time he is an affiliated user. In a similar way in the distribution grid research project in Köstendorf as well as in the smart energy project in Hvaler, participants take on several user roles at the time; they serve as research partners, prosumers, and some of them act as energy citizens. In the e-car park in Austria, user innovators and affiliated users complement each other. In the following we will discuss the different user roles in some selected configurations and their respective effects in more detail.

Example 1: 100 % renewable energy household

This configuration is located in a detached building on the outskirts of the small village of Köstendorf (Austria). The only two residents are an adult couple. The man is the driving force behind the project that he has been pushing for many years. While not having any related professional background, he managed – mostly with the help of professionals – to install and combine a variety of energy technologies. Examples for those are thermal solar panels, a storage tank, a heat pump, rooftop PV, and a stationary battery. Over the years, considerable sums of money have been spent on the equipment. Only recently, he even managed to get included into the subsidised EV and stationary battery scheme of the nearby smart-grid research project. His stated goal was and is to show that a green local energy transition is possible. The energy supply of the home is based exclusively on renewable resources. However, the household is not completely autonomous from the grid, but shows a very high degree of locally produced energy.

Although there are only two people in this household, we could identify four different user roles in this case: (1) energy citizen, (2) user-producer, (3) prosumer, and (4) ordinary user. The owner of the house definitely acts as an energy citizen; he is an active member of a local energy activism group that promotes the use of renewables, e.g. in the context of his professional activity. In addition, he holds lectures and teaches sustainability related topics at a university. He follows a clear vision and aims to build a sustainable future through the use of renewable energy. Many years ago, he was one of the first members of the then very active DIY solar energy groups in this region. Since then he has pursued the goal of completely converting his own house to renewable energies. He sees himself as an activist, attempting to influence the energy transition from bottom-up. The many years of commitment made it possible to develop this quite unique configuration, as the person is dedicated to improve the installed system through trial and error approaches, while accepting the considerable economic costs of these activities. Thus the homeowner is also a user producer. He planned and partly installed the elements for the configuration over several years, with a clear long-term vision in mind. The resulting concept is largely based on DIY activities and, according to the owner, it is certainly not perfect from today's perspective, but the entire installation became a part of the identity of its builder. He still is very enthusiastic about it, although he would revise many of the past decisions. As a result, the configuration is comprehensive, but remains a patchwork of several technical systems. Together the couple takes on the roles of a prosumer, being still dependent on consumption through the grid-connection, but also producing and selling PV electricity to the grid. Again, the monitoring of the technology and the energy produced (e.g. via web portal) is also carried out exclusively by the male household member. The fourth kind of user-type that can be seen in this configuration is the ordinary user. This role is occupied by the female member of the household, who slowly tries to adapt to the new routines revolving around the now more fluctuating energy supply. This person thus performs a kind of ‘control function’ which, for example, deals with questions of usability and thus clearly goes beyond the role of the energy citizen or the prosumer.

In this configuration we see a productive interplay between the energy citizen and the user consumer. On the one side the energy citizen is the driving force for the progressing development of the private energy system and the introduction of new technologies to fit the overall vision of a 100 % renewable energy household. On the other side, the user consumer serves as a practicability check for these technical attempts. Both roles are influencing the way in which the role of the user producer role can be exercised. Thus, the user producer’s institutional frame is encouraged by the overall vision of an active energy citizen of being a role model for a sustainable energy transition and therefore dares developing and installing advanced technologies. Hereby, the interaction with other likeminded peers gives new ideas and input to the improvement of the configuration. In turn, new plans are checked by the practicability concerns of the ordinary user.

Example 2: ZEROhome (and Innovation Fur)

The ZEROhome programme launched by ProjectZero in 2010 focuses on engaging house-owners in energy retrofitting their private-owned homes. ZEROhome is thus one of a variety of ProjectZero’s initiatives that overall aim to facilitate a transition of the municipality of Sønderborg to a CO2-neutral community by 2029. Embedded in the overall community-led transition strategy, ZEROhome aims to qualify ways to improve the individual houses’ current energy standards by promoting energy efficiency by offering independent energy advise. Moreover, smart grid solutions to increase renewables in private homes, such as installing PVs, are significant strategic efforts within the programme. In the following, it is outlined how private home-owners are a diverse group of humans who perform/interact in various ways with the smart technologies and are motivated to install and invest in PVs in combination with electric vehicles (EVs) and heat pumps by different reasons. Thus, the specific socio-technical configuration consists of the technologies: PV panels, electric vehicles and heat pumps entangled within the everyday life of households, e.g. including social elements such as specific kinds of relations between actors, network of knowledge sharing, support and inspiration, drivers of motivation, stage of life phases, etc.

The users or owners of respectively PVs, EVs and heat pumps install the technologies for several reasons. This socio-technical configuration shows how participants combine different roles such as prosumers, energy citizens, user innovators and ordinary users.

Obviously, all households were prosumers (having PVs and connected to the grid), and thus were motivated by consuming their own production of renewable energy. The prosumer role was a key driver for purchasing the technologies for most of the households studied. The ‘synergies’ of combining PVs with an EV or/and heat pump was a significant driver for acquiring more than one technology. Thus, the purchase of different technologies typically reflects a certain sequence of investments; PVs seem to be the first object of investment, whereas heat pumps and EVs came after in order to optimize the utilisation of their own power production.

Often, the original idea of becoming a ‘prosumer’ was a consequence of other plans about comprehensive home renovation, e.g. replacing the roof or the old energy heating system (e.g. replacing an oil burner). This opened new dimensions of thinking in energy-related terms. Here, several users express a great interest in investing in the newest possible product on the market. In continuation of these considerations, some users were motivated by making eco-friendly choices. This indicates that users are driven by innovation and pursuing to test ‘new technology’ and in some cases simultaneously value sustainable energy performances. The acquisition of EVs was an example of this.

Although none of the users explicitly mentioned political activities, the users seem to be very aware of their role as 'sustainable citizens' or/and, in some cases, self-sufficient energy-independent consumers that are resilient to external threats. That said, the users did not manage to time shift the electricity consumption for the EVs according to their own "surplus" production of PV power. All users plugged in their EVs when they came home in afternoon. In addition, the only households who time shifted and changed routines on dish-washing, clothes-washing and baking were on the newest scheme of account settlement (hourly net metering), which increased the incentive to use the consumption while producing the energy.

The ZEROhome households were not 'producers of knowledge' as in the 'research partner' user role. ProjectZero attempts to maintain a good contact and relation with the households in order to have some good showcases to be used in their running campaigning for an energy transition in the Sønderborg area. Even though none of the participants were directly engaged in the initiatives facilitated by ProjectZero, the users positively declared the value of being a part of the ZEROhome network, which demonstrates how ProjectZero succeeded in creating and anchoring the vision within the local community as a shared vision. Thus, many of the ZEROhome members acted as "best practice" cases through hosting visits for guests at ProjectZero and/or being interviewed for news pieces on the ProjectZero website etc. In this way, they to an extent were 'casted' in the role of being local promoters of the energy transition – a role resembling the energy citizen role.

Finally, a few households were engaged in experimenting with combining different energy solutions and optimising energy efficiency and self-sufficiency within the home (cf. the example mentioned in the previous section). This shows that a smaller group of the ZEROhomes were dedicated user-producers (user-innovators), somewhat similar to the 100 % renewable energy household of Köstendorf.

Example 3: The multi-level user innovator

This example is located at the regional branch of a large Norwegian grocery wholesaler with the core activity related to selling and distributing groceries to stores, retailers and the catering industry across the country. The company has a 27 000 m^2 storage facility and distribute goods to more than 1700 stores and restaurants. Much of the storage space is energy intensive, as is used for cooling and freezing food by means of hydroelectricity. To distribute the goods, they have around 50 distribution trucks. The activities of the company are both fuel and electricity intensive.

The company is owned by a large national actor that possesses a broad portfolio of corporations such as grocery store and fast food chains. The last 7-8 years, a key group of owners have become environmental protagonists arguing for the importance of broader societal and environmental engagement in order for both the company and the planet to survive. In line with this, they have been able to reconfigure the overarching goal of the company. Thus, the ASKO case clearly highlights the energy citizen perspective of its owners. Environmental concern, climate mitigation and responsibility for future generations have been one of the driving factors behind the development of this development. The goal is to become climate neutral in every aspect of its operations. This first became manifest through a decision by the board of directors five years ago, where it was stressed that the return on environmentally oriented investments could be much lower that than return on "ordinary" investments. Thus, they have worked intensively to change the rules of the game towards a less profit oriented and towards an environmentally benign direction, both internally and externally. The owners did not dictate how companies in the structure should work to become sustainable, only that they should. However, it was quickly translated into concrete goals for ASKO being 100 % self-supplied with new renewable energy by 2020, as well as switching to 100 % renewable fuels for transport. On a corporate level, the first decision was to invest roughly 20 million euros in a wind park with a 60 GHW annual capacity.

This would cover the equivalent of 75 % of all annual electricity consumption throughout the corporation. Several respondents from the regional branch highlighted how their own initiative was the result of a combination of external push and internal motivation: they decided to install PV on the rooftop of the storage facilities, in total 12,000 square meters of PV. This would cover 15-20 % of the consumption. Thus, ASKO was now a prosumer.

Internally, this new emphasis on environmental issues on the company level was also used to promote sustainable choices to employees. An annual environmental fund of roughly 1 million Euro was established, funding electric bikes, environmentally and energy efficient home renovations, or tickets for collective transport for employees, as well as on-site electric vehicle chargers, which employees could use for free. This turned out to give employees a sense of pride and motivated the employees to think about the environment and to change to more environment-friendly practices.

Apart from being interested in building a sustainable business, they have also been interested in being innovative or “ahead of the pack”, which of course can be seen as a business strategy as much as a will to act as energy citizens, as well as interests to innovate and being a research partner. In light of this, and their long relationship with certain research institutes, ASKO agreed to participate in a project to replace some of the lift batteries used in trucks with hydrogen fuel cells, which turned out to give approximately 85 % reduction of CO_2 emissions on the trucks. This success was essential for ASKO in terms of energy efficiency. However, just as important was the fact that the ASKO management now became convinced of the potential practical qualities of hydrogen fuel cells. Hydrogen, they now believed, was an option to pursue in the strategy to decarbonize their fleet of heavy-duty transport trucks and forklifts. This was not only a result of being newly convinced of the qualities of hydrogen itself. The move was further motivated by the prospects of surplus electricity production from their PV installation. Thus, what was originally a move to engage in energy generating practices was suddenly an essential ingredient in a shift towards producing their own fuels, and decarbonizing their transport fleet through hydrogen. Together with a long-term research partner institute, ASKO thus approached several large actors in European car manufacturing, with the goal of acquiring trucks for a pilot project on hydrogen trucks. Through intense lobbying together with the research institute, targeting their existing car manufacturer, they were able to commission three 27-tonne trucks, to be experimentally developed by the supplier in tandem with a project group consisting of people from ASKO and the research institute. The hydrogen tucks, will of course need fuel, thus ASKO proceeded to investing around €2.3 million in an off-the-shelf hydrogen production facility which will be installed on-site.

Over a few years, ASKO have substantially re-configured their relationship to energy and have gone from being a large consumer of energy to producing large quantities of electricity, as well as substantial quantities of hydrogen fuel cells for their transportation needs, as well as being involved with developing new transport technologies. Thus we clearly see how ASKO act as a driver of innovation developing a smart energy solution, according to own needs and mainly based on own resources and capacities. In this constellation, we see how the user acts as a producer and as a technology developer, where the grocery wholesaler is developing a hydrogen infrastructure for hydrogen-powered fleet of heavy-duty delivery trucks.

Externally, they have worked to push authorities into tightening demands and supporting transitions to more sustainable transport. Thus, they have worked to achieve both market and policy acceptance, and have had agency and capacity to enact transition agency. Further, they have taken part in re-writing the semi-coherent grammar or rule-set (Geels 2011) that they are embedded in. ASKO is a large company, and as we have seen above we could identify four different user roles in this case: the (1) energy citizen, (2) user-producer, (3) prosumer, and (4) user-innovator and the user-scientist.

4.4.3 Conclusion

The main focus of this subchapter was on the role of users in the studied smart energy solutions. Our analysis has clearly shown that users actively contribute to the success of the solutions. Users contribute to the development and the running operation of the solutions, help to build up and stabilize supporting social networks, and shape the political meaning and legitimization of smart energy solutions. In most cases different users take on specific roles, in other cases even individual actors perform several user roles. Based on our case studies, we were able to identify six different user roles and their respective characteristics.

As research partners, users participate in temporary projects and provide valuable information for the further technical development. Traditional users, on the other hand, represent more or less the mainstream, which provides important information for the wider dissemination of the solutions. Prosumers actively participate in the generation of electricity and partly they act as commercially oriented producers – they take on risks and expect profits. Energy citizens, on the contrary, are users who play a politically active role in the transition of the energy system towards greater sustainability and often accept larger financial costs during the process. Affiliated users – a type of user that has not yet been discussed in the literature – usually are employees of the project owner which take on the role as early end-users and test the solutions under development in real-world contexts. Finally, user innovators are social players who themselves develop new solutions according to their ideas and needs to a wide extent. We have found a selection of all these user roles in our cases. Together they contribute to the success of the solutions. In other words, our analysis has shown that users of smart energy solutions are collectives consisting of different constellations of users who perform different roles.

Since the different roles always occur in combination with each other, we speak of 'bundles of user roles'. These 'bundles' reveal a wider variation of requirements and preferences and therefore make it possible to influence our constellations on three levels effectively; (1) they contribute to the solutions functioning, i.e. fulfilling their intended purposes, (2) they enable problems and shortcomings to be identified and the solutions to be further developed, and (3) they support the social and political stabilisation of the solutions. It is only through the combination and interaction of different user roles that new knowledge is generated, practical experience is gained and the solutions are given social meanings that possibly go beyond the concrete situation.

5 Conclusion

In WP3 we have tried to compare projects and configurations across countries and cases to find common patterns that improve our understanding of the success of the studied solutions. The results of this work package are summarised in this report.

Our research strategy was mainly inductive, i.e. we searched for meaningful topics and cases that could be compared based on the available empirical material. The aim was to identify differences and similarities in our total ‘sample’, and based on this overview, we selected a number of ‘clusters of solutions’ for in-depth analysis. Thus, the following four topics were selected: Balancing generation and demand using solar PV and storage, renewable powered company fleet as a smart energy solution, comprehensive energy concepts, and the role of users in emerging socio-technical configurations. The first three topics represent empirically developed bottom-up thematic clusters, whereas the fourth issue was more theoretically motivated – since the role of users in any form of innovation is a critical issue.

The research on the four comparisons followed a similar approach. First, the projects and solutions used were described in more detail. Then differences and similarities were elaborated. Thereby we again accessed the existing empirical material and evaluated it from new perspectives. The final aim was to discuss critical factors and common patterns across countries and projects.

The first comparison of solutions that aim to better balance supply and demand revealed that working configurations most notably depend on local anchoring activities, favourable economic conditions, and ample opportunities for social learning. Usually those solutions fit well with existing local or regional policies and strategies, the activities are part of already on-going developments, and there are responsible actors on the ground who actively drive the developments forward. The economic situation of these configurations has been strengthened both by direct financial support and by advantageous tariff systems. Whereas social learning has been enabled by a high degree of social interaction, town hall meetings, or education and information campaigns.

In the case of the two company vehicle fleets powered by renewable energies: a number of outstanding similarities were found – despite major differences regarding the initial situation. In both cases a highly supportive political context, already existing social resources and network-building skills, an encouraging corporate culture focusing on innovation, external know-how strategically involved to solve emerging problems, and two companies acting as user-innovators with a real use case and actual end-users as test persons. In one of the two cases, the development has meanwhile progressed so far that the company is already offering the resulting knowledge as a consulting service to potential emulators. This was possible because the necessary development ‘environment’ (development, testing and application) was available and/or made available in the company's own operations.

A further comparative analysis related to the development of comprehensive energy solutions. In this context, the term ‘comprehensive’ refers to solutions with which as many energy-relevant measures as possible can be addressed simultaneously. As the analysis has shown, such solutions are also characterised by effective local anchoring. Usually, those examples are enrolled and embedded within ambitious community-led transition strategies that involve a wide range of different interconnecting initiatives, technologies and multiple actors. It seems that successful comprehensive solutions in any case are part of longer (political) processes involving previous experiments, implementations and reiterated initiatives. Hence, the studied solutions represent just single elements in a much wider spectrum of energy transition initiatives. Thus, path dependencies of innovation related activities cast a long shadow for follow-up projects. Although those solutions usually build on pre-existing social networks, one local key player seems of particular importance as the 'leading' actor for designing the solutions as well as driving and facilitating the processes and initiatives of cooperation, network building and communication.

The final comparative analysis dealt with the role of users in the solutions studied. The most remarkable finding of this analysis was that, in most cases, a variety of different user types or roles contributed to the functioning of the solutions. We were able to identify six different user roles and their respective characteristics: Research partners, traditional or ordinary users, prosumers, energy citizens, affiliated users, and user-innovators. Since the different roles (not all roles in any case, but most of them) did always occur in combination with each other, we called the resulting principle 'bundle of user roles'. These bundles were able to inform the technical functioning, to influence the way in which problems have been solved, and to support the social and political stabilisation of the solutions. In summary, it was the diversity of perspectives, interests and requirements that had a positive impact on the development and operation of the solutions and the socio-political context that made this diversity of user roles possible.

The analysis carried out in this report forms the basis for the development of recommendations from the MATCH project (see the deliverable D 5.1 of MATCH). The comparisons presented in detail in this report will only briefly be taken up in the context of the recommendations from the project. The two reports therefore complement each other in this context.

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Abbreviations

CHP	**Combined Heat and Power (plant)**
DH	District Heating
DSM	Demand Side Management
DR	Demand Response
el	electricity
ESA	Energy System Analysis
EV	Electric Vehicle
HP	Heat Pump
PES	Primary Energy Supply
PP	Power Plant
PV	Photovoltaic (systems)
RES	Renewable Energy Sources
th	Thermal energy
V2G	Vehicle-to-Grid
Wh **kWh** **MWh** **GWh** **TWh**	Watt hour 1000 Wh 1000 kWh 1000 MWh 1000 GWh

Disclaimer

About ERA-Net Smart Energy Systems and MATCH

ERA-Net Smart Energy Systems (ERA-Net SES) – formerly ERA-Net Smart Grids Plus – is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programs along the innovation chain provides a sustainable and service oriented joint programming platform to finance projects in thematic areas like Smart Power Grids, Regional and Local Energy Systems, Heating and Cooling Networks, Digital Energy and Smart Services, etc.

Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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The *Markets, actors, technologies: a comparative study of smart grid solutions* (MATCH) project runs from February 2016 to October 2018 and is supported by ERA-Net SES.

https://www.match-project.eu

Improving energy efficiency and replacing fossil fuels with renewable energy are among the most important measures on the road to a sustainable energy system. This implies new ways of generating and consuming energy as well as new forms of relations between the energy producers and consumers. The MATCH project contributes to the shift to a carbon-neutral energy system by zooming in on the changing roles of small consumers in the future electricity system (the “smart grids”).

The overall objective of MATCH is to expand our knowledge on how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. The study is cross-disciplinary and based on detailed studies of current smart grid demonstrations in Norway, Austria and Denmark. Through comparative analysis across cases and countries, the study identifies key factors related to technology, market and actor involvement in developing integrated solutions that “work in practice”.

MATCH also covers energy system analyses and modelling of scenarios to discuss the wider energy system implications of upscaling the studied cases and solutions. This is addressed in this report.

1 Introduction

This is the deliverable of work package (WP) 4 of MATCH. Its purpose is the presentation of the WP's energy system analyses, which are influenced by the previous work packages and related studies. The main aim is the analyses of the dynamic relations between different smart grid solutions for small consumers to provide recommendations on how to combine and integrate solutions on a system level. The outcome is a number of scenarios that visualize the system-related consequences of combining different solutions.

Specifically, the case studies from WP2 describe various technological solutions in relation to consumer involvement [1]–[3], of which the core characteristics are the focus in WP4. Therefore, the energy system analyses in WP4 investigate the technological aspects rather than the social involvements. However, society and consumer can shape the energy system as much as the technologies which supply it. If demand side management on the consumer side is a result from the demonstration projects, it would influence the energy systems as well.

The scenarios of this WP aim at the evaluation of the various technological solutions from the case studies in Austria, Denmark and Norway. With different energy systems, markets and stakeholders involved in each region, technological solutions might have different impacts on the overall energy systems of the three countries. The resulting comparison can point to strengths and weaknesses of certain technologies, of the combination of technologies with markets or actors, and of regions with different energy systems. Furthermore, it touches on the question if certain combinations work better than others and under which circumstances. Finally, the consequences of upscaling or rescaling the solutions to other contexts are explored and what lessons can be learned. This can lead to interesting conclusions for others studying smart grid approaches.

As part of the MATCH project, the main areas of "markets", "actors" and "technologies" are included to the best extent. While markets influence not only decision-making processes, it can have impacts on the evaluation of technological solutions, such as feasibility and pay-back times. In the energy system analysis, a market perspective can be applied to evaluate this further. The actors, on the other hand, do not have a direct influence on the analysis, but are rather part of the decision process, which leads to the choice and implementation of technologies. As pointed out in the first Deliverable of MATCH [4], technology is *an integral element of society, which means that we cannot analyze society without a view to technology*. Finally, the technologies form the main area of this WP and are evaluated in various scopes and several scenarios. This is done with the energy system simulation tool EnergyPLAN, which evaluates them in regards to technical and environmental feasibility.

The last part enables a process-oriented view on smart energy system solutions. As practices and technologies are introduced and changed constantly, a thorough simulation of scenarios can adapt to this. It, furthermore, shows how solutions can work from a technical view, excluding the influences from markets and actors, such as business and personal views. While the technologies' role, interpretation, understanding and consequences are evaluated in WP2 and 3, this WP4 aims to include the impacts for the energy systems. The technological approaches from MATCH that are focused on and can be analyzed are:

- Demand side management and demand response solutions (for demand reductions or shifts)
- Micro-generation (on consumer side)
- Storage technologies

The tool for creating the scenarios around these approaches is defined and explained in Chapter 2. Here it becomes clear to which extent the interaction and acceptance of technologies with the social and the market level influence the analysis or not. The three approaches are further discussed in Chapter 3 in relation to the outcomes from the case studies as well as in relation to the further analysis. The result is presented in Chapter 4 with three main energy system analyses (ESA 1-3), after which Chapter 5 sums the report up with a discussion and conclusion.

2 Modelling tool

This chapter presents the approach to the energy system analysis in general and in the specific case for the MATCH project. Therefore, general steps, characteristics of the energy systems simulation tool and the connection to the components of the MATCH study cases are presented. An energy system analysis aims at the investigation and evaluation of factors or technologies that aim at improving a part of the energy system, while simultaneously influencing the whole system. The impacts of smart grid solutions, for instance, not only affect the electricity sector but also the heating sector and the transport sector, thus these are also to be analyzed from a holistic energy systems approach. Energy systems with a strong integration between sectors may be denoted smart energy systems.

In a smart energy system there is a focus on the exploitation of synergies in the energy system to ensure high efficiency and feasibility. They additionally aim at 100% renewable systems - including a sustainable use of bioenergy. A sole focus on the electricity sector (as with a smart grid) is advised against as it could lead to the requirement of expensive storages and flexible demand solutions instead of integrating the electricity sector as part of the smart energy system, where electricity surplus and deficits can be managed through heating, industry, gas and transport technologies.[5]

The operation of a (smart) energy system can be simulated with EnergyPLAN [5]. EnergyPLAN includes demands in the electricity, heating, cooling, industry and transport sectors, production and storage technologies, and technologies integrating different sectors. It performs the simulations of the energy system on an hourly basis. Being in line with MATCH's aim of *improving energy efficiency and replacing fossil fuels*, EnergyPLAN is designed to coordinate the various demands with the utilization of renewable energy and conversion technologies with the potential to replace fossil fuels or improve efficiencies in the system. *"Consequently, the EnergyPLAN tool can be used for analyses which illustrate, e.g., why electricity smart grids should be seen as part of overall smart energy systems"* [6]. In the MATCH project frame, this includes smart-grid technologies, such as demand side management solutions, micro-generation and storages.

The main focus of WP4 can be summarized as the analysis of the dynamic relations of smart grid solutions for consumers by investigating and showing how to combine and integrate solutions on a system level. The outcome is scenarios that visualize system-related consequences of different solutions. Using EnergyPLAN, the energy system(s) can be modelled in a simplified way, with the possibility of comparing different regulation strategies, as well as abilities to integrate and trade RES.

However, EnergyPLAN also has characteristics, which might limit the possibilities for the energy system analysis in the MATCH scope. It operates on a holistic level, encompassing all sectors and focuses on connections between the different energy sectors with some level of aggregation. The MATCH case studies, on the other hand, primarily focus on single constellations of technological solutions with some level of detail. This WP goes beyond the sociological perspective of previous WPs by adding the system perspective. It models energy supply and demand on an aggregated level, representing various production and demand units of a particular technology typically by one unit, while not investigating all single units individually. Here, the up-scaling of the various approaches becomes important.

Furthermore, the scope of analyses in EnergyPLAN varies typically from small town to national models, excluding smaller system set-ups like single buildings. Specifically, EnergyPLAN works well for municipalities and cities that have various interrelations of sectors. This is done on an hourly basis for a full reference year, taking into account seasonal and daily variations, which enables detailed studies. For the MATCH analysis, national models are therefore analyzed with up-scaled versions of the various small approaches that proved successful in the case studies.

Finally, the energy system simulations in EnergyPLAN can be done in a technical or economic optimization approach. Usually, the technical simulation is chosen when focusing on energy balances, CO_2 emissions and excess electricity production, or when focusing on the technical possibilities of future energy systems. Alternatively, a market exchange simulation focuses on the economically optimal exchange strategies where dispatchable units are operated on an external electricity market. With MATCH emphasizing energy efficiency and replacing fossil fuels in future energy systems, the technical simulation is chosen.

An overview of energy sector relations that EnergyPLAN can simulate is shown in the energy system overview in Figure 2.1. While some of the units presented are only used in specific cases, the supply and demand of electricity, heat and transport present the basic energy system cornerstones. Additionally, the technological approaches suggested in MATCH can be addressed through the drop-down menu of the different tabs on the left, as illustrated in the same figure.

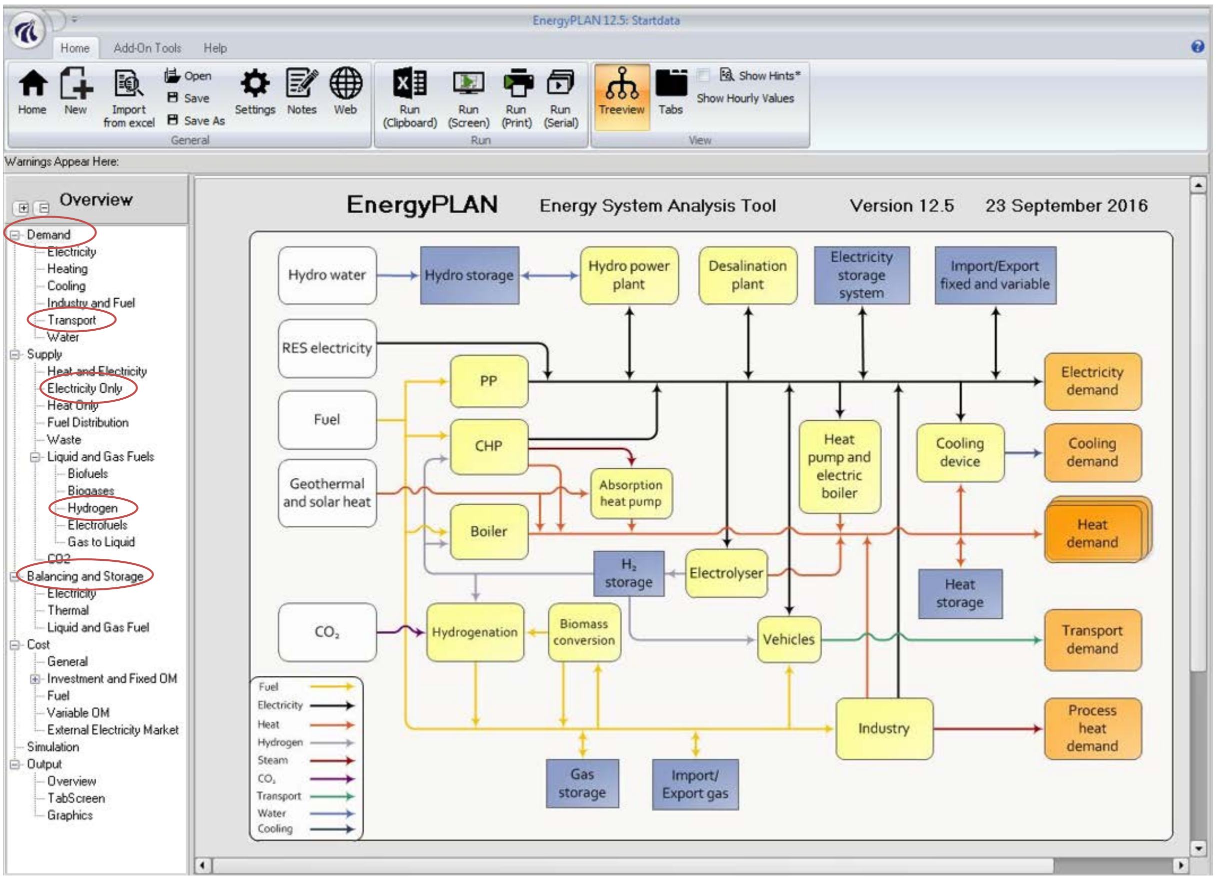

Figure 2.1: Energy system overview in EnergyPLAN and MATCH approaches possible to analyse

Concluding from the previous WPs, new components that are part of the MATCH project include changes in the demand (DSM), changes in the transport demand through additional Electric Vehicles (EV), supplying electricity with Photovoltaics (PV) through micro-generation, hydrogen as alternative fuel as well as storage solutions, both electric and thermal. Their variation, interaction and dependencies can be tested and evaluated in the system through EnergyPLAN.

The MATCH solutions can be tested and analysed by adjustments of the corresponding energy supplying units or demand profiles. Demand side management and response solutions for demand reductions or shifts can be analysed by defining the hourly demand profiles, which EnergyPLAN employs to model demand and seeks to furnish the supply to. Lower demands in general or in the peak hours would result in lower fuel demands and emissions for the energy system supply. As transportation is part of demand, an increase in EVs could simultaneously lead to less fossil-driven cars. Micro-generation, for example PV systems, can be added in the electricity supply section in EnergyPLAN. The additional approach of hydrogen addition to an energy system, as it is addressed in the case study of a Norwegian wholesaler, is a further conversion and supply technology. The final MATCH approach of storage technologies is addressed in the balancing tab, where electric battery systems are classified with capacity and discharge/charge powers. However, these are modelled to balance the total energy system, not individual users privately. The focus areas from the previous MATCH investigation are explained in more detail in the following.

3 Focus areas/shaping modelling approaches

In the following, the three general main technological approaches are discussed in greater detail. Afterwards, the study cases are related to the individual approaches to give an overview of what is applied where. Based on that, the outline and approach of the energy system analysis is presented.

The first approach is **demand side management and demand response** (DSM/DR), which addresses the demand side of the energy system: the customer or consumer. The idea is that with various metering and feedback technologies, awareness is raised on the consumers' side, leading to possibly altered practices or reduced energy usages. This can be supported by remote control of cooling/heating devices in relation to the current markets or simply by education of the consumers.

A good example is the approach the Samsø Energy Academy took with shops and businesses, analyzing possible energy efficiency measures and options for demand management. Next to others, consumption was suggested to be shifted to off-peak hours for a small dairy farm. Energy saving actions were proposed for off peak hours in shops and supermarkets, for example nightly temperature setback. Similarly, ProjectZero in Sønderborg, Denmark, addresses shops, public facilities and other buildings with efficiency measures, such as efficient light bulbs or natural ventilation supporting the heating and cooling demands. In addition, PVs in combination with EVs and/or heat pumps (HP) in households was investigated. In the case of the island of Fur, Denmark, households invested in PVs, which are categorized as micro-generation, in combination with batteries, which are storage technologies. The result is an alteration of the demand side through monitoring and response of local production and consumption, connected to changing their own consumption patterns. This shows how some of the MATCH approaches are closely related and might not be able to be analysed separately. [2]

Similarly, the involvement of the consumer in the demand side management was addressed in the Austrian and Norwegian cases, which often led to improvements [1], [3]. However, no concrete results were documented on what these approaches would look like in a larger scale or a longer timeframe. For an energy system analysis, the management and response on the demand side can therefore best be analyzed with a changed demand profile in the EnergyPLAN models. As discussed, the integration of PV and EV can be considered a contribution to DSM, which is both strongly represented in Austria and Norway.

The second general approach is the **micro generation** in relation to create and support a smart grid as part of a smart energy system. Most commonly, the investment in PV panels is considered within the MATCH study cases, but also a small combined heat and power plant (CHP) in the Rosa Zukunft project in Salzburg, Austria, and a hydrogen production facility in Norway are included. This can be evaluated with the energy system analysis, as the production and supply of other energy types, such as electricity from power plants (PP) or fuel for transport, can be influenced.

PV panels, on the other hand, influence not only the consumers' demand from the grid (DSM, DR) but also feed into the grid when the electricity production exceeds the local demands. Micro generation with PV is addressed in most of the study cases as Table 3.1 shows. Some exceptions are Rosa Zukunft and some of the approaches on Samsø and in Sønderborg, as they do not directly focus on this topic, but DSM as explained above.

The final approach refers to all the **storage** possibilities that were investigated in the MATCH study cases. These vary from battery electricity storages to heat and hydrogen storages. Some studies also consider the batteries of EVs as storage options, where EV batteries are also used for electricity supply (vehicle to grid (V2G)). In Vorarlberg, some stationary electricity batteries were made out of old EV batteries, while the other listed batteries in Table 3.1 are common residential batteries of typical sizes for households, often in connection to PV systems. Heat storage is only applied at the Rosa Zukunft project in combination with CHP and HP, and hydrogen storage results from the local hydrogen production from the Norwegian wholesaler Asko, making them both very specific storage solutions.

Table 3.1: Variation of MATCH approaches in study cases

		DSM/DR	Micro generation	Storage technologies
Austria [1]	Köstendorf (Salzburg)	Smart meters, DR	PV	EV/Battery
	HiT Rosa Zukunft (Salzburg)	DR, Energy efficiency, HP	CHP, PV	Heat storage
	Vorarlberg (VLOTTE)	/	PV	EV/Battery
Denmark [2]	Fur	Smart meters	PV	Battery
	Samsø (NightHawks)	Smart meters, Energy efficiency	/	/
	Sønderborg (ProjectZero)	Energy efficiency	PV	EV
Norway [3]	Trøndelag (Demo Steinkjer)	Smart meters	PV	/
	Hvaler	Smart meters, DSM	PV	EV
	Asko wholesaler Midt Norge	/	PV, Hydrogen	Hydrogen storage

All three solution areas include proven technologies to some extent, but in various scales and scopes. In order to make energy system analyses, the relation to the specific study cases as presented in Table 3.1 is not directly utilized, but general findings are chosen and evaluated for three different regional areas: an Austrian, a Danish and a Norwegian case. For these national cases, successful solutions are modelled as they were applicable in the respective countries of the case study, but successful solutions of one country are furthermore analyzed for other countries as well to see their replicability in other frameworks. More details on this follows in the next section.

3.1 Areas of investigation

The individual investigations of the different approaches take their point of departure in the most successful or most common study cases for each of the studied countries. While these are analyzed on the national scale, the second step is the investigation of its success in different national contexts. Table 3.2 illustrates the idea, where the various national cases are formed into three approaches to be adapted to the whole country and afterwards to the two other countries.

Table 3.2: MATCH approaches to be analyzed

<table>
<tr><td></td><td colspan="3">DSM/DR - Micro-generation – Storage technologies</td></tr>
<tr><td>Austria reference model</td><td rowspan="3">Austrian approach (Applied micro-generation and storage: CHP; HP; PV, heat storage)
↓</td><td rowspan="3">↑
Danish approach (Applied DSM/DR and micro-generation: PV, tariffs, energy efficiency → demand shift)
↓</td><td rowspan="3">↑
Norwegian approach (Applied DSM and storage: EV)</td></tr>
<tr><td>Denmark reference model</td></tr>
<tr><td>Norway reference model</td></tr>
</table>

As described before, PV is often a complimentary technology in addition to other solutions in the case studies. Since it is furthermore a rather well known technology with a predictable outcome, it is not further included in all of the approaches. Only the Austrian case includes actual PV capacity increases.

The Austrian case – to be known as Energy System Analysis (ESA) 1 – reflects the idea of the Rosa Zukunft study case with a focus on its (micro-) generation and storage qualities. For this case, the heating sector is also addressed next to the electricity sector. This is due to the considered increase in the district heating (DH) share by implementing CHP and HP on a larger scale. While Rosa Zukunft's idea is about micro-CHP and building-size solutions, the ESA1 scales this up to a national scale, resulting in using the general term DH, even though Rosa Zukunft technically is not. To evaluate the feasibility of the HP, an additional PV capacity is added. Whether having several micro-CHP or a few large CHP will give the same results in EnergyPLAN due to its aggregation, as explained in Chapter 2. [7]

The Danish approach (ESA2) focuses on the DSM and DR ideas, which are strongly represented in the Danish cases, but in general all countries know about its importance and therefore, a widely known approach is considered in the second approach: time shifts in the electricity consumption. This is also partly discussed with possible dynamic/variable electricity tariffs and with the aim of peak shaving. While PVs are not added in this analysis, the effect of PVs making homeowners shift their demands is indirectly represented, by reducing some of the demands, which would have otherwise occurred in the evening hours.

The third ESA approach evolves from the Norwegian trend of increased EV usage affecting their energy system [8], but also from an increased focus in other countries and in various constellations, such as private, public or commercial transportation. With EVs playing a minor role also in other countries, the implications of this technology, also as a possible storage option, becomes interesting to study in the various national contexts.

All three approaches can also be recognized in the other study countries to various extents. For example, the case study of Hvaler, Norway, includes not only the plans to roll out a high number of charging stations for EVs, but also the introduction of power tariffs, which resembles the "Danish" approach [3]. In addition, EVs have played an important role in Austrian case studies and appeared in studied areas in Denmark as well. Electrifying the transport sector is thereby addressed through ESA3.

Table 3.3 presents the idea of the various energy system analyses (ESAs) and their relations to the core MATCH points: Markets, actors, technologies; specifically DSM, micro-generation and storage. Each of the ESAs presents a different combination of MATCH's focus areas and targeted technologies.

Table 3.3: Overview of energy system analyses regarding focus areas and technologies

	Markets	Actors	Technologies:	*DSM*	*Micro generation*	*Storage*
ESA1	Heat and electricity (prices)	-	CHP, HP, PV	-	PV (CHP, HP)	Heat storage
ESA2	Electricity	Interaction partly required 5-10%	(only indirect)	Peak shifts (based on PV, tariffs, "efficiency")	-	-
ESA3	Electricity	EV owners	EVs, Smart Charger, V2G	EV charging hours	-	V2G

To investigate these approaches, the national reference models are adjusted and comparisons of the three energy system analyses with the reference are made. The evaluation concentrates on the impacts on changed fuel consumption, CO_2 emissions, import and export balance. The questions that will be answered are:

> *How do the case studies work in different energy systems? What do they do to the rest of the energy system? Where does what work best or worse and why?*

4 MATCH approaches on a national scale

Based on the before-mentioned successful approaches from the various study cases in Austria, Denmark and Norway [1]–[3], as well as the limits presented, this chapter focuses on the resulting energy system analysis of the three countries.

For comparability with the existing national energy systems and to model close to reality, the models are based on reference scenarios from 2015. These function as baseline models, to which the MATCH approaches are applied and analyzed. The application of the national models of Austria, Denmark and Norway enables a thorough investigation of the approaches through the different national energy system layouts.

Each represents a different energy system layout. Denmark has a lot of CHP, wind turbines and DH; Norway has a lot of hydro power, though its flexibility relies to a large extent on seasonal demands and precipitation, and a large share of electrified heating; Austria is also well-equipped with hydro, but also conventional power plants (PP), and has a more dense population than the other two countries. The main characteristics are presented in the following section.

4.1 Reference energy systems

While some things do not influence the MATCH analysis, they nonetheless play a role in the set-up of the energy system and explain not only the current system but also the possibilities for future energy systems. While an energy system is made up of more than the electricity sector, as explained in Chapter 2, the following addresses mainly that sector as well as the heating sector as MATCH operates mainly within these. The complete systems' details of the fuels consumed and capacities available are found in Table 4.1.

With the largest population of the three study countries with 8.8 million inhabitants, Austria's electricity production is only the second highest with 66 TWh, but the largest heat production of 73 TWh. The DH share in the reference model is 29% and the renewable energy contribution to the primary energy supply (PES) is just below 21%, while the electricity sector is supplied with 54% RES.

Denmark represents the medium country in terms of population (5.7 million), but the lowest in electricity and heat production: 37 and 56 TWh respectively. The comparably highest share of 47% of heat supplied through DH is connected with a large CHP capacity. The RES share of the PES reaches above 31%, which increases to 42% RES for the electricity supply.

Norway is the country with the largest land area, but with the smallest population of 5.3 million people. The high electricity consumption is closely related to the heating sector, as Norwegians use a lot of electric heating, which again is comparably high due to the colder temperatures. Therefore, the total electricity production in Norway is 141 TWh and heat production is 60 TWh. The DH share is a modest 9% in the reference model and the renewable share of PES is about 29% due to large hydro power capacities. Electricity-wise, Norway produces more renewable energy than it consumes itself (108%).

Figure 4.1 and Figure 4.2 compare the electricity and heat supply for Austria, Denmark and Norway, pointing out the large contribution of hydro power in Austria and especially Norway, as well as the other supplying units and fuels. Regarding the heat supply, Figure 4.2 presents the share of DH in comparison to individually (indv.) heated buildings and the respective fuels or technologies.

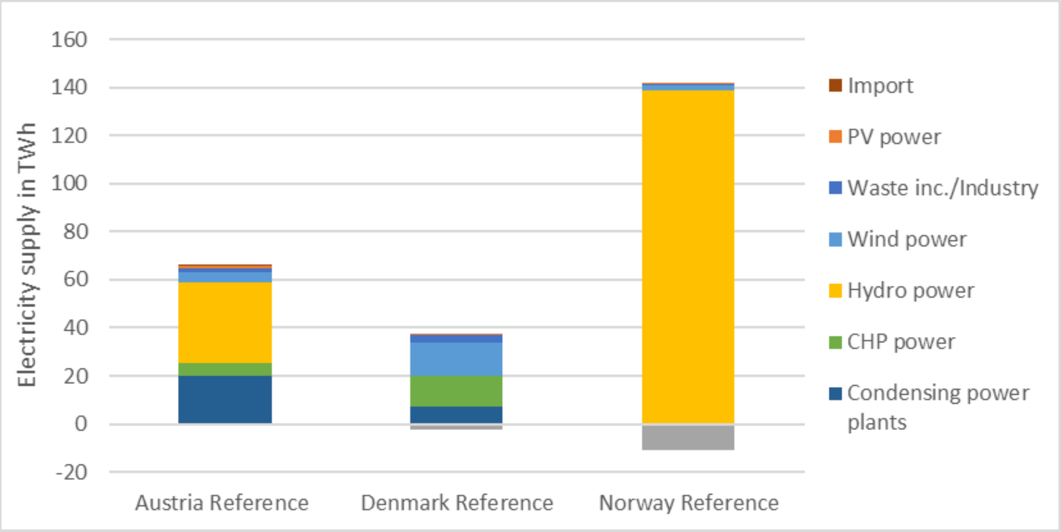

Figure 4.1: Electricity supply by type and country

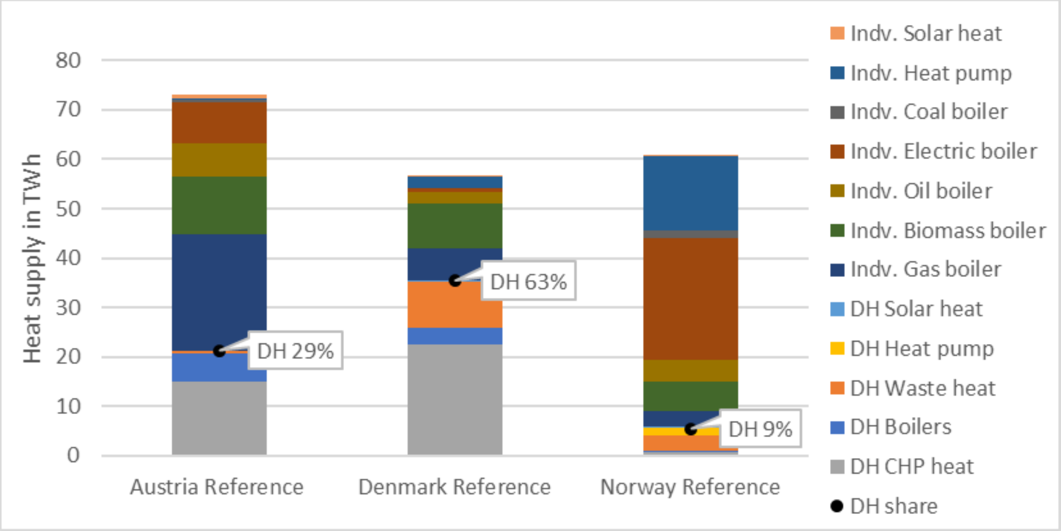

Figure 4.2: Heat supply by type, incl. DH shares, and country

Besides the RES, the power production in Austria is mainly supplied via natural gas, then coal, namely 53% natural gas and 44% coal in in condensing PPs and 44% natural gas and 47% coal in CHP plants. In Denmark, biomass also plays an important role. Next to 63% coal used in the condensing PPs and 57% coal in CHP, biomass is used with 28% and 30% in PPs and CHP respectively. In Norway, the power production from PPs plays generally a minor role, see Figure 4.1, and the also small CHP units are supplied 100% with natural gas. Some details of the three reference systems can be seen in Table 4.1. More details on the energy systems, including various production units and fuel consumption, can be found in the Appendix.

Table 4.1: Overview of national reference models of Austria, Denmark and Norway

Annual modelled values	Austria 2015 reference scenario[1]	Denmark 2015 reference scenario	Norway 2015 reference scenario[2]
Inhabitants in million	8.8	5.7	5.3
Interconnection capacity in MW	12650	6005	8895
Electricity Import/Export in TWh	0.01/0.02	0/2.6	0/10.8
Electricity production in TWh	65.7	37.5	141.2
Heat production in TWh	73.1	56.4	60.1
DH share	29%	63%	9%
PP capacity in MW_{el}	8350	5617	0
CHP in MW_{el} CHP in MW_{th}	1093 2925	4801 8704	100 275
Total DH boiler capacity in MW_{th}	12017	12463	624
Wind capacity in MW	2143	5836	867
Hydro Power capacity in MW	10323	7	31372
PV capacity in MW	797	780	14
Total RES production in TWh_{el}	38.4	14.8	140.6
Coal consumption in TWh	50.9	28.8	16.3
Oil consumption in TWh	119.3	77.3	278.7
NGas consumption in TWh	100.8	36.5	89.5
Biomass consumption in TWh	30.6	50.2	14.1
RES share of PES	20.5%	31.4%	28.7%
RES share of electricity demand	53.9%	42.3%	107.7%
CO_2 emissions in Mt	70.0	39.3	98.3

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[1] Denmark and Austria Model by Various, HRE4, Aalborg University [9]

[2] Norway Model by K. Askeland and K. Bozhkova, AAU Master thesis, Aalborg University [10]

4.2 Energy system analyses

As presented in Chapter 3, three approaches are investigated covering the various MATCH ideas, study cases and beyond. Table 3.3 gives an overview over this. This chapter analyses how these ideas are implemented in the reference systems of Austria, Denmark and Norway presented above. The impacts in each of the countries are presented and compared, while Chapter 5 will give a final discussion and conclusion of the analyses.

4.2.1 ESA 1 – CHP and/or HP replacing individual heating with PV support

The technological choice of increased CHP and HP capacity addresses not only the heat supply, but also the electricity supply due to the dependency on the electricity market and prices. The idea results from the Rosa Zukunft study case in Salzburg, Austria [7] and is slightly modified to fit into the first ESA. While Rosa Zukunft focusses on micro-CHP and a building-size solution with various living units in the building, the upscaling of this approach leads to the investigation of DH being the main idea, being supplied with CHP and HP with the support of PV. In terms of aggregated system modelling using EnergyPLAN, there are no differences between modelling multiple micro-scale system or fewer small-to-medium-scale systems.

The main idea is on the one hand to lessen dependency on import from other power or heat producing facilities or countries by increasing self-sufficiency with local and renewable resources. At the same time, CHP and HP are energy efficient technologies that in e.g. Denmark already play an important role in the transition to a sustainable energy system.

Electricity production from CHP can replace production on condensing mode power plants (PP) and replace or support boilers and other heating technologies, depending on the demands of electricity and heat. For this purpose, the heat should be supplied through DH, therefore, this is simulated in the ESA1. For Austria – and afterwards also for Denmark and Norway – 10% of the individual heat supply is upgraded to DH, targeting the individual oil and gas boilers. The corresponding capacities of CHP and HP are aligned with the peak demands for these additional 10% by studying the annual and hourly demand profiles.

Regarding MATCH, this approach addresses markets and technologies, namely (micro-) production and storage. The PV panels are considered to supply electricity for the HPs, which otherwise buy electricity when it is cheap / use electricity when appropriate from a systems perspective. Alternatively, heat can also be supplied through CHP. The PV production and electricity prices, therefore, influence if electricity should be sold, bought or produced. However, PV production is known to be in an opposing cycle to the heating season, so even if the PV capacity is increased by 25%, the question remains about its suitability in this set-up of increased electricity demand for the HPs.

Ideally, this double-investment (CHP and HP) might be cheaper due to this resulting flexibility, but how does it look from the system's perspective in a technical analysis? In EnergyPLAN, the simulation primarily uses renewable energy sources and secondly technologies according to fuel efficiency, meaning where the least fuel would be required. Finally, the electricity prices are not relevant from the technical simulation's perspective. However, the utilization of the CHP (and likewise the HP) depends therefore strongly on the local energy system, specifically available RES, existing CHP capacity and PP characteristics.

Due to the currently existing fuel supplies for PP/CHP, the resulting DH supply will be covered differently in each country as the same fuel shares are applied as used in the reference models. Adding a marginal contribution of extra CHP in a system means that even if the new capacity is higher or more efficient, due to the aggregation, these effects will not be visible in the EnergyPLAN simulations. At the same time, when the HP relies on electricity, the existing market conditions influence and are influenced by its operation. While Austria currently relies by 46% on fossil fuel for its electricity supply, Denmark's electricity demand is covered by 58% by fossils still and Norway produces more renewable electricity than it can use (108%).

Concluding, the analysis addresses an increase of PV capacity of 25% and a transition of 10% individual (fossil-based) heating to DH based on CHP and large-scale HP. For comparison reason, the CHP is afterwards removed to see the result if the focus was on PV and

HP alone, as this would cause the HP to increase its operation and give further information about the capability to increase HP vs. CHP.

Figure 4.3 presents the CO_2 emission, the electricity and the heat supply by technology for the mentioned CHP/HP scenarios in comparison to the reference systems for each of the three studied countries. The details can be found in the Appendix with all the results, while the highlights are as follows:

CO_2 reductions always max 1.35% (if DH would be biomass or RES electricity-based, this could be better)
HP operation very different in each country (see graph)

Austria

- DH share increased from 29 to 36%
- With both CHP and HP
    - heat production mainly on CHP (5 TWh compared to 0.2 TWh)
    - fuel consumption and CO_2 emission lowest
    - Reduces power production from condensing PP
    - Exports more electricity, import 0
- With only HP
    - Coal increases due to higher electricity demand, import required
    - Indv. Heating fuels similar to fuel demand for HPs (almost no CO_2 reduction)
- There is a demand for CHP or better electricity supply for HP

Denmark

- DH share increased from 63 to 67%
- Both CHP and HP
    - HP-based heat production increases more than CHP (+1 TWh from CHP and +2 TWh from HP)
    - More CHP enables more RES integration (flexibility), less export
    - CHP reduces electricity from PP and heat from boilers
    - Lowest CO_2 emissions
- Only HP
    - increases electricity demand, which is provided with (existing) CHP and the additional DH demand can be partly covered with existing CHP and the new HP (+0.8 TWh from CHP and +2.1 TWh from HP)
    - Also reduces export to same extent
- electrification to a certain extent good, but DH increase can also be covered with existing technology

Norway

- DH share increased from 9 to 18%
- CHP/HP both utilized (+3.4 TWh, +1.8 TWh)
    - The additional electricity from CHP is mostly exported (export +20%)
    - Boiler and storage use minimized
- Only HP
    - reduces export (-10%) and increases heat production from existing CHP slightly (0.05 TWh), rest covered by HP
- CHP can be implemented, but HP can be better regulated with the existing hydro power

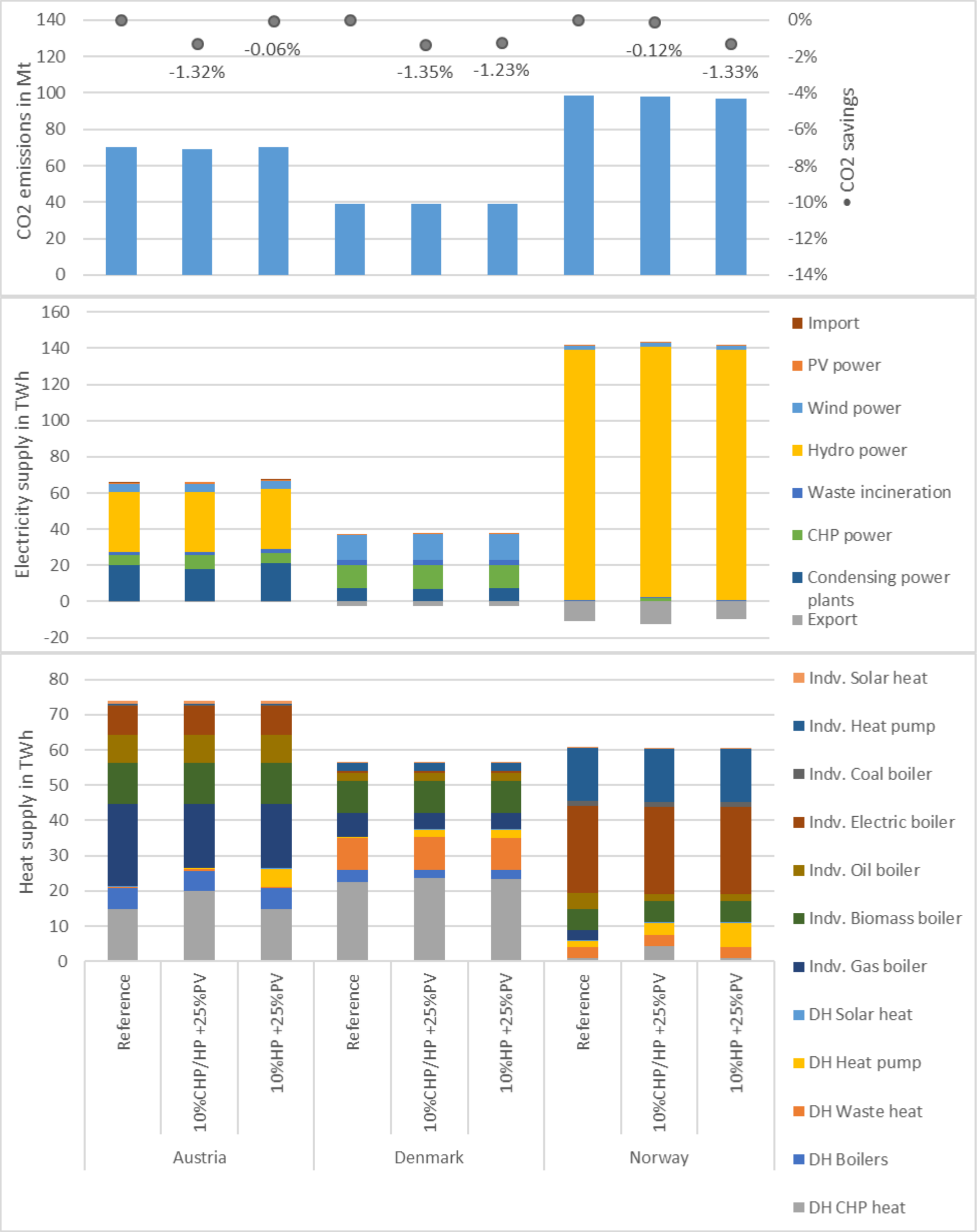

Figure 4.3: Electricity and heat supply by technology for DH scenarios, incl. CO_2 emissions

4.2.2 ESA 2 – Electricity demand time shift based on DSM

As described in Chapter 3, the idea of addressing energy issues through DSM and DR is a widespread idea, which can take its point of departure in various ways. DSM often refers to improving the management of both electricity and heat demands, addressing the high periods of demands or the general idea of demand reduction through energy efficiency.

While leaving the general reduction of demands aside, the peak demands are preferably approached as they often relate to back-up units to provide electricity and heat in the short term under fuel-intense processes. Peak demands are often (thought to be) in evening hours after work due to routines involving household appliances, such as cooking, washing and entertainment. All three countries typically have the highest values in four-hour blocks, e.g. 17:00-21:00 (20:59), when looking at the hourly profiles of a few days in the beginning of the year in the reference models of the selected countries. For this, see Figure 4.4, specifically for the January graphs.

Some of the peak shaving can be addressed through generally efficiency (reduction) measures or – more specifically – batteries in combination with PVs or price tariffs addressing these potentially problematic hours. This approach therefore represents the ideas and discussion of representatives of the study cases of Sønderborg, the idea behind Fur or the ideas from Hvaler, where higher prices in peak hours should encourage the consumers to reduce the energy demand in these periods [2], [3]. No matter what the reason behind the DSM, this ESA2 tries to solve the question if a “simple” DSM measure such as this shift is suitable in every context.

Now, the peak is not always at the same time on the different weekdays and in different seasons, but would the tariffs adjust every day or stay fixed? Can the consumer be expected to always stay up to date to the current peak tariffs? Experience from Rosa Zukunft show that residents are not overly content and a negative response can be assumed, therefore, the DSM approach of addressing 17-21:00 is assumed fixed here (so-called static time-of-use pricing), as it makes most sense for consumer acceptance, understanding and regulation.

In an optimal case, the reduction on the residential side can reach magnitudes of 10-30%, depending on the energy system and the shares of other consumers. This leads to an average of 5% of these peaks to be reduced (of the total national electricity demand, incl. residential, commercial and industrial demands, but excl. transport, heating, cooling). This reduction can entail processes, such as dishwashing, laundry or car battery charging to be moved to the night hours 23:00-6:59.

Figure 4.4 shows the 48-hour spans of two days in January and in July for the studied countries, where this approach is analyzed. In January, the peaks are in the evening hours, as mentioned above, but also partly around noon as a typical increase in demands due to lunch preparations. In the summer, such as July, peaks are actually in the morning/noon, partly because the winter demands for lightning and heating are reduced and because of the increase in consumption in the morning from starting daily operations at work and at home.

The dashed lines in the figure present the possible impact the tariffs from 17-21.00 could have. With different total electricity demands, also the 5% shares vary, as can be seen in the magnitude of Norway’s DSM approach. As can be expected from this graph, the “simple” DSM might not have solely positive impacts as the summer peaks are (mostly) missed with this approach – so does it still make sense to move demands to the night? How does the energy system react to this idea?

Next to the 5% approach, a sensitivity study of 10% is added to clarify and amplify the impacts such actions could have. While the details of this analysis can be found in the Appendix, Figure 4.5 presents the two approaches in comparison with the reference energy systems.

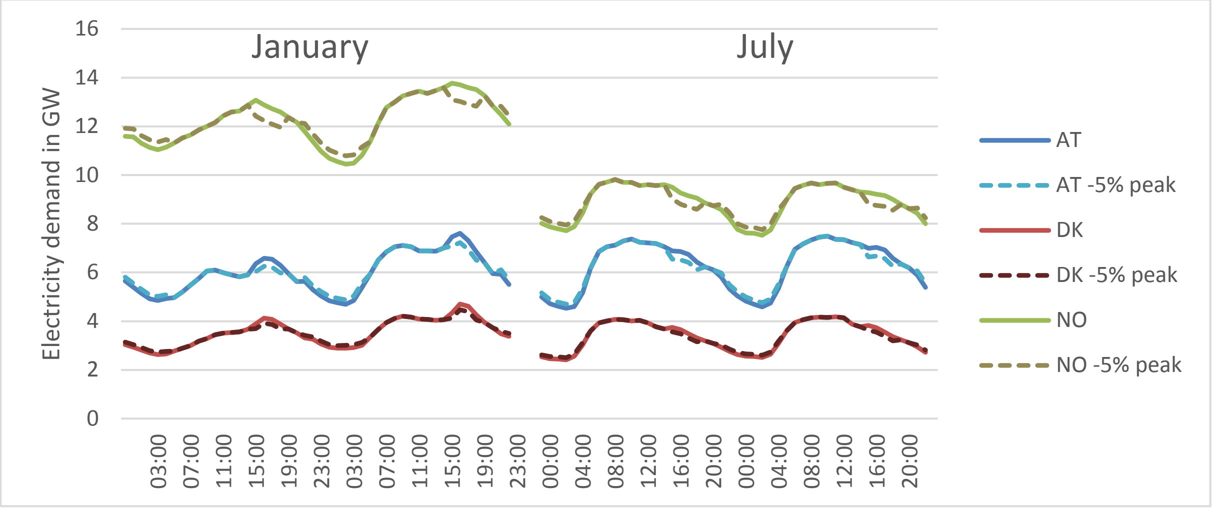

Figure 4.4: DSM approach illustrated by electricity demand profiles for 48 hours in winter/summer before and after peak shift

The highlights of the results (referring to 10%, even though that is not the realistic case, but points to general trend and insignificant changes in the 5%-shift):

Austria

- CO_2 reductions by 47 kt/year (-0.07%)
- Decreases fuel consumption by 210 GWh
- More hydro power can be used
- Export decreases
- PPs need to run less
- Instead, CHP run more and also provide a little more heat, so less heat from boilers

Denmark

- CO_2 reductions by 48 kt/year (-0.12%)
- Fuel consumption -190 GWh
- Less CHP, less PP
- Less export
- Reduced CHP operation = more heat from boilers

Norway

- CO_2 reductions by 10 kt/year (+0.01%)
- More CHP, because Hydro is prioritized to supply the electricity demand (heat can also be supplied with CHP; HP is reduced)
- Hydro modelling is limited by the fixed storages at end/beginning of the year (same level)
- Compared to the reference, the shift reduction increases the electricity demand at hours, when there is also high heat demand (conflict of hydro supporting electricity and heating demand)
- More fuel +30 GWh (+0.01%) due to increased CHP operation

With alternative demand profiles, this could change easily (both alternative reference and new profiles, e.g. DK profile results in less conflict)

In Figure 4.5, it can be noticed that the CO_2 reduction is not as significant as in ESA1. Furthermore, the heat supply graph presents only the DH supply, as the individual heating is not affected.

While Figure 4.5 indicates only minor implications of this approach, the details in the tables in the Appendix show small improvements for each of the countries, incl. reduced fuel consumption in Austria and Denmark, while the demand shift is not as flexible in Norway.

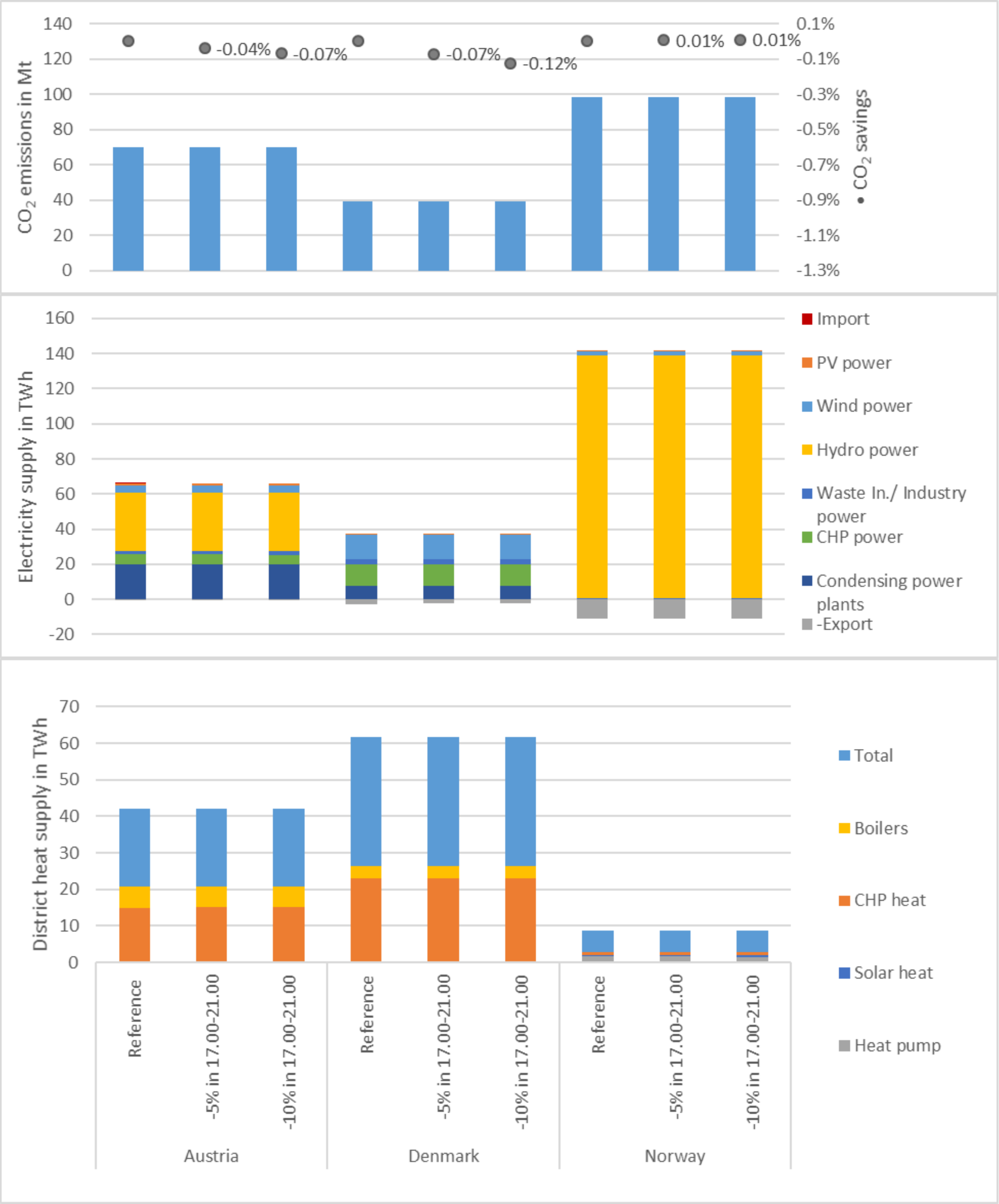

Figure 4.5: Electricity and DH supply by technology for DSM scenarios, incl. CO$_2$ emissions

4.2.3 ESA 3 – EVs and charging variations: dump/smart/V2G

After the micro-generation with heat storage and the DSM focus through peak shifts in Sections 4.2.1 and 4.2.2, this section is focusing on EVs as a contribution to the demand side through increased electricity consumption, but also as a possible contribution to electricity storage through the V2G option. While several of the study cases investigate EVs, batteries and charging options, the Norwegian situation has the most influence on ESA3. [8]

EVs are a technology with possibly high impacts and interactions with the systems, markets and the consumers. Depending how the trend develops, its growth can have large implications on the energy system, depending on its configuration, but even more so on the way the technology is integrated. Not only do the charging option and owner habits matter, but also the capabilities of the car batteries. Nonetheless, the EVs, either with or without V2G option, have a large impact on the electricity demand (and for countries with a large CHP share, also on the heating sector).

An important factor is the share the EVs would demand as part of the whole electricity demands. In ESA3, if EVs are to cover 25% of the driving demand (of total distances covered; not energy demanded), it represents 3-10% of the electricity demand in Austria, Denmark and Norway. As it depends on the registered transport needs in each of the countries' reference models, 25% are of very different magnitudes. Therefore, the electricity demand for 25% of transport to be covered from EVs in Austria, Denmark and Norway is 6.9, 3.6 and 4.0 TWh/year from the total electricity productions of 68.7, 40.3 and 141.3 TWh/year respectively.

When it comes to the importance of duration and ways of charging the cars, two main trends are analysed: firstly, constant dump charge and secondly, smart charge depending on the driving demand and when it is optimal to charge – taking the energy system into consideration – hence smart for the energy system and for the technology required. The difference of the two trends is shown with Figure 4.6, where constant charging and smart charging based on driving demand profiles are illustrated. The blue bars are hourly charging demands, while the red bars represent the hourly driving demand of two days in January. The latter one is resulting in changing charging profiles for every day under the smart charging simulation.

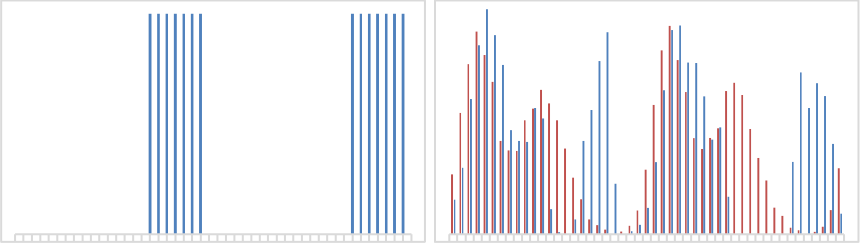

Figure 4.6: 48 hours of two charging profiles (in blue). Left: constant/dump from 17-24:00. Right: smart/ depending on the driving demand (in red)

The dump charging is often considered to take place during the evening/night time, starting from after work hours, as people return home and are able to plug the cars in for charging. Depending on the charger and car, this process could take a few hours and up to the whole night. In contrast, some studies may suggest that EVs could be charged during the daytime, when they are connected to a charger during the working hours. No matter which one is studied, the important factor is the fact that it takes place in a dump way, meaning no flexibility in the quantity of electricity required. The second option of charging takes place whenever it makes sense from the energy system's point of view and when there is a driving demand. This option takes several more factors into account, namely:

- Typical weekday, weekend driving demands
    - Whenever there is no driving demand, a certain share of cars can charge. Likewise, when the driving demand is high, the charging demand is low.
- Max. share of cars during peak demand 20%

- 70% of parked cars grid connected
- 90% charging efficiency

For this, the EVs need to be defined in more detail, including charging and battery capacities. In this ESA, the typical values of a Nissan Leaf are used: Capacity of connection is 6 kW per car and battery storage capacity is 21.3 kWh per car, resulting in total added capacities of 51, 27 and 29 GWh for Austria, Denmark and Norway respectively.

In addition to the smart charge option comes the V2G ability. For this, an additional discharge connection capacity 6 kW per car is added at a 90% discharge efficiency.

While the dump charge can take place in various ways, the one from 17-24:00 is considered the most likely and is therefore put in contrast to smart V2G charging. This can be seen in Figure 4.7, while Figure 4.8 present the various charging times and options for the Danish case as an example. As can be seen in Figure 4.8, the differences are minor and therefore, the focus is set on the two main contrasting options in Figure 4.7. The results are as follows:

The references have very few EVs, so compared to that, CO_2 is always reduced (0.6-3.7% for dump charged EVs and up to additional 1.7% reduction for smart/V2G)

From diesel to EVs: more electricity demand and increased PP, CHP reduction and therefore higher boiler share

Dump charge overnight adds in average the lowest demand on top of the electricity demand profile (charging is spread over 14h), this additional load is twice as much when charging time is shortened to midnight (7h) – daytime charging is over 8h, but adds up to daily demands, which puts strain on the already higher daytime demands (Figure 4.4)

- 8h daytime charging better than 7h night time charging but worse than 14h night charging for Austria and Denmark, but in Norway evening charging is the best, closely followed by daytime charging
- Smart charge not so good in Austria, good in Denmark and Norway
- V2G: Best results for Austria; Denmark only minor and Norway only smallest improvement

Austria

- Lowest CO_2 and fuel reductions (-1%)
- Electricity import increases for dump charge
- Hydro power production increases, raises the RES share of electr. demand from 54 to 58%
  - V2G balancing only used 0.03 TWh
  - Austria has some fixed export, fixed PP production, large electricity storage already (dammed hydro/storage: 4365/4793 MW capacity)

Denmark

- CO_2 and fuel reductions of up to 5.4 and 4%
- Electricity export reduced, V2G balancing utilized 0.51 TWh
  - Denmark has no hydro storage, so it can use the additional EV storage
- CHP operation increases with increasing electricity demand, therefore boiler heat production reduces

Norway

- CO_2 and fuel reductions of 3%
- Electricity export reduced by 35%, V2G balancing utilized 0.29 TWh
- No large impacts on the heating sector (no major CHP)
  - Norway has some storage in combination with the dammed hydro (1350/30020 MW capacity)

In Figure 4.7, only the two scenarios of dump charge (17-24:00) and V2G is presented, as explained above, due to the high similarity between the various dump charging alternatives and the two smart charging variations. The details of these, however, can be viewed in Figure 4.8 with the exemplary Danish reference system and all results from the dump and smart charge variations.

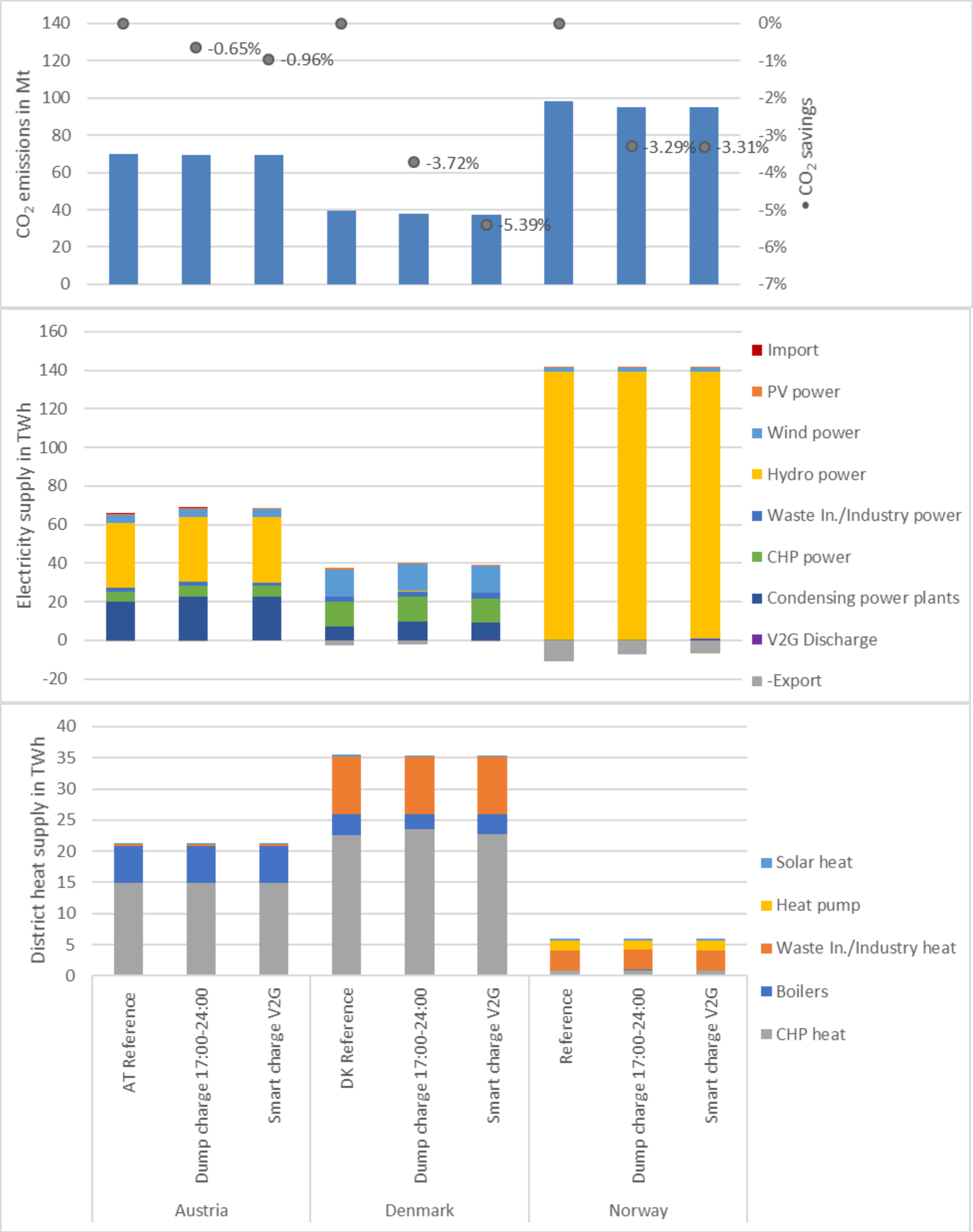

Figure 4.7: Electricity and DH supply by technology for EV scenarios, incl. CO_2 emissions

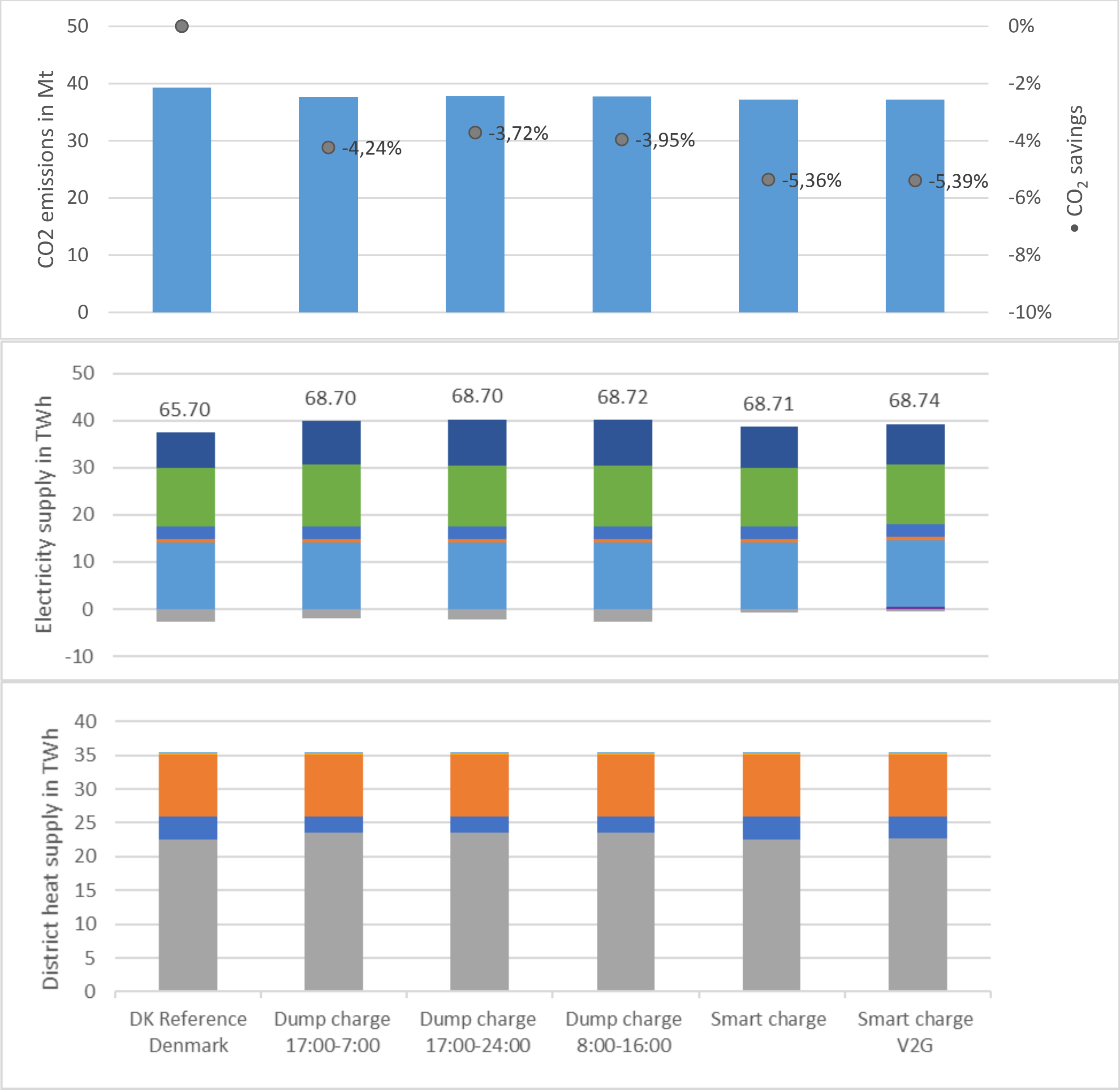

Figure 4.8: Energy supply by technology for EV scenarios in Denmark, incl. CO2 emissions (supplementary)

As can be seen in Figure 4.8, the three dump charge approaches result in similar values for CO_2, electricity and heat supply, as well as the two smart charge approaches. The first approaches already show a big increase in electricity demand, which effects the electricity production, and in the case of Denmark, also strongly the heating production. A main tendency from the second one is the advantages of V2G besides only focusing on the charging aspect. If the option exists, the V2G can enhance the results from smart charging, if this should be considered.

5 Discussion and conclusion

WP4 of the MATCH project focuses on the ESAs of the various suggested study cases and approaches from WP2. The results are presented in three areas of investigation: *ESA 1 – CHP and/or HP replacing individual heating with PV support*, *ESA 2 – Electricity demand time shift based on DSM* and *ESA 3 – EVs and charging variations: dump/smart/V2G.*

The ESAs show the dynamic relations of not only the different smart grid solutions, but also the impacts on the electricity sector and the heat sector, as seen from the national perspective. For this, the case studies are rescaled and extended to the national scale of Austria, Denmark and Norway.

The visualization of the system-related consequences of combining different solutions did not show clear tendencies of advantages and disadvantages of the different approaches, but rather the variation they can have in different contexts.

Generally, all approaches have the tendency to reduce CO_2 emissions and fossil fuel consumption, but not all improve the electricity exchange significantly, which is also an important indicator for a successful technology. Being able to supply a country locally without depending on other countries increases security of supply and stability in the local market.

While the energy systems analyses do not focus on the market implications – i.e. how the units will operate in an electricity market – the general costs for the systems also have a positive tendency, because for example fuels can be saved. This is added to the detailed results of each country in the Appendix, but should be regarded with some caution, as the simulation and its results (also the costs) are performed using a technical simulation strategy where the aim is to simulate the best load-following capability and most energy efficient operation of the energy system. For proper market simulations, actual hourly future prices would need to be known. However, the technical simulations presented in this paper give the correct indication of the future energy system's tendency nonetheless. This can be assumed since high shares of RES would also be reflected in generally lower electricity costs and hence economic incentives to use electricity on heat pumps and other units or use heat from a heat storage – and incentives not to produce on e.g. CHP units; just as the system also would operate in a technical simulation.

Regardless of the initiatives, due to a general electrification of the society, more electricity production capacity is required, preferable based on RES. With the current energy systems, the increased demands would otherwise lead to increased fuel consumption in the currently fossil-fueled production units, like old condensing-mode power plants. This is the situation for the reference systems of Austria and Denmark, while the impact on Norway would be the possible exhaustion of the hydropower production. While the renewable electricity production in Norway is currently above the local demands, the ESA3 reduces the excess production by 45% already, indicating a limit in the increase of electricity consumption without other improvements in the electricity sector.

Overall, the ESAs give an indication to regard seemingly good technologies and approaches more carefully. While HPs and EVs are considered in a positive light, they can have negative consequences on certain energy systems or constellations, shown in ESA1 and ESA3. In addition, the DSM idea of aiming at peak reductions should be well considered, as presented in ESA2. Energy planners and decision makers need to take hourly demands, seasonal changes and the possible consequences of certain DSM approaches into account. The complexity of different technologies and approaches in different energy systems is shown with this MATCH WP4 by evaluating the same ideas in different contexts. This directs to the importance of carefully designing and evaluating markets, actors and technologies.

In general, however it may be concluded: that the CHP DH combination has a role to play particularly in the Austrian energy systems; that HPs are well-suited in the Norwegian context and that EVs must be well integrated using smart charging and possibly also V2G facilities – as proven valuable for Denmark – to minimize negative impacts and maximize positive impacts on the electricity system.

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Appendix

Austria EnergyPLAN model Annual modelled values	Reference	ESA1		ESA2		ESA3	
		10%CHP/HP +25%PV	10%HP +25%PV	-5% DSM in 17.00-21.00	-10% DSM in 17.00-21.00	Dump charge 17:00-24:00	Smart charge V2G
CO2 emissions in Mt	70.026	69.107	69.982	69.999	69.979	69.57	69.355
RES share of PES	20.5	20.8	20.6	20.5	20.5	20.6	20.8
RES share electr. demand	53.9%	54%	53%	54%	54%	52%	58%
Fuel consumption	**301.49**	296.54	299.91	301.37	301.28	299.45	298.71
Electricity production	**65.71**	**65.85**	**67.42**	**65.71**	**65.72**	**68.66**	**68.74**
Heat demand	**73.09**	73.05	73.05	73.04	73.04	73.04	73.04
DH share	29%	36%	36%	29%	29%	29%	29%
Import	0.01	0	0.01	0	0	0.06	0
Export	0.02	0.09	0.01	0.01	0.01	0.02	0
Electricity production & demand (TWh)							
RES1 (Wind onshore)	4.11	4.11	4.11	4.11	4.11	4.11	4.11
RES2 (Wind offshore)	0	0.21	0.21	0	0	0	0
RES3 (PV)	0.83	0.83	0.83	0.83	0.83	0.83	0.83
RES4 (River Hydro)	11.6	11.6	11.6	11.6	11.6	11.6	11.6
Dammed Hydro	21.87	21.85	21.89	21.9	21.93	21.88	22.23
Waste inc./Industry	1.82	1.82	1.82	1.82	1.82	1.82	1.82
CHP power	5.57	7.46	5.59	5.59	5.6	5.57	5.54
Condensing PPs	19.91	17.97	21.37	19.86	19.83	22.85	22.58
V2G	0	0	0	0	0	0	0.03
Electricity demand (direct)	55.08	55.08	55.08	55.08	55.08	55.08	55.08
Electricity for transportation/flexible	7.04	7.04	7.04	7.04	7.04	10.05	3.13
Electricity for heating DH HP	0	0.06	1.73	0	0	0	0
Electricity for heating HH HP	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Electricity for heating HH EB	8.33	8.33	8.33	8.33	8.33	8.33	8.33
Electricity for cooling	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Heat production & demand (TWh)							
DH Solar heat	0.08	0.08	0.08	0.08	0.08	0.08	0.08
DH Waste heat	0.44	0.44	0.44	0.44	0.44	0.44	0.44
DH CHP heat	14.92	19.97	14.97	14.95	14.98	14.92	14.84
DH Heat pump	0.01	0.19	5.19	0.01	0.01	0.01	0.01
DH Boilers	5.82	5.77	5.76	5.78	5.76	5.82	5.9
DH Electr. Boiler	0	0.01	0.01	0.01	0.01	0.01	0.01
Balance heat	0	0	0	0	0	0	0
Indv. Heat pump	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Indv. Electric boiler	8.33	8.33	8.33	8.33	8.33	8.33	8.33
Indv. Fuel Boiler	42.37	37.2	37.2	42.37	42.37	42.37	42.37
Indv. Solar heat	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Heat demand DH	*21.27*	26.40	26.40	21.22	21.22	21.22	21.22
Heat demand HH	51.82	46.65	46.65	51.82	51.82	51.82	51.82
Fuels (TWh)							
Coal consumption	50.87	51.3	52.66	50.83	50.8	54.42	54.07
Oil consumption	119.3	119.71	119.38	119.3	119.3	109.44	109.42
NGas consumption	100.77	95.01	97.36	100.72	100.67	105.04	104.63
Biomass consumption	30.55	30.52	30.51	30.52	30.51	30.55	30.59
Annual costs (k€)							
Fuels excl. Gas	6795	6760	6753	6794	6793	6341	6338
Gas	2510	2367	2426	2509	2508	2617	2607
Marginal operation costs	94	94	99	94	94	102	102
Electricity exchange Import	0	0	0	0	0	0	0
Electricity exchange Export	0	0	0	0	0	0	0
CO2 costs	1064	1050	1064	1064	1064	1057	1054
Fixed operations costs	19	18	18	19	19	19	19
Investments	3827	3743	3707	3827	3827	3827	3827
Total	14304	14027	14061	14301	14299	13957	13940

Denmark EnergyPLAN model Annual modelled values	Reference	ESA1		ESA2		ESA3	
		10%CHP/HP +25%PV	10%HP +25%PV	-5% DSM in 17.00-21.00	-10% DSM in 17.00-21.00	Dump charge 17:00-24:00	Smart charge V2G
CO2 emissions in Mt	39.291	38.761	38.807	39.263	39.243	37.831	37.174
RES share of PES	31.4	31.9	31.9	31.4	31.4	33	33.1
RES share electr. demand	42.3%	42%	42%	42%	42%	39%	43%
Fuel consumption	192.76	190.58	190.69	192.65	192.57	187.89	184.92
Electricity production	37.46	37.84	37.85	37.40	37.35	40.27	39.30
Heat demand	56.42	56.43	56.43	56.42	56.42	56.42	56.42
DH share	63%	67%	67%	63%	63%	63%	63%
Import	0	0	0	0	0	0	0
Export	2.55	2.42	2.42	2.53	2.49	2.2	0.57
Electricity production & demand (TWh)							
RES1 (Wind onshore)	9.31	9.31	9.31	9.31	9.31	9.31	9.31
RES2 (Wind offshore)	4.84	4.84	4.84	4.84	4.84	4.84	4.84
RES3 (PV)	0.6	0.76	0.76	0.6	0.6	0.6	0.6
RES4 (River Hydro)	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Dammed Hydro	0	0	0	0	0	0	0
Waste inc./Industry	2.8	2.8	2.8	2.8	2.8	2.8	2.8
CHP power	12.45	13	12.88	12.44	12.43	12.97	12.49
Condensing PPs	7.44	7.11	7.24	7.39	7.35	9.73	8.73
V2G	0	0	0	0	0	0	0.51
Electricity demand (direct)	31.27	31.27	31.27	31.27	31.27	31.27	31.27
Electricity for transportation/flexible	0.4	0.4	0.4	0.4	0.4	3.63	0
Electricity for heating DH HP	0.02	0.56	0.57	0.02	0.02	0.01	0.01
Electricity for heating HH HP	0.77	0.77	0.77	0.77	0.77	0.77	0.77
Electricity for heating HH EB	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Electricity for cooling	1.67	1.67	1.67	1.67	1.67	1.67	1.67
Heat production & demand (TWh)							
DH Solar heat	0.23	0.23	0.23	0.23	0.23	0.23	0.23
DH Waste heat	9.18	9.18	9.18	9.18	9.18	9.18	9.18
DH CHP heat	22.58	23.63	23.41	22.58	22.58	23.59	22.67
DH Heat pump	0.06	2.12	2.16	0.06	0.06	0.05	0.05
DH Boilers	3.38	2.38	2.57	3.4	3.39	2.38	3.3
DH Electr. Boiler	0	0	0	0	0	0	0
Balance heat	0.01	0.01	0.01	0.01	0.01	0.01	0
Indv. Heat pump	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Indv. Electric boiler	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Indv. Fuel Boiler	17.8	15.69	15.69	17.8	17.8	17.8	17.8
Indv. Solar heat	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Heat demand DH	35.44	37.55	37.55	35.44	35.44	35.44	35.44
Heat demand HH	20.98	18.88	18.88	20.98	20.98	20.98	20.98
Fuels (TWh)							
Coal consumption	28.76	28.39	28.56	28.7	28.65	32.1	30.63
Oil consumption	77.33	77.32	77.33	77.33	77.33	66.71	66.57
NGas consumption	36.48	34.54	34.48	36.46	36.45	37.19	36.71
Biomass consumption	50.19	50.33	50.32	50.16	50.14	51.89	51.01
Annual costs (k€)							
Fuels excl. Gas	4955	4923	4924	4953	4952	4456	4418
Gas	795	752	751	794	794	810	800
Marginal operation costs	33	32	33	33	32	39	36
Electricity exchange Import	0	0	0	0	0	0	0
Electricity exchange Export	-33	-31	-31	-32	-32	-28	-7
CO2 costs	299	295	296	299	299	288	283
Fixed operations costs	4170	4185	4171	4170	4170	4170	4170
Investments	8549	8558	8536	8549	8549	8549	8549
Total	18767	18715	18679	18765	18764	18285	18249

Norway EnergyPLAN model

Annual modelled values	Reference	ESA1		ESA2		ESA3	
		10%CHP/ HP +25%PV	10%HP +25%PV	-5% DSM in 17.00-21.00	-10% DSM in 17.00-21.00	Dump charge 17:00-24:00	Smart charge V2G
CO2 emissions in Mt	98.337	98.221	97.03	98.345	98.347	95.104	95.08
RES share of PES	28.7	28.7	29	28.7	28.7	29.3	29.4
RES share electr. demand	107.7%	108%	107%	108%	108%	105%	108%
Fuel consumption	398.59	398.78	392.97	398.62	398.64	386.41	386.29
Electricity production	141.23	143.07	141.25	141.24	141.24	141.26	141.52
Heat demand	60.06	60.07	60.07	60.06	60.06	60.06	60.06
DH share	9%	18%	18%	9%	9%	9%	9%
Import	0	0	0	0	0	0	0
Export	10.75	12.61	9.63	10.78	10.79	7.14	6.99
Electricity production & demand (TWh)							
RES1 (Wind onshore)	2.12	2.12	2.12	2.12	2.12	2.12	2.12
RES2 (Wind offshore)	0	0	0	0	0	0	0
RES3 (PV)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
RES4 (River Hydro)	4.88	4.88	4.88	4.88	4.88	4.88	4.88
Dammed Hydro	133.57	133.57	133.57	133.57	133.57	133.57	133.57
Waste inc./Industry	0.35	0.35	0.35	0.35	0.35	0.35	0.35
CHP power	0.3	2.14	0.32	0.31	0.31	0.33	0.3
Condensing PPs	0	0	0	0	0	0	0
V2G	0	0	0	0	0	0	0.29
Electricity demand (direct)	96.91	96.91	96.91	96.91	96.91	96.91	96.91
Electricity for transportation/flexible	0.27	0.27	0.27	0.27	0.27	3.96	0
Electricity for heating DH HP	1.19	1.17	2.33	1.18	1.17	1.14	1.19
Electricity for heating HH HP	6.52	6.52	6.52	6.52	6.52	6.52	6.52
Electricity for heating HH EB	24.59	24.59	24.59	24.59	24.59	24.59	24.59
Electricity for cooling	1	1	1	1	1	1	1
Heat production & demand (TWh)							
DH Solar heat	0	0	0	0	0	0	0
DH Waste heat	3.25	3.25	3.25	3.25	3.25	3.25	3.25
DH CHP heat	0.83	4.28	0.87	0.85	0.86	0.9	0.82
DH Heat pump	1.6	3.44	6.84	1.58	1.57	1.53	1.6
DH Boilers	0.03	0	0	0.03	0.03	0.03	0.03
DH Electr. Boiler	0	0	0	0	0	0	0
Balance heat	-0.2	0	0	-0.2	-0.2	-0.2	-0.2
Indv. Heat pump	15	15	15	15	15	15	15
Indv. Electric boiler	24.59	24.59	24.59	24.59	24.59	24.59	24.59
Indv. Fuel Boiler	14.94	9.5	9.5	14.94	14.94	14.94	14.94
Indv. Solar heat	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Heat demand DH	5.51	10.97	10.97	5.51	5.51	5.51	5.51
Heat demand HH	54.55	49.1	49.1	54.55	54.55	54.55	54.55
Fuels (TWh)							
Coal consumption	16.32	16.32	16.32	16.32	16.32	16.32	16.32
Oil consumption	278.7	276.05	276.05	278.7	278.7	266.41	266.41
NGas consumption	89.49	92.36	86.55	89.53	89.54	89.6	89.48
Biomass consumption	14.08	14.05	14.05	14.07	14.08	14.08	14.08
Annual costs (k€)							
Fuels excl. Gas	113978	112203	111985	113978	113979	106013	106010
Gas	23473	24226	22701	23483	23486	23501	23471
Marginal operation costs	510	401	360	510	510	510	510
Electricity exchange Import	0	0	0	0	0	0	0
Electricity exchange Export	-1322	-1536	-1173	-1325	-1335	-859	-801
CO2 costs	5900	5893	5822	5901	5901	5706	5705
Fixed operations costs	5258	8719	5287	5258	5258	5258	5258
Investments	16970	26194	17744	16970	16970	16970	16970
Total	164768	176100	162726	164775	164769	157100	157123

Recommendations for researchers, designers and system planners

Version 2.0

Deliverable 5.1

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Disclaimer

About ERA-Net Smart Energy Systems and MATCH

ERA-Net Smart Energy Systems (ERA-Net SES) – formerly ERA-Net Smart Grids Plus – is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programmes along the innovation chain provides a sustainable and service-oriented joint programming platform to finance projects in thematic areas such as smart power grids, regional and local energy systems, heating and cooling networks, digital energy and smart services, etc.

Co-creating with partners who help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

In addition, ERA-Net SES provides a knowledge community, involving key demonstration projects and experts from all over Europe, to facilitate learning between projects and programmes from local level up to European level.

www.eranet-smartenergysystems.eu

The *Markets, actors, technologies: a comparative study of smart grid solutions* (MATCH) project ran from February 2016 to October 2018 and was supported by ERA-Net SES.

https://www.match-project.eu

Improving energy efficiency and replacing fossil fuels with renewable energy are among the most important measures on the road to a sustainable energy system. This entails new ways of generating and consuming energy as well as new forms of relationships between energy producers and consumers. The MATCH project contributes to the shift towards a carbon-neutral energy system by focussing on the changing roles of small consumers in the future electricity system (the “smart grids”).

The overall objective of MATCH was to expand our knowledge on how to design and implement comprehensive smart grid solutions that take into account the complexity of factors influencing the effectiveness and success of smart grid initiatives targeted at small consumers. The study is cross-disciplinary and based on detailed studies of current smart grid demonstration projects in Austria, Denmark and Norway. Through comparative analysis across cases and countries, the study identified key factors related to technology, market and actor involvement in developing integrated solutions that “work in practice”. Furthermore, the project applied energy system analysis and scenarios to discuss the wider energy system implications by upscaling the studied cases and solutions.

On this basis, the project developed recommendations for decision-makers, engineers and project developers. This final part of the MATCH project is included in this report.

1 Introduction

The overall objective of MATCH was to expand our understanding of how to design and implement comprehensive smart energy systems solutions that take into account the complexity of factors influencing the effectiveness and success of such initiatives targeted at small consumers.

Based on detailed case studies (three in each country), comparative analysis and an energy system modelling analysis, key factors related to technology, market and the involvement of actors (stakeholders) in developing integrated and workable smart energy solutions were identified. In addition, a number of energy system scenarios were developed in order to further explore the systemic implications of local solutions. The results from the project may inform designers, system planners and policy-makers about how to develop better smart energy solutions for small consumers such as households and small to medium-sized enterprises (SMEs).

As a result, MATCH aims to contribute to the ongoing energy transition in Europe. Main policy targets of this envisioned transition are 1) energy saving (reduction in absolute terms), 2) energy efficiency (reduction in relative terms), and 3) a higher share of renewable energy sources in all the systems (European Commission 2016). In addition to these energy objectives, the European Commission addresses industrial policy aims (global leadership in renewable energies) and societal goals (providing a fair deal for consumers) as equally important objectives. All these political positions are important points of reference when it comes to recommendations based on findings from the MATCH project.

Smart energy solutions – as studied in MATCH – usually involve a high degree of complexity: More (and new) actors and more (and new) technologies are involved in emerging configurations to create working and integrated solutions that fulfil several functions at the same time. A good example of this is the building-to-grid configuration in the *Rosa Zukunft* project. The configuration aims to support several goals of the politically encouraged clean energy transition at the same time: Energy saving, energy efficiency, a higher share of renewables (locally and trans-regional by providing balancing capacities for the electricity grid) and satisfied customers. The studied solution certainly worked in the specific local context. Moreover, to analyse whether these context-specific solutions can have positive system effects on a national level, when generalised and upscaled, a system analysis was carried out in MATCH.

Based on the nine case studies carried out in the project (WP2), we gained knowledge about the history of the studied projects, the actors involved, the (national, regional) framework conditions, the aims and objectives, outcomes and lessons learned. In WP3, we compared (and contrasted) findings from similar types of solutions obtained from different sites to identify key factors (e.g. similar patterns) related to technology, market and the involvement of actors (stakeholders) in developing integrated and workable smart energy solutions. WP4 relied on these findings, selected promising solutions and analysed their implications for the existing national energy systems in Austria, Denmark and Norway.

An earlier version of the following recommendations was presented to and discussed in detail with interested audiences in each of the three partner countries. The results of these three workshops have been incorporated in the formulation of the below recommendations.

2 Recommendations from the MATCH project

Each of the following sections starts with a presentation of the issue under discussion, followed by a brief analysis based on MATCH's results, and the resulting recommendation. Most recommendations deal with the overall question of how to develop and operate locally successful solutions. On the one hand, this was the main focus of the empirical research in the project. On the other hand, most of the solutions presented here are still at a relatively early innovation stage. It can therefore be assumed that further diversification (broadening) and improvement of existing solutions (deepening) will be seen over the coming years. However, given the socio-technical nature of the solutions studied, even a more or less straightforward replication of already tested solutions will heavily rely on tacit knowledge and experience from previous demonstration projects in order to adapt solutions as effectively as possible to existing local and regional conditions – in technical, economic, legal and social terms. This was one central argument for focussing the recommendations on the development of locally well-functioning solutions.

However, since we are aware that solutions functioning locally may lead to suboptimal results on a regional or national level, a final recommendation is presented with regard to the systematic effects of local solutions – based on the energy system analysis applied in WP4.

The recommendations presented below focus on the design of concrete solutions as socio-technical configurations, the question of their local anchoring, the role of tariff systems and price incentives, the question of how consumption and demand can be better aligned with each other, the role of users in the development and the operation of local solutions for small consumers, and finally the question of possible systemic effects of locally successful solutions.

2.1 How to design a “working” smart energy solution in general

Issue: The anticipated transformation of the energy system demands a wide range of different solutions that fit local and regional conditions and simultaneously fulfil various functions and requirements (e.g. better integration of renewable energy sources, higher levels of energy efficiency, grid parity, security of supply). Based on previous research, we might expect that a few one-fits-all solutions are not going to be the answer. Hence, socio-technical variation and testing of a large number of possible solutions is (and will be in the future) key for a successful transition of the energy system. Solutions studied in the MATCH project represent a good part of the current state-of-the-art, but certainly not the final stage of development in this area. Additional and better solutions must and will be developed and implemented over the coming years. Based on this assumption, we may ask which general recommendations can be derived from the MATCH analysis of already applied solutions for further development of new and enhanced solutions in the European context.

Analysis: The MATCH project showed that the studied projects successfully defined, set up, tested, and in most cases also ran a considerable number of new and quite different smart energy solutions. Main actors involved did provide sufficient information about the working of the implemented solutions and were able to name various qualities of “success”. In WP2 and WP3 we aimed to improve our understanding of the different aspects of what was defined as success. One of our main research claims was that the working of the solutions could only be understood adequately if they were framed as socio-technical configurations. In doing so, technologies appear as one element amongst several others combined into a working structure. Consequently, this specific combination is the basis for their functioning. Technical elements such as photovoltaic (PV) panels, smart meters or battery systems are closely linked to social elements such as formal and informal agreements, tailor-made tariff schemes, specific ownership structures, user preferences and aspirations, or new maintenance routines. Designing such a "working" smart energy solution thus requires a broad focus, a variety of skills, different kinds of knowledge, and a sense of flexibility and adaptability with regard to pre-existing local conditions (culture, technology, infrastructure, social capital, etc.). In almost all of our cases, interdisciplinary teams were responsible for the development of the studied solutions. Moreover, designing is a process that does not end with the first implementation of a concept, but usually needs an introduction phase allowing for information, mutual exchange, social learning and adaptation. Such a design approach may in the end lead to working business models; however, what we did see in our cases usually went beyond a simple supplier-customer relationship.

Recommendation: Smart energy innovation could benefit from an approach that takes the comprehensive socio-technical configurations into account from the outset. Such a design approach would recognise heterogeneous elements as equally important for the working of solutions, focus on the combination and interaction of crucial elements, and consider and mobilise existing local conditions in a sensible way. The most important criterion for the development of such solutions is that the best possible outcome is achieved through joint alignment of social and technical elements. Critical for the implementation of such a strategy are interdisciplinary project teams and robust local networks.

2.2 How to ensure local anchoring, acceptance and support

Issue: A thorough transition and decarbonisation of the energy system ideally involves a wide range of actors and should be grounded upon widespread public acceptance. One promising road towards this appears to be the combination of comprehensive energy solutions that cover all sectors and the development of a wide range of integrated solutions (as already described in section 2.1) with local anchoring. In this section, we focus particularly on how to ensure the local anchoring of the energy transition. The assumption is that without this local anchoring, it will be difficult to realise the energy transition on a wider scale. Also, local anchoring can be part of activating local resources and actors in realising ambitious transition goals. On this basis, we may ask what general recommendations can be derived from the MATCH analysis of different cases for the development of locally-anchored solutions in the European context.

Analysis: The MATCH project shows that the success of community-oriented projects is dependent on three key characteristics. First, ambitious community-led *transition strategies* covering a specific locality or region played a strategic role in several cases. These strategies create a frame and narrative for local initiatives targeted at energy transition. It helps to coordinate and organise individual initiatives into a coherent move towards a decarbonised, local economy. By associating single initiatives with the overall strategy, the strategy itself becomes an organic and evolving vision that helps branding the local area. The strategies often also become recognised nationally or even internationally, which helps new initiatives secure funding by referring to the overall strategy and vision. In some of our cases, the energy transition strategies and visions were also connected with broader societal goals such as revitalising the local economy through attracting more business and citizens. This seems to provide the energy transition with further legitimacy within the local community. In this regard, we even found evidence of local citizens and business people being proud of the local achievements and their contributions to this. Second, a long history of transition initiatives played a key role in several of the studied cases. The history of energy conservation and installing local renewable energy capacity sometimes dated back several decades and represents a long list of initiatives that together form a successive progression towards decarbonisation and energy autonomy. New initiatives often build upon *previous experiences and local networks* of actors developed throughout the years. The long history of activities often also contributes to a local identity or narrative of being a national or international frontrunner in terms of the energy transition. Third, in the studied cases we identified one or more *"entities" that coordinate and align* the single, local initiatives. This entity can be the previously mentioned shared narrative (strategy) of local energy transition or the long history of initiatives that creates a local network of actors with mutual trust and interests. Another type of coordinating entity can be a local key actor (e.g. an energy provider/grid owner or a public-private partnership) that facilitates communication between other local actors, provides advice or technical expertise, coordinates proposals for funding, etc. In addition to these three key elements, *long-term funding opportunities* (e.g. local/regional funding programmes for energy transition) can play an important role. In most of the studied MATCH cases, several – or even all – of the above-mentioned three key characteristics could be identified.

Recommendation: Smart energy innovation needs to support processes of local anchoring in order to promote solutions with a high level of local legitimacy and to make local resources and actors become an active part in the transition. This can be done by promoting and nurturing the three key characteristics identified in the MATCH study: creating ambitious and community-led transition strategies covering local areas or regions; creating conditions that support a continued local engagement (e.g. through long-term funding programmes or by tapping into and build upon existing and previous energy transition initiatives); and supporting locally-anchored entities (key actors or shared narratives) that can help coordinate and align individual initiatives.

2.3 How to make price incentives work in practice

Issue: Throughout the years, much trust has been put in financial incentives as a main driver for behavioural change. In particular, time-of-use (ToU) pricing (or "dynamic pricing") has attracted attention as a way to promote demand response (DR) through making consumers time-shift their consumption from hours with high electricity prices to hours with low prices. This rests upon the idea of the price-sensitive energy consumer (customer), i.e. the idea of the individual customer as a "rational agent" who responds to price-signals. However, experience from pilots and demonstrations shows a more mixed picture as households did not respond to economic incentives in the expected way. Therefore, there is a need to revise the naive conceptualisation of the price-sensitive and economic-rational customer and develop a more nuanced and productive understanding of what role price can play, and under which conditions?

Analysis: The studied cases in MATCH included a variety of ToU pricing schemes, e.g. combining micro-PV generation with hourly net metering (promoting self-consumption through synchronisation with PV power generation), dynamic prices reflecting spot market prices or tariffs based on the customer's peak power consumption. Several analytical observations can be made regarding the role of economic incentives (price) in promoting load shifting (demand response) in households. First, ToU pricing (including capacity-based tariffs) had a positive influence on households' active engagement in time-shifting consumption in several of the studied cases. Also, the size of the price spread between lowest and highest price appears to play a role for households' engagement (with lower spreads implying lower interest). However, the specific impact of price incentives on households' active demand response engagement depends on a wide range of other (non-economic) elements in the socio-technical configuration, which the price schemes are part of. In particular: a) micro-generation appears to help make the local power production more "visible" to households and thereby promote engagement in active load shifting; b) dynamic ToU pricing schemes with unpredictable prices are generally refused by households as they are seen as too difficult to adapt to and build new routines around; c) the framing of ToU schemes and households' trust in these are important (e.g. distrust in the energy company promoting a scheme can disengage participants, while local anchoring of ToU initiatives is often a productive framing for active engagement); d) physical and material conditions such as the proximity to neighbours are pivotal, e.g. households in apartment buildings find it difficult to time-shift consumption to night hours due to problems of noise; f) the socio-economic parameters of the households such as education and income level, job, age, size, etc., also seem to influence the flexibility of households to time-shift; g) the design of ToU trials in terms of the strategic participatory approach, value framing and process is significant for households' persistence and commitment to establish and perform new routines related to demand respond; h) finally, it is mainly energy-intensive and/or semi-automated energy consumption such as dishwashing, laundering and electric vehicle (EV) charging that households manage to time-shift. With regard to the latter, it seems that households generally prefer automation of load shifting (e.g. by use of home batteries to store PV surplus production for later self-consumption), although automation only works in cases where the automated time-shifting of consumption does not affect daily household routines too much.

Recommendation: The overall recommendation is to avoid overestimating the effectiveness of financial incentives and ToU pricing as the essential means to promote active load shifting amongst small consumers and households. Financial incentives (and their size) do play a role, but often more as a "marker" or "signifier" that can attract households' attention to demand response schemes and to anchor the idea of time-shifting consumption. The actual effectiveness of ToU pricing schemes is conditioned by the wider context of the schemes, i.e. the socio-technical elements that the pricing schemes are embedded in. From the analysis, the following specific recommendations can be made: 1) Combining ToU pricing with local renewable energy production (e.g. rooftop PV systems) can help motivate local consumers to time-shift their consumption because of the visibility and profitability of the intermittent energy production; 2) it is recommended to avoid too complex ToU pricing schemes, especially those based on dynamic and unpredictable ToU prices – overall, static ToU pricing schemes should be preferred as these make it possible for people to adopt new daily routines and temporal rhythms according to the price scheme; 3) if possible, it is recommended to ensure a long-lasting and local anchoring of the ToU demand response initiative – noteworthy in this context is awareness of the importance of establishing people's trust and confidence in the scheme, e.g. through communication and local meetings; 4) local material conditions, e.g. households living in apartment buildings often find it more challenging to time-shift consumption (especially to night hours because of noise), must be taken into consideration; 5) consideration should be given to whether a proposed ToU pricing scheme promotes time-shifting actions that are practical and can easily be adapted to the daily routines and temporal rhythms of the (socio-economic) individual characters of the households.

2.4 How to balance generation and demand

Issue: A main challenge concerning the influx of smart energy technologies in households, such as e.g. PV systems and storage, is how to effectively use these additions when it comes to grid balancing. The fundamental expectation of the smart grid is that it introduces ways of alleviating strain in the grid as well as on the climate by giving end users the tools to reduce and time-shift electricity use to better accommodate intermittent resources and reduce grid investment costs.

Analysis: The move towards a smarter grid is happening in a context of ever-increasing electricity use, as for instance e-mobility and heating are switched over to electricity as energy carrier. This challenge has a double solution. On the one hand, smarter appliances can be programmed to achieve concerted load profiles that take into account restrictions in the system on a large scale. In our analysis, this was found to be a successful strategy in the case of apartment complexes and in professional settings. Here, the benefit was centralised and professionalised control of medium and large-scale measures (a fleet of EVs, a large PV park, heat pump, large water storage, etc.), ensuring they were effective and continuously maintained, in combination with a robust and powerful control and monitoring unit. This type of solution leaves out the role of end user agency to a large extent, and requires a high level of competence on part of the building operators who have a long-term commitment to deal with the system.

Conversely, our findings included cases where new technology, tariff schemes, knowledge, and practices were introduced into households in order to have balancing measures maintained by end users themselves. This proved feasible in several cases, but requires resources spent on professional surveillance/control of robust automation are instead diverted to spending time and resources on social learning. Social learning is necessary when the aim is to enrol end users as prosumers or flexibility providers, in addition to merely introducing the technological tools required for empowering households to participate in balancing generation and demand. Technological tools are of course necessary, and in our cases included things that either contributed or consumed a lot of electricity, for instance PV systems, EVs, heat pumps, and water boilers. But in order to influence and change the practices related to the use of these material objects, and thereby bringing about the actual load shifting behaviour that allocates and allows making use of end use flexibility, monitoring technologies and price signals are important, too. A higher degree of success in engaging end users and making them partake in balancing of generation and demand is thus contingent on a *sufficient* process of social learning. By sufficient we mean that it provides impetus for action in the form of price signals and potential for economic remuneration, but that it also provides practical knowledge of methods and tools that may be effectively employed to achieve results, such as reaping benefits from price incentives (e.g. capacity-based tariff). In other words, users must be in a position to act in accordance with smart grid design.

Notably, when relying on end users for bringing about the flexibility the successful smart grid relies on, it is possible to also introduce measures alongside user-centred interventions that are more or less centrally controlled with professional surveillance/control. This was demonstrated for example in the case of Heat-as-a-Service (GreenCom) and a trial involving intelligent demand-side management (DSM) equipment for appliances (Smart Energi Hvaler).

Recommendation: Balancing generation and demand on the scale of the household or neighbourhood can successfully be accomplished in two ways, either by 1) implementing automation that is maintained by professional operators, or 2) have users manually implement balancing measures by installing and programming automation and/or changing behaviour and practices. Our findings suggest both are feasible, but relying on user agency is less predictable (more contingent) and necessitates that project owners focus time and resources on social learning. Social learning involves applying multiple tools and inroads to increase user knowledge and agency over balancing measures. In sum, social learning should rely on an introduction of price signals and visualisation tools as well as training in what constitutes effective practice change, and/or automation tools and how to ideally employ them.

2.5 How to involve technology users

Issue: A key debate in discussions about smart energy technologies and their deployment revolve around how to engage and motivate users. The same is true for the socio-technical configurations and solutions explored in the MATCH project. This is not unusual since the “success” of all smart energy technologies heavily depends on the way they are actually used: e.g. technologies that aim at producing end user flexibility require practice changes amongst users in order for them to “work”; a technology meant to enable shared electro mobility does not really work unless anyone uses it to share electro mobility services. In addition, however, users may already play a decisive role in earlier phases of development under certain conditions, which has an influence on the design of the respective configuration.

Analysis: The analysis in the MATCH project supports recent claims in the sustainability transition literature highlighting that the role of users in smart energy innovation is much more diverse than “end users” who either accept or reject pre-defined technology scripts (e.g. Schot *et* *al.* 2016; Ryghaug *et al.* 2018). Instead, many of the cases indicated that users can take on a range of different roles which allow them to engage with the solution in question in different ways.

First, users, in cases studied in the MATCH project, have taken the form of *ordinary consumers* in which their engagement with the solution is limited to being a customer of companies involved in developing a demonstration project. Second, in other instances, users have been engaged as *research partners or citizen scientists*. In these cases, recruited technology users try out new technology and agree to be studied, but they often also contribute actively in developing and disseminating new knowledge. Sometimes, this is done in explicit technology development collaboration, sometimes even initiated by prospective users themselves. Third, several of our cases involved users as *prosumers*, which entails producing and selling electricity to the grid operator. An important, not to be underestimated aspect in this case is the fact that these users take a certain amount of entrepreneurial risk. Fourth, we have identified users that act as *energy citizens.* These users act as politically engaged stakeholders in the transition of the energy system towards greater sustainability, thus taking on a sense of responsibility that transcends participation as buying or selling something. Fifth, *affiliated users* are usually employees of the project owner. They effectively take on the role as early end users and test the solutions under development in real-world contexts. Sixth, there are *user-innovators or user-producers.* These users are drivers of innovation who develop a smart energy solution according to their own needs, and that are mainly based on their own resources and capacities.

The study of users in MATCH indicates that technology development and use is a much more complex phenomenon than simple instances of human-technology encounters in which humans either accept or reject technologies. Rather, we have seen that users participate in transition activities in very different ways. Since different roles usually appear in combination with each other, we called the resulting principle “bundles of user roles”. These bundles inform the technical design, influence the way in which problems are solved, and support the social and political stabilisation of the solutions.

Recommendation: The success of most smart energy solutions depends on users and their adoption of technology as well as associated changes in behaviour. Yet, this is not a challenge of “acceptance” where the clue is to find a “trick” to bring all possible users (addressed as customers) on board. Instead, it is important to manage the necessary diversity of different user roles and their associated perspectives, interests and requirements that may have a positive impact on the development and operation of the solutions. Based on our analysis, it can also be concluded that a certain degree of diversity makes sense even in early development phases, and that it is therefore less a question of a chronological sequence than of the particular bundles of different user roles in parallel. Generally speaking, project developers have to think about users as a diverse resource, and also a potential source of innovation from which we can pool important insights.

2.6 How to integrate smart energy solutions into national energy systems

Issue: Even though the studied socio-technical configurations work well for small customers and can be replicated and rescaled to a certain extent, the dynamic relationships and integration into the system level can prove difficult. A number of smart energy system solutions were studied and presented in WP2, but the question remained on how small-scale solutions can fit into the national energy system in Austria, Norway and Denmark. What works well in one situation cannot always be expected to work in a similar way in even slightly different situations. Instead, some solutions might only work on a certain local or national level, but may not work in a different location or nation. The remaining issue is therefore to discuss options and limits when wanting to replicate small successes to a larger scale. In this context, the focus cannot stay on the electricity sector only, but should evaluate smart energy system solutions affecting the whole energy system(s).

Analysis: Whilst the various study cases were successful on a small scale, some of their aspects were addressed on the national scale to point out opportunities as well as weaknesses. For this, the approaches in the field of DSM or DR, micro generation and storage were included, while representing typical technical solutions for the studied countries. Instead of being seen as independent smart grid solutions, the MATCH demonstration projects were rather put into context, both in terms of size and sector integration. This was done to evaluate the expansion or upscaling of the solutions as well as evaluating changes in the electricity sector and their impact on other sectors, such as the heating or transport sector, with its effects on fuel consumption and emissions. This way, the smart energy solutions are seen as not just individual projects, but as part of something bigger, namely as an integrated part of an energy system. In doing so, the possible implications can be evaluated beyond the local level and under different circumstances. At the same time, local aspects such as behaviour and social conditions can be included and tested on a larger scale than individual projects would have done. In relation to 2.2 (Ensure local anchoring), local anchoring was also kept in mind for the analysis. The coordination and communication in the smaller local context creates the basis for the results in the larger context. However, WP4 is rather addressing the technical simulation of upscaling the demonstration projects that included social aspects to a large extend, but cannot keep up with all the details of the small-scale versions. Three final energy system analyses (ESAs) were made addressing: applied micro-production and storage; DSM and DR; and DSM through electric vehicles – thereby including markets, actors and technologies (see MATCH deliverable D4.1 for further details on the energy system analyses). Therefore, the energy system analyses present options and possibilities that require the reader to bridge the gap between real projects and system evaluation, looking at both the local and the national level at the same time.

Recommendation: Through the ESAs, a basic comprehension of the contextual consequences should be achieved to understand the full impact of smart energy projects and “solutions”. This entails further research and modelling of the MATCH study cases, for example their functionality in other geographical areas or on different scales. Furthermore, the varying results and impacts must be understood because a certain solution might not be replicable elsewhere under the same conditions, and therefore causing different results. Depending on the targeted outcome, a replication or up-scaling can be seen as positive for some but not for others. For example, a reduction in imported and exported electricity or fuels can have different effects and results in different countries. Depending on the existing renewable energy sources capacity, the impact can vary greatly, and our recommendation is therefore to have awareness of the necessity of locally establishing sufficient renewable electricity, heat and fuels. If demands increase without such accompanying development, existing capacity will be drained fast and power plants would have to supply them by using coal or gas. For this, a detailed analysis, taking into account short-term variations, seasonal changes and future possibilities, is recommended, too. Finally, these considerations can help choose and integrate the “right” smart energy solutions to design and balance future energy systems.

3 Concluding remarks

The main focus of the MATCH project was to improve our understanding of how "successful" local energy solutions are designed and implemented. Success, however, was defined in relative terms, elaborated through statements and ascriptions mainly by the actors directly involved in the various projects and solutions. By comparing projects and configurations across the three participating countries, it was possible to describe a number of critical aspects more precisely and conduct more thorough analyses.

- We have pointed out that successful implementation of the solutions depends to a large extent on a well-designed interplay of social and technical elements. We have furthermore argued that smart energy solutions should be considered as heterogeneous configurations from the very beginning.
- We have shown that such solutions must rely on local anchoring activities and, based on our case studies, have made suggestions as to how this can be achieved in practice.
- We have discussed the role of tariff systems and price incentives (ToU pricing) and have concluded that financial incentives often work as a "marker" or "signifier" that may attract consumers' attention, but the actual effectiveness of pricing schemes is determined by the wider context of the schemes, i.e. the overall socio-technical configuration the pricing scheme is embedded in.
- We have addressed the issue of balancing consumption and demand, and pointed out that the success of such approaches essentially depends on the extent to which social learning is implemented.
- We have studied the role of users in innovation processes and seen that successful solutions are simultaneously influenced by a variety of user roles already during early phases of development. Based on this knowledge, we recommend that it is important to ensure diversity of different user roles and their associated perspectives, interests and requirements from early on.
- Finally, on the basis of our energy system modelling, we have suggested that it is important to examine the various systemic effects of locally successful solutions for existing energy systems (regional, national) before replicating or upscaling them.

One topic repeatedly addressed over the course of the project and discussed more intensively in the three public MATCH workshops carried out in 2018 relates to the upscaling and increased dissemination of already available (and well-working) smart energy solutions. Given the ambitious energy policy goals within the European Union, this is a legitimate question. Although this highly relevant question was outside of the scope of MATCH, a few comments and observations from the project will be addressed in this final section in brief.

- Although we have been presenting configurations that are already successful, there is hardly any solution in our sample which could be distributed on a large scale in its present form. There are three main reasons for this: First, the success of these solutions depends to a large extent on a coordinated interplay of elements and well-functioning local anchoring activities. This means, on the other hand, that replication depends on appropriate adaptation services: in another local or regional context, different elements of a successful configuration would need to be arranged differently. Second, from the point of view of the system as a whole, the widespread dissemination of a solution often does not appear to make sense, but rather the combination of many different solutions (see Eikeland and Inderberg 2016). And third, an explicit recommendation for the accelerated dissemination of solutions would have to include an external assessment of the direct effects and possible unintended consequences, something which could not be achieved in the present project.

- However, we were also able to observe diffusion processes in the context of this research. Some operate mainly via traditional *market mechanisms*, others essentially via locally established *social networks*. An example of the first type of distribution is the building-to-grid solution in the city of Salzburg. Following the example of the *Rosa Zukunft* project, the local energy supplier has already implemented similar projects in cooperation with local housing developers. Another example is the electric vehicle fleet solution from the VLOTTE project: the experience gained over the years is already being offered as a consulting service. ProjectZero in the Danish region of Sønderborg represents an example in which solutions are predominantly disseminated via social networks. ProjectZero is a public-private partnership between several local (energy-related) companies and the municipality of Sønderborg. The project acts as an intermediary that promotes and coordinates all relevant actions that support the local energy transition. The dissemination of solutions is very effective with this model, but remains limited to the respective region.
- Another way in which the results of local demonstration projects can be disseminated is by *generalising* specifically selected experiences. We found such an example e.g. in the case of the low-voltage grid field test in the municipality of Köstendorf in the province of Salzburg. The conducted real-world experiments showed that – at least up to a certain extent of PV distribution – the existing grid is sufficiently protected against overloading by phase shifting (phase-shifted current is fed into the low-voltage grid). Consequently, high investment costs for controllable transformers can be avoided with this measure in the future. The grid operator translated this result into an obligatory requirement for all new PV systems in the area.

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