# Final report

## 1.1 Project details

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| **Project title** | EUDP 11-I, Energy & Greenhouse Gas Optimized Building Renovation<br><br>EUDP 12-II, Fase 2, Omkostningseffektiv Energi- og CO2-emissions-optimering – tillæg 2012 |
| **Project identification (program abbrev. and file)** | EUDP 11-I (2011) Journal no. 64010-0078<br>EUDP 12-II (2012) Journal no. 64012-0227 |
| **Name of the programme which has funded the project** | EUDP 11-I<br>EUDP 12-II |
| **Project managing company/institution (name and address)** | Danish Building Research Institute (SBi), Aalborg University Copenhagen, A.C. Meyers Vænge 15, DK-2450 København SV |
| **Project partners** | Kirsten Engelund Thomsen & Jørgen Rose, SBi, AAU<br>Ove Christen Mørck, Cenergia Energy Consultants<br>Iben Østergaard & Søren Østergaard Jensen, Teknologisk Institut<br>Søren Peter Nielsen, Boligselskabet Sjælland |
| **CVR** (central business register) | 29102384 |
| **Date for submission** | 29.2.2016 |

## 1.2 Short description of project objective and results

The objective of Danish participation and contribution to IEA EBC Annex 56 was to accelerate extensive energy renovation of the existing buildings in Denmark and worldwide. To accomplish this 4 sub-objectives have been identified within the Annex:

- Development of a new methodology as the basis for future standards, to enable cost-effective renovation of existing buildings towards the nearly-zero energy and emissions objective.
- Development of tools, guidelines, recommendations, best-practice examples (case studies) covering as well energy efficient building renovation as renewable energy production - for policy makers, designers, users, owners and promoters.
- The introduction of a broader approach going beyond the energy efficiency concept and focusing on the overall added value achieved in an energy renovation process, which means that comfort improvement, global quality improvement and economic impact of the intervention in a cost/benefit perspective will also be considered.
- Directly link the IEA to the target audience through accessible language and tools that enable them to understand the benefits, but also pinpoint problems and risks associated with building energy renovation.

Results
The project has achieved the following outputs:

- A methodology for setting up standards for energy renovation of buildings;

- Flexible decision making tools and guidelines in the perspective of users, owners and promoters, designers and policy makers;
- Commented successful case-studies highlighting the added value of each renovation process. The detailed case studies present and illustrate the developed methodology;
- A renovation guide, based on cost-effective solutions and on an optimal value concept.

Danish participation in and contribution to IEA Annex 56 is important as a means towards extensive energy renovation of the existing building stock which will contribute to reach the political goals regarding energy- and $CO_2$-reductions. The outcome of the project may also form the basis for a future EU directive on the energy performance of existing buildings.
Cenergia Energy Consultants was co-leading subtask C, i.e. as a part of the management team and has thereby assured the best possible relevance of project activities and results in relation to Denmark.

**In Danish:**

Formålet med projektet var grundliggende at sikre dansk deltagelse i IEA EBC Annex 56 "Energi- og $C0_2$-optimeret Bygningsrenovering". Projektet skulle dermed medvirke til at forøge det danske udbytte af IEA EBC Annex 56.

Formålet med Annex 56 projektet var at fremskynde en omfattende energirenovering af de eksisterende bygninger i Danmark og på verdensplan. For at opnå dette blev 4 delmål identificeret:

- Udvikling af en ny metode som grundlag for fremtidige standarder, for at muliggøre omkostningseffektiv renovering af eksisterende bygninger til "nearly zero energy" og "nearly zero emissions" -målene defineret i EU's EPBD.
- Udvikling af værktøjer, retningslinjer, anbefalinger, "bedste praksis"-eksempler (case studies), der dækker såvel energieffektiv bygningsrenovering som produktion af vedvarende energi - for de politiske beslutningstagere, designere, brugere, ejere og initiativtagere
- Indførelse af en bredere tilgang som fokuserer videre end energieffektiviteten, og dermed samtidig sætter fokus på den samlede værditilvækst opnået i en energirenoveringsproces. Hermed inddrages også komfortforbedringer, global kvalitetsudvikling og de økonomiske konsekvenser af interventionen i et cost/benefit perspektiv.
- Linke IEA-arbejdet direkte til målgruppen gennem lettilgængelig kommunikation og lettilgængelige værktøjer, der sætter målgruppen i stand til at forstå de fordele, men også lokalisere problemer og risici, der er forbundet med energirenovering af bygninger.

Resultater
Projektet forventedes at opnå følgende resultater:

- En metode til fastlæggelse af standarder for energirenovering af bygninger;
- Fleksible beslutningstager-værktøjer og -retningslinjer i perspektivet af brugere, ejere og initiativtagere, designere og beslutningstagere;
- Kommenterede succesfulde case-studies som fremhæver merværdien af hver enkelt renoveringsproces. Case-studies benyttes samtidig til at præsentere og illustrere den udviklede metode;
- En renoveringsvejledning, baseret på omkostningseffektive løsninger og et koncept om opnåelse af optimal værdi.

Dansk deltagelse i og bidrag til IEA Annex 56 har været vigtigt for at opnå mere viden om omfattende energirenovering af den eksisterende bygningsmasse i forhold til bygninger som anvendes til beboelse. Denne viden vil bidrage til at nå de danske politiske mål om energi- og $CO_2$-reduktioner og resultatet af projektet kan samtidig danne grundlag for et kommende EU-direktiv om den energimæssige ydeevne for eksisterende bygninger.

## 1.3 Executive summary

The project has ensured Danish participation in the IEA EBC Annex 56 ”Energy & Greenhouse Gas Optimized Building Renovation”. In this way Denmark participated in the development of solid knowledge on how to energy renovate buildings to reach a Nearly Zero Energy Buildings level in a sustainable and cost-effective manner. The most important market and policy obstacles for doing so were identified.

The participating countries were Austria, Czech Republic, China, Denmark, Finland, Italy, The Netherlands, Norway, Portugal, Spain, Sweden and Switzerland. Within this project, the gathering of case studies was one of the activities undertaken to reach the overall project objectives, because it is a recognized fact that the process of decision-making has to be strongly supported by success stories from real life and experiences and lessons learned from practice. Therefore exemplary residential renovation projects from all participant countries were collected for motivation and stimulation purposes, highlighting the advantages of aiming at far reaching energy and carbon emissions reductions, being still cost-effective. The focus was to highlight advantages and innovative (but feasible) solutions and strategies.

The project started in May 2011 and ended December 2015.

The work in IEA Annex 56 was organised within 4 subtasks:

Subtask A - Methodology
Development of a methodology for defining standards for energy renovation that can be adapted and applied by different countries with different conditions.

Subtask B - Tools
Development of modular and flexible tools, with different levels of complexity and a renovation guideline.

Subtask C - Case-Studies
Case-studies used as sources of relevant technical information and as ways of testing the proposed methodologies by carrying out detailed analysis on selected ones.

Subtask D - User Acceptance and Dissemination
i) User acceptance
ii) Dissemination of results to target users.

The Annex dealt with several types of residential buildings and similar buildings, including protected and historical buildings:

- Simple office buildings (only simple ventilation systems)
- Multi-storey blocks of flats
- Schools
- Single family houses

The Annex has resulted in a series of technical reports and workshops (some reports are still awaiting approval at the EXCO):

- Methodology for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation [Subtask A].
- Investigation based on calculations with generic buildings and case studies [Subtask A].
- Co-benefits of energy related building renovation [Subtask A].
- Decision making tools - Data base with renovation measures for the optimization process [Subtask B].
- Shining Examples of Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation [Subtask C].

- Compilation and analysis of major energy building renovations across Europe. Report on Detailed Case Studies of the IEA EBC Annex 56 [Subtask C].
- Owners Guidelines for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation [Subtask D].
- Policy Makers Guidelines for Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation [Subtask D].

Danish participation in and contribution to IEA EBC Annex 56 was important as the outcome of the project could form the basis for both national legislation on building energy renovation of buildings and a future EU directive on the energy performance of existing buildings.

## 1.4 Project objectives

During the last decade, several standards and regulations regarding energy consumption of buildings have emerged, specifying increasing levels for energy efficiency requirements. As an example, the concept of "nearly-zero energy" buildings has been recently adopted by the EU to define tangible limits for EU Member States national building energy efficiency regulations.

Although its borders are not yet fully clarified, prospects point to a hierarchical approach that will value energy conservation and efficiency, which implies a strong investment on the envelope and in building systems as well as the use of on-site renewables. However, present standards are mainly focused on new buildings, providing most of the time less guidance on the renovation of existing buildings that will have to face similar challenges in the near future.

Today's standards do not respond effectively to the numerous technical, functional and economic constraints of existing buildings and often, the requirements, mainly targeted to energy efficiency measures, result in expensive processes and complex procedures, seldom accepted by users, owners or promoters. But, having in mind the overall objective of slowing down climate change, carbon emissions reduction measures, like the use of renewable energy or on-site produced renewable energy, can be as effective as energy conservation and efficiency measures and sometimes be obtained in a more cost-effective way. Therefore, in existing buildings, the most cost-effective renovation solution is often a combination of energy efficiency measures and carbon emissions reduction measures. Hence it is relevant to investigate where is the balance point between these two types of measures in a cost/benefit perspective, which means to achieve the best building performance (less energy consumption, less carbon emissions, overall added value achieved by the renovation) at the lowest effort (investment, intervention in the building, users' disturbance). Therefore, a new methodology for energy and carbon emissions optimized building renovation, as a basis for future standards, has been developed to be used by interested private entities and agencies for their renovation decisions as well as by governmental agencies for the definition of regulations and their implementation. This methodology is accompanied by good-practice guides that integrate appropriate and cost-effective technologies as well as by good renovation examples.

This Annex aimed at developing a new methodology, as the basis for future standards, to enable cost-effective renovation of existing buildings while optimizing energy consumption and carbon emissions reduction.

The main objective was to provide tools, guidelines, recommendations, best-practice examples, and background information to support decision makers, which includes technicians, owners, promoters and policy makers, in the evaluation of the efficiency, cost-effectiveness and acceptance of the renovation measures towards both the nearly-zero emission and the nearly-zero energy objectives. The overall objective was to identify the optimal range of "minimization of demand" and "generation of renewable energy" measures, i.e., "level a" and "level b" measures, according to Figure 1, in a cost/benefit perspective. One of the main questions was to understand how far it is possible to go with energy conservation and efficiency measures (initially often less expensive measures) and from which point the carbon emissions reduction measures become more economical taking into account the local/regional context.

The project followed a broader approach going beyond the cost-effective reduction of carbon emissions and energy consumption, focusing also on the overall added value achieved in a renovation process, which means also identifying global quality improvement, economic impact of the intervention, operating cost reductions and some co-benefits like comfort improvement (thermal, natural lighting, indoor air quality, acoustics, etc.), increased value of the building and fewer problems related to building physics.

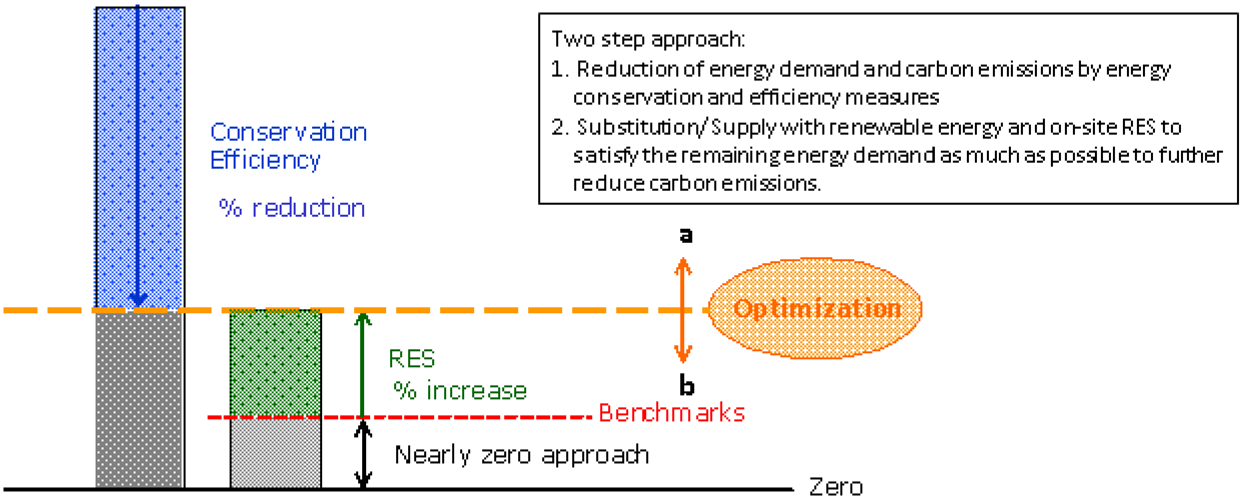

Fig. 1: Energy and carbon emissions optimized building renovation concept (Geier S., Ott W.)

To achieve these goals, to have a bigger impact and to shorten the path to the application of the project results, it is important to take advantage of good examples and good practices already implemented as well as of existing and emerging efficient technologies with potential to be successfully applied. Summarizing, the main objectives are the following:

- Define a methodology for the establishment of cost-optimized targets for energy consumption and carbon emissions in building renovation;
- Clarify the relationship between the emission and the energy targets and their eventual hierarchy;
- Determine cost-effective combinations of energy efficiency measures and carbon emissions reduction measures;
- Highlight the relevance of co-benefits achieved in the renovation process;
- Develop and/or adapt tools to support the decision makers in accordance with the developed methodology;
- Select Exemplary Case-Studies to encourage decision makers to promote efficient and cost-effective renovations in accordance with the objectives of the project.

It was also a goal of this project to directly link the IEA to the target audience through accessible language and tools that enables them to understand the benefits but also the problems and risks associated with building renovation. Accurate understandable information must be provided so that decision-makers can make better decisions and choose the best options that apply to their specific needs.

The results of this project are of major relevance for policy makers helping them to define the most appropriate policies, measures and incentives to put into practice for an effective renovation strategy. At EU level, these results will be very helpful in the preparation of the National Energy Efficiency Rehabilitation Plans that are required for all Member States by 2015 as a consequence of the implementation of the Energy Performance of Buildings Directive (EPBD) and its 2010-recast.

Other objectives for the EUDP project were:
1. To ensure Danish participation and contribution to the new IEA EBC Annex 56.

2. To collect and process knowledge from existing projects in both Denmark and abroad. The knowledge would be gathered in a database of lessons learnt that could be applied to future energy retrofit projects.
3. To make knowledge accessible and usable regarding how to implement far-reaching energy renovation of buildings to reach NZEB standards in a sustainable and cost-effective manner without compromising the indoor environment.

The following meetings and seminars were held:

| Date | Place | Meeting/seminar/conference |
|---|---|---|
| **2011** | | |
| 19.09. – 20.09. | CH, Zürich | 1. Task meeting |
| **2012** | | |
| 16.04. – 17.04. | IT, Venice | 2. Task meeting |
| 10.09. – 12.09. | NO, Oslo | 3. Task meeting |
| 14.11. | CH, Bern | ECBCS Technical Day |
| **2013** | | |
| 18.03. – 20.03. | DK, Copenhagen | 4. Task meeting |
| 22.09. – 25.09. | AU, Graz | 5. Task meeting + IEA EBC Industry Workshop |
| **2014** | | |
| 10.03. – 12.03. | ES, Alicante | 6. Task meeting |
| 15.09. – 17.09. | CZ, Brno | 7. Task meeting |
| **2015** | | |
| 24.1-27.1 | USA, Chicago | Ashrae conference |
| 16.03. – 18.03. | SE, Lund | 8. Task meeting |
| 15.06. – 18.06. | IT, Torino | 6$^{th}$ IBPC Conference. Special session with IEA Annex 56 presentations |
| 16.09. – 18.09. | PO, Porto | 9. Task meeting - final |
| 17.09 | PO, Vila Nova de Gaia | Industry Workshop |

## 1.5 Project results and dissemination of results

**Projects results**
Several reports have been produced in the project. In the following the main findings of each subtask is described.

**Subtask A: Methodology**

Objectives:
- Define scope and methodology as well as calculation guidelines to enable cost-effective building renovation towards the nearly zero emissions objective;
- Contribute to the establishment of cost-optimized targets for energy consumption and carbon emissions within building renovation;
- Clarify the relationship between the emission targets and the energy targets depending on the respective country specific conditions and backgrounds;
- Highlight the relevance of co-benefits achieved in the renovation process and to evaluate how they can be used in decision-making processes;

To achieve these objectives, Subtask A is divided in four work packages:

Work packages (WP):

*WP A1: Methodological Guidelines and National Framework Conditions*

The goal of this WP is the development of the methodology for the assessment of building renovation as well as for the derivation of target values for energy and carbon emissions optimized building renovation;

*WP A2: Cost-optimization with respect to varying energy and carbon emissions reduction targets*

The goals are the assessment of renovation strategies to determine cost-effective combinations of renovation measures which optimize energy and carbon emissions savings as well as to evaluate the trade-offs between energy and carbon emissions reduction measures in the case of building renovation;

*WP A3: Primary energy consumption and greenhouse gas emissions with LC-approach*

The goal is to define a flexible methodology that allows assessing the primary energy consumed and the greenhouse gas emissions of renovated buildings. The methodology will be based on the state of the art of LCIA approaches for buildings;

*WP A4: Co-Benefits of Renovation Measures*

The goal of this WP is the identification of relevant co-benefits related to building renovation and to demonstrate how such co-benefits can be integrated into decision making in the case of building renovation.

The main deliverables of subtask A are:

- Methodology Report on Cost-Efficient Energy and carbon emissions Optimized Building Renovation
- Report on Integration of Embodied Energy and LCA into the Assessment of Renovation Measures
- Report on Co-Benefits and overall Added Value of Energy and carbon emissions optimised Building Renovation.

**Subtask B: Tools**

Objectives:

- Make further use of the methodology developed in Subtask A by developing and/or adapting tools to support the various decision makers in their renovation strategies or in evaluating and optimizing renovation measures for reaching (and defining) nearly zero carbon emissions in buildings renovation;
- Support the economic evaluation of energy and carbon emissions optimized building renovation on a general level highlighting the balance between energy efficiency measures and renewable energy use.

To achieve these objectives, Subtask B is divided in four work packages:

*WP B1: User requirements and needs and tools overview*

The main goal of this WP is to get a clear overview of the needs and requirements of the different target groups taking into consideration the developed methodology, and further to clarify to what extent these needs are already covered by existing tools.

*WP B2: Building Information Models and data bases*

The goal is to explore the possibility of integrating modules with innovative renovation measures in existing BIM tools;

*WP B3: Tools development*

The main objective of this WP is to develop new tools and add-ons to existing ones to fulfil the identified needs and requirements. The main issue will be to support the economic evaluation of energy and carbon emissions optimized building renovation as well as deal with added value related issues;

*WP B4: Renovation Portal with guidelines for different user groups*
The goal is to create a renovation portal where different users can find targeted information on how the different measures contribute to energy savings and GHG reductions.

The main deliverables of subtask B are:

- Decision making tools. These tools will integrate data bases with renovation measures for the optimisation of the renovation process.

**Subtask C: Case-Studies**

Objectives:

- Understand barriers and constraints for high performance renovations by a thorough analysis of case studies and feedback from practice in order to identify and show measures how to overcome them
- Validate the theoretically developed methodology in STA with practical experiences within realized renovations in order to identify possible inconsistencies and providing feedback to refine the methodology;
- Reach an in-depth understanding of the performance of some selected case studies in order to increase the general understanding of the performance of technologies applied in practice;
- Support decision-makers and experts with profound, science based information (as result of thoroughly analysed case-studies) for their future decisions;
- Show successful renovation projects in order to motivate decision-makers and stimulate the market.

To achieve these objectives, Subtask C is divided in three work packages:

*WP C1: Case Studies I - "Shining Examples"*
The goal if this WP is the publication of a series of successful realized demonstration projects within all Annex 56 partner countries that will highlight successful solutions and provide general findings, similarities and differences emerging out of the demonstration projects from the different countries;

*WP C2: Case Studies II – "Detailed Case Studies"*
The objective is to perform a deeper analysis of selected case studies in order to validate the theoretically developed methodology based on generic data with data and experiences from practice;

*WP C3: Reporting*
The goal is to obtain an optimized and target group oriented publication of the results of Subtask C (the successful demonstration projects) in order to contribute to the overall Annex 56 dissemination strategy.

The main deliverables of subtask C are:

- Brochure "Shining Examples" as a stepwise publication (presentation, web-based brochure, printed brochure);
- Final report on "Detailed Case Studies".

The list of Shining Examples renovation projects is available on the Task webpage (and listed in the table on the following pages). The 18 individual projects are described in 6-page brochures presenting the key renovation actions as well as energy performance numbers. The main objective is motivation and stimulation purposes, highlighting the advantages of the energy and carbon emissions cost-optimized renovation. The focus is to highlight advantages and innovative (and feasible) solutions and strategies. A cross-section analysis of the projects has also been carried out to identify similarities, differences and general findings. The results of this analysis are presented in 5 sections covering: barriers/solutions, anyway measures, rational use of energy/renewable energy supply (RUE/RES) balance of measures, co-benefits and country/climate specific measures.

| Project description | Picture |
|---|---|
| **Bruck an der Mur, Austria**<br>• Built: in 1960s<br>• Official building which includes the district court, the financial authority and the Federal Office for Metrology and Surveying<br>• Gross heated floor area: 6486 $m^2$ (total) |  |
| **Kapfenberg, Austria**<br>• Built: 1960-1961<br>• Residential building with four floors<br>• On each floor six flats were located<br>• The living space varied from 20 to 65 $m^2$<br>• Total gross heated floor area: 2845 $m^2$ |  |
| **Kamínky 5, Brno-NovýLískovec, Czech Republic**<br>• Elementary school with consisting of 3 blocks (classrooms, kitchen and cafeteria, gymnasium)<br>• Built: 1987<br>• Maximum capacity: 380 students, 44 staff<br>• Net heated floor area: 7296 $m^2$ |  |
| **Koniklecová 4, Brno-Nový Lískovec, Czech Republic**<br>• Block-of-flats<br>• Built: 1983<br>• Capacity: 60 flats(47.21 to 75.17 $m^2$)<br>• Net heated floor area: 5412 $m^2$ |  |
| **Sems Have, Roskilde, Denmark**<br>• 2 blocks<br>• Built: 1973 – new windows and additional insulation in 1995<br>• General information: Energy label C before renovation<br>• Gross heated floor area: 3,626 $m^2$ after renovation |  |
| **Skodsborgvej, Virum, Denmark**<br>• Two-storey villa with red bricks and red tiled roof, built in 1927<br>• Energy label G<br>• Gross heated floor area: 121 $m^2$ |  |
| **Traneparken, Hvalsø, Denmark**<br>• 2 blocks<br>• Built: 1973 – new windows and additional insulation in 1995<br>• General information: Energy label C before renovation<br>• Gross heated floor area: 3,626 $m^2$ after renovation |  |
| **Ca' S. Orsola, Treviso, Italy**<br>• Listed building located in Treviso<br>• It was the old seat of a Polish Institute<br>• Total site area: 4500 $m^2$<br>• Gross heated area: 1800 $m^2$<br>• Gross volume: 6300 $m^3$ |  |

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|---|---|
| **<u>Ranica, Bergamo, Italy</u>**<br>• Detached single family house<br>• One floor over a basement (+ 2nd floor after renovation)<br>• Initial energy class: G (the worst based on Italian regulation)<br>• Gross heated floor area (after): 329 m$^2$ |  |
| **<u>Wijkvan Morgen, Kerkrade, Netherlands</u>**<br>• Built 1974<br>• 70 apartments (two storeys)<br>• 83 single-family houses |  |
| **<u>Pontes Country House, Portugal</u>**<br>• Located in a small rural village in the hills of Peneda<br>• Individual vernacular stone (granite) wall house<br>• Originally built in 1940<br>• Currently inhabitable, almost in ruins<br>• Gross heated area:180 m$^2$ |  |
| **<u>Residential building upgrade in Montarroio, Portugal</u>**<br>• Ancient residential building located in Coimbra<br>• Strong restrictions imposed by its location<br>• Monument, and the UNESCO protection area<br>• Total site area: 22 m$^2$<br>• Useful heated area: 36 m$^2$, potential 46 m$^2$ |  |
| **<u>Rainha Dona Leonor Neighborhood, Porto, Portugal</u>**<br>• 150 dwelling that will be reduced to 90 after renovation<br>• Multifamily building, with concrete structure and brick walls<br>• Originally built in 1953<br>• Gross heated area of the selected building: 123.60 m$^2$ (2 dwellings)<br>• Gross heated of the total renovated neighbourhood: Approx.: 5000m$^2$ |  |
| **<u>Viviendasde Corazónde María, Bilbao, Spain</u>**<br>• A complete renovation of the building has been projected<br>• Includes improvements on building thermal performance and accessibility<br>• It is a building with concrete structure, brick walls and light weight slabs. Average area of each dwelling is 75 m$^2$ |  |
| **<u>Backaröd, Gothenburg, Sweden</u>**<br>• First 16 energy renovated apartments (of 1,564)<br>• Heated usable floor area 1,357 m$^2$<br>• Built: 1971<br>• Prefabricated concrete elements and balanced ventilation without heat recovery |  |
| **<u>Brogården, Alingsås, Sweden</u>**<br>• Built 1971-73<br>• First 18 renovated apartments (of 300)<br>• Heated usable floor area (18apartments) 1,274m$^2$<br>• Three storey buildings<br>• Poorly insulated building envelope and ventilation without heat recovery |  |

| | |
|---|---|
| **Maratonvägen 36, Sweden**<br>• Built 1963-65<br>• Three - four story buildings<br>• 51 apartments (of 579 apartments)<br>• Heated usable floor area (51 apartments) 4,521 m² |  |
| **Les Charpentiers, Morges, Switzerland**<br>• 5-storey with 61/59 flats (before/after)<br>• Year of construction:1964-65<br>• GHFA: 4280/4836 $m^2$ (before/after) |  |

For most of the shining examples the energy reduction reached by implementing RUE (rational use of energy) technologies lie between 40% and 83% - extremes are 16% and 90%. The RE (renewable energy) contribution to the remaining energy demand lies between 7% and 47% - extremes being 0% and 90%. The total energy reductions achieved by the combination of RUE- and RE-technologies are between 40% and 95%. Here the extremes are 29% and 98%.

**Subtask D: User Acceptance and Dissemination**

Objectives:

- Deal with user acceptance issues in order to understand how the methodology for building renovation can interact with users and therefore become useful and effective for their needs;
- Dissemination of outputs among identified target groups.

To achieve these objectives, Subtask D is divided into two work packages:

*WP D1: User Acceptance*
The goal of this WP is to characterize and understand the acceptance, motivation, needs, obstacles and drivers of the chosen target groups to the renovation process;

*WP D2: Dissemination*
The objective is to disseminate the Annex outputs among key stakeholders since the beginning of the project.

The main deliverables of subtask D are:

- Website;
- Annex 56 Newsletters;
- Renovation Guidebook for Professional Building Owners;
- Renovation Guidebook for Policy Makers.

**Dissemination of results**
The deliverables described above will be uploaded on the website as soon as approval from the EXCO exists: http://www.iea-annex56.org/index.aspx

In addition to the main deliverables from the project the Danish team has disseminated project results through oral presentations and written articles and conference papers.

The IEA Annex 56 project has been mentioned on many different occasions including:

- Fremtidens lavenergibyggeri. Danvak dagen, 24 April 2012
- Bygningers energiforbrug. Temamøde om Bygninger og Smart Grid, 17 September 2012

- Fremtidens byggeri. Oplæg for byggeteknisk afdeling i Gladsaxe, Lyngby, Gentofte og Furesø kommuner, 21 September 2012
- Fremtidens intelligente bygninger. Oplæg på strategiseminar hos OJ Electronics, 23 October 2012
- Fremtidens intelligente bygninger. Tekniq-rådsseminar, 15 January 2012

The Danish group has written two papers with peer review for the conference: "Building Physics for a Sustainable Built Environment", Torino 14-17 June 2015. The titles were: "Shining examples analysed within the EBC Annex 56 project" and "Energy consumption in an old residential building before and after deep energy renovation".

In connection with several of the project meetings "Industry workshops" have been held, where results from the project have been presented. In Graz in September 2013 the Danish group presented results from Subtask C. In Brno in September 2014 the Danish delegation presented the case study brochure. In Lund in March 2015 a presentation "Shining Examples of Multi-Family Building Renovation from Annex 56" was held. In Portugal in September 2015 two presentations were given: "Shining Examples under Annex 56 concept" and "ASCOT, a free tool for Cost Effective Energy and Carbon Emissions Optimization in Building Renovation".

Two articles have been written to the Danish HVAC Magasinet. In no 10, October 2015 an article "Omkostningseffektiv energirenovering af boliger" describes the Annex 56 work and the Danish case studies in general. In No 11, November 2015 an article "Traneparken – gennemgribende energirenovering af tre boligblokke" describes the renovation and the energy savings.

Cenergia has adapted the ASCOT programme (Assessment of Sustainable Construction and Technology Cost model) to a version specifically developed for Annex 56 purpose that includes LCA calculations. It is available on the Annex 56 Website.

A SBi 2015:20 report "Tenant experiences and satisfaction in social housing subject to comprehensive retrofitting" is a study from Traneparken – one of the Danish case studies in Annex 56. The report describes the results from a questionnaire survey that included assessment of possible co-benefits like e.g. improved perceived indoor climate parameters and new balconies. Furthermore the report includes results from measurements in three flats concerning the ventilation conditions after the renovation.

## 1.6 Utilization of project results

The project involves participation in the IEA project, so there is no apparent technology added value for users. The project has generated some of the necessary knowledge to help Danmark to meet stringent national energy policy objectives on energy retrofit of the existing building stock. Thereby, Denmark can help meet individual and joint international demands for deep reductions in $CO_2$ emissions.

The project has had the purpose of securing Danish participation in an IEA project and did not have the purpose to develop commercial products. However, it should not be excluded that future methods developed during the project can be commercialized at a later stage.

## 1.7 Project conclusion and perspective

The project had an international character so it was expected to encourage greater international cooperation in the development and research with regard to extensive energy retrofit projects and knowledge. The project could be instrumental in ushering in deep renovation of large properties and break down some of the barriers that exist in this area. At a national level this could lead to a large energy saving potential, since Danish enterprises will be able to access the latest knowledge and information about good and efficient renovation examples.

One of the main results from the project is the developed methodology which provides the necessary basics for the assessment of existing buildings undergoing energy related renovation processes and for the comparison of possible energy related renovation alternatives. The results of the assessment and evaluations allow for appraising the energy performance of the building, the options to use renewable energy, the trade-offs between measures increasing energy efficiency and renewable energy use and related costs. It provides indications for future standard design or amendments and for target setting in the sector of existing residential buildings and low-tech office buildings. The methodology also delivers guidelines for policy makers, building owners, investors and occupants.

The methodology provides for correct and comprehensive assessments and evaluations of renovation measures. Comprehensive impact assessment means:

- Taking into account all relevant cost elements (also maintenance, repair, replacement costs) and all relevant impacts i.e. also embodied energy of renovation measures;
- Life cycle cost assessment (during the whole life cycle of the building or during the whole calculation period (taking into account residual values)) and life cycle impact assessment as far as feasible (e.g. embodied energy);
- Dynamic cost assessment, discounting future costs and benefits;
- Comparison with a reference case involving «anyway» renovations, which are renovations restoring full functionality of the building, renewing building elements which are at the end of their life time. «Anyway» renovation does not aim at improving energy performance of the building or deployment of renewable energy within building rehabilitation.

Hereby the methodology can be utilised in Denmark to form the basis for future renovation projects. This allows the results of the project to help reducing gross energy consumption in the existing Danish building mass, so that the overall energy policy goals can be obtained.

Another important result is the focus on and quantification of the co-benefits related to comprehensive energy renovation. The project has identified the relevant co-benefits related to building renovation and demonstrates how such co-benefits can be integrated into decision making in the case of building renovation.

Comprehensive energy renovation will rarely present a good economy if one looks at energy alone and therefore a main goal of the project is to give guidance to building owners, investors and promoters to integrate qualitative information regarding co-benefits in their cost/benefit assessment and subsequent decision-making for energy related building renovation and to policy-makers to highlight the relevance of considering the broader impact of energy policies in several other areas of policy making. Co-benefits will also be very relevant to incorporate into a Danish context where we often face similar issues regarding the funding of energy renovation projects, when only the simple payback time is used as a measure of a renovation package's economy.

**Annex**

Link for the webpage: http://www.iea-annex56.org/index.aspx