Final report

1.1 Project details

Project title	EUDP 12-II, Deep energy renovation of government/public buildings EUDP 12-II, Vidtgående energirenovering af statslige/offentlige bygninger
Project identification (program abbrev. and file)	EUDP 12-II (2012) Journal no. 64012-0228
Name of the programme which has funded the project	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 Ove Christen Mørck, Cenergia Energy Consultants Jacob Madsen/Lisbeth Berg, Egedal Kommune
CVR (central business register)	29102384
Date for submission	28.2.2017

1.2 Short description of project objective and results

The objectives of Annex 61 “Business and Technical Concepts for Deep Energy Retrofit of Public Buildings” were to:

- provide a framework and selected tools and guidelines to significantly reduce energy use (by more than 50%) and improve indoor environment quality in government and public buildings and building communities undergoing renovation
- gather and, in some cases research, develop, and demonstrate innovative and highly effective bundled packages of ECMs (Energy Conservation Measures) for selected building types and climatic conditions
- develop and demonstrate innovative, highly resource-efficient business models for retrofitting/refurbishing buildings and community systems using appropriate combinations of public and private funding such as ESPC (Energy Savings Performance Contract) and other concepts to be developed together with the building owners
- support decision makers in evaluating the efficiency, risks, financial attractiveness, and contractual and tendering options conforming to existing national legal frameworks
- engage end-users, mainly building owners and other market partners in the proceedings and work of the Annex Subtasks.

The project has achieved the following main outputs:

- Guides for deep energy retrofit of buildings and building communities towards different target groups: Decision makers, financial institutions and building designers.
- “Business model of deep retrofit/refurbishment of buildings and building communities using combined government/public and private funding”, and

- "Description of results of several realized projects and case studies demonstrating whole or a part of the developed model for deep energy retrofit using combined government/public and private funding".

Danish participation in and contribution to IEA Annex 61 is important as a mean 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 leader of subtask A, 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 Annex 61 var grundlæggende at forbedre beslutningsprocessen for at opnå vidtgående energirenovering af statslige/offentlige bygninger, begyndende med fastlæggelsen af pakkeløsninger af teknologier og tilhørende forretningsmodeller med kombineret offentlig og privat finansiering.

Formål:
- udvikle en metodik og udvalgte værktøjer og retningslinjer til at reducere energiforbruget (med mere end 50%) og forbedre indeklimaet i statslige og offentlige bygninger
- indsamle og i nogle tilfælde analysere, udvikle og demonstrere innovative og yderst effektive pakkeløsninger af ECMs (Energy Conservation Measures) for udvalgte bygningstyper og klimaforhold
- udvikle og demonstrere innovative, ressourceeffektive forretningsmodeller for energirenovering af bygninger og grupper af bygninger, der anvender egnede kombinationer af offentlig og privat finansiering, såsom ESPC (Energy Savings Performance Contract) og andre begreber, der skal udvikles sammen med bygherrer
- støtte beslutningstagere i at vurdere effektiviteten, risici, den finansielle tiltrækningskraft, og kontraktlige og udbudsrelaterede muligheder i overensstemmelse med de eksisterende nationale retlige rammer
- involvere slutbrugerne, primært bygningsejere og andre markedsdeltagere i sagen og anneksets arbejde.

Delopgaver:

Subtask A:
Forberede og evaluere casestudies på allerede gennemførte projekter med vidtgående energirenovering, samt udvikle en vejledning, så der kan opnås økonomisk attraktive forhold i forbindelse med vidtgående energirenovering.

Subtask B:
Udvikle forretningsmodeller for vidtgående energirenovering af bygninger og grupper af bygninger ved hjælp af kombinerede statslig/offentlig og privat finansiering.

Subtask C: Demonstrere udvalgte vidtgående energirenoveringskoncepter hvor der er anvendt kombineret statslig/offentlig og privat finansiering samt forberede casestudies.

Subtask D. Udvikle et IT-værktøj til beslutningstagere og energitjenesteselskaber, der kan fastlægge lav-risiko tilgange i den tidlige design- og beslutningsfase.

Resultater
Projektet forventedes at opnå følgende resultater:

- Vejledninger for vidtgående energirenovering af bygninger og grupper af bygninger rettet mod forskellige målgrupper: Beslutningstagere, banker og andre finansielle stakeholders, samt arkitekter og ingeniører.
- "Forretningsmodel til vidtgående energirenovering/ombygning af bygninger og grupper af bygninger ved hjælp af kombinerede statslig/offentlig og privat finansiering", og
- "Beskrivelse af resultaterne af flere realiserede projekter og casestudies der demonstrerer hele eller en del af den udviklede model for vidtgående energirenovering med kombineret statslig/offentlig og privat finansiering."

Dansk deltagelse i og bidrag til IEA Annex 61 har været vigtigt for at opnå mere viden om omfattende energirenovering af de eksisterende statslige / offentlige bygninger. Denne viden kanl bidrage til at nå de danske politiske mål om energi- og CO_2-reduktioner.

1.3 Executive summary

The scope of the Annex is to improve the decision-making process to achieve deep energy retrofits of government/public buildings, starting with the determination of working bundles of technologies and corresponding business models using combined public and private funding.

The project has ensured Danish participation in the IEA EBC Annex 61. Danish participation in and contribution to IEA Annex 61 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 and has thereby assured the best possible relevance of project activities and results in relation to Denmark.

The participating countries were USA, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Poland, Sweden and UK.

Receptors are:

- Buildings owners: executive decision makers and energy managers of public, governmental, and military administrations
- Private capital financiers considering investment in building energy efficiency such as Energy Service Companies (ESCOs), utility companies, and energy efficiency funds
- Technical experts: ESCOs and general contractors; design, architectural, and engineer firms, and manufacturers of energy efficient products and systems

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.

The project started January 2013 and ended December 2016.

In Annex 61 the definition of Deep Energy Retrofit (DER) is: Deep Energy Retrofit is a major building renovation project in which site energy use intensity, including plug loads, has been reduced by at least 50% from the pre-renovation baseline.

The work in the IEA Annex 61 was organised within 4 subtasks:

Subtask A: Prepare and evaluate case studies on existing deep energy retrofit concepts, develop a Guide for achieving financially attractive deep retrofits.

Subtask B: Develop business models for deep energy retrofit/refurbishment of buildings and building groups using combined government/public and private funding.

Subtask C: Demonstrate selected deep energy retrofit concepts using combined government/public and private funding and prepare case studies.

Subtask D. Develop an IT-tool for decision makers and ESCOs that emphasizes low-risk approaches for early design and decision-making stages

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

- "Guide for deep energy retrofit of buildings and building communities",
- "Business model of deep retrofit/refurbishment of buildings and building communities using combined government/public and private funding", and
- "Description of results of several realized projects and case studies demonstrating whole or a part of the developed model for deep energy retrofit using combined government/public and private funding".

Furthermore the Danish team has participated in several conferences and many papers have been written about the results gathered in Annex 61.

1.4 Project objectives

The energy saving potential achievable through energy renovation of existing buildings in Denmark is significant since 40% of the total energy consumption is used in buildings and most of the building stock is in poor condition regarding energy performance. Implementation of the potential energy renovation throughout the building stock in Denmark will to a great extend contribute to reach the goals for energy supply security and CO2- reductions. However only a fraction of the potential energy savings are realized. One of the barriers for conducting energy saving retrofit measures might be lack of knowledge on how the renovations should be handled the right way and which specific measures that will give the largest savings in the particular building. Therefore there is a need for guidelines describing the best energy renovation measures for different types of buildings.

IEA ECBCS Annex 61 - Development and Demonstration of Financial and Technical Concepts for Deep Energy retrofits of Government/Public Buildings and Building Clusters aimed at developing the necessary tools for an increase in energy renovation of the existing government/public building stock and reductions of energy use by more than 50 %.

In recent years, ESPC projects have been established in many countries as a very attractive way to address problems resulting from limited funding and other weaknesses in "owner-managed" retrofitting projects, and to delegate the primary performance risks to the ESCOs and other energy and design service companies. The ESPC has become a useful instrument for meeting energy policy targets in the building sector, while providing a guarantee on the performance of the projects. To date it has been used primarily as an instrument for retrofitting heating, ventilating, and air-conditioning (HVAC), lighting, and controls. In the face of the ambitious energy efficiency objectives it will be necessary to provide integrated solutions and corresponding business models to the market. ESPC for example is not yet the chosen vehicle for integrated retrofit projects that include the building thermal envelope.

The scope of the Annex was to improve the decision-making process to achieve deep energy retrofits of government/public buildings (office/administrative buildings, dormitories/-barracks, education buildings, etc.), starting with the determination of working bundles of technologies and corresponding business models using combined public and private funding. This decision-making process must improve to overcome existing barriers in the execution of complex projects co-funded by government, public entities, ESCOs, and other market partners. Barriers include the exclusion of individual ECMs with long payback times, and the challenges of combining energy-related measures with non-energy-related measures (e.g., building sustainment, repurposing, and improvement in quality of life).

While some countries have demonstrated successful renovation projects that reduced energy use by up to 70% in pilot projects subsidized by the government, penetration of such retrofit concepts into privately funded/co-funded retrofit projects is limited, or (in some locations) non-existent.

The objectives of this Annex was to:

- provide a framework and selected tools and guidelines to significantly reduce energy use (by more than 50%) and to improve indoor environment quality in government and public buildings and building communities undergoing renovation
- gather and, in some cases research, develop, and demonstrate innovative and highly effective bundled packages of ECMs for selected building types and climatic conditions
- develop and demonstrate innovative, highly resource-efficient business models for retrofitting/refurbishing buildings and community systems using appropriate combinations of public and private funding such as ESPC and other concepts to be developed together with the building owners
- support decision makers in evaluating the efficiency, risks, financial attractiveness, and contractual and tendering options conforming to existing national legal frameworks
- engage end users, mainly building owners and other market partners, in the proceedings and work of the Annex Subtasks.

Other objectives for the EUDP project were:

- To ensure Danish participation and contribution to IEA EBC Annex 61
- To collect and process knowledge from existing projects in both Denmark and abroad.

The following meetings, seminars and conferences were held:

Date	Place	Meeting / seminar / conference
2013		
9.05 – 10.05	Washington DC, USA	Pre-meeting
9.09	Darmstadt, Germany	Workshop ”Deep Energy Retrofit in Buildings (Case Studies, Performance and Financing)”
10.09 – 11.09	Darmstadt, Germany	1. Experts meeting
8.12 - 10.12	SB13 Dubai konference	SB13 Dubai conference abstract ”Analysis and Monitoring of Energy Use and Indoor Climate in Two Schools Before and After Deep Energy Renovation”
2014		

17.03	Copenhagen, Denmark	Technical conference "Business and Technical Models for Deep Energy Retrofit"
18.03 – 19.03	Copenhagen, Denmark	2. Experts meeting
22.09	Tallinn, Estonia	Technical conference
23.09 – 24.09	Tallinn, Estonia	3. Experts meeting
6.11	Brussels, Belgium	Annex 61 First Investors' Day Forum: Investing in Energy Efficiency in Buildings – Why and How?
2015		
24.01 - 25.01.	Chicago, IL	1. Interim Experts meeting
24.01 - 28.01	Chicago, IL	2015 ASHRAE Winter Conference
13.04 – 15.04	Reading, UK	4. Experts meeting
27.06 - 01.07	Atlanta, GA	2015 ASHRAE Annual Conference
21.09 - 23.09	St Nikolai, Austria	5. Experts meeting
23.09	St Nikolai, Austria	IEA EBC Industry Workshop
2016		
23.01 – 24.01	Orlando, FL	2. Interim Experts meeting
25.01 - 27.01	Orlando, FL	2016 ASHRAE Winter Conference.
22.02 - 23.02	Brussels, Belgium	Second Investors' Day Symposium.
11.04 - 13.04	Darmstadt, Germany	6. Experts meeting
14.04 - 15.04	Edinburgh, Skotland	CIBSE konference i Edinburgh
22.05 - 25.05	Aalborg, Denmark	12th REHVA World Congress Clima 2016
12.09 - 14.09	Washington, DC	7. Experts meeting
15.09 - 16.09	Washington, DC	Conference: "Deep Energy Retrofit of Buildings"

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: Bundles of Technologies

Subtask A is focusing on the evaluation of case studies of existing deep energy retrofit (DER) projects, and on the development and analysis of financially attractive DER bundles of technologies for three categories of buildings and climate conditions of participating countries.

Deliverables

- Summary and Analysis of 26 International Case Studies
- Deep Energy Retrofit Guide for Decision Makers
- Deep Energy Retrofit Guide for building designers

Case Studies: One of the major obstacles for the implementation of DER is the lack of data from best practice projects. The Annex 61 team has developed a comprehensive case study template to be used for collecting information on accomplished DER case studies. In Annex 61. a total of 26 DER case studies have been collected from the United States, Ireland, Germany, Denmark, Austria, and the Netherlands. Each case study provides information addressing:

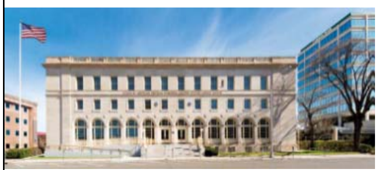
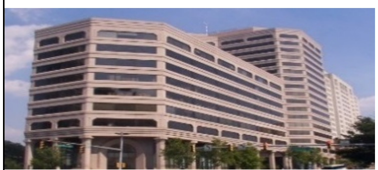
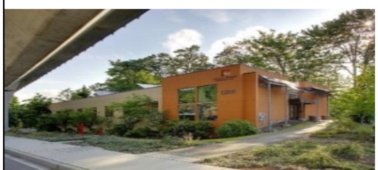
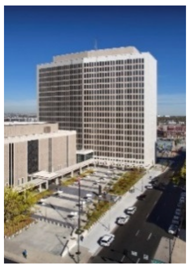
1. Type and characteristics of the renovated building, its location, climate, time of construction, and renovation
2. Site and source energy use reductions that have been achieved and how these results compare to existing building stock and national energy targets
3. The specific technologies (descriptions of their characteristics) and bundles of technologies used in these projects
4. Quantified differences between predicted and measured energy use
5. The investment costs of DER measures and measure bundles
6. Cost effectiveness of DER projects
7. Energy and non-energy related benefits of DERs
8. The reasons for which renovation was considered
9. The business models and funding sources used
10. The experiences and lessons learned drawn from the retrofit

The collected information was used to develop the decision-making guide. In addition, the findings are collected in an Annex 61 case study book, and several case studies have been presented at the 2015 ASHRAE Winter Conference and published in the 2015 ASHRAE Transactions as technical papers.

Table 1. Subtask A case studies

Number of case	Country	Site	Building Type	Pictures
1	Austria	Kapfenberg	Social Multi-family building	
2	Denmark	Egedal, Copenhagen	School	
3	Denmark	Vester Voldgade	Office building	
4	Estonia	Kindergarten in Valga	Kindergarten	
5	Germany	Ludwigshafen-Mundenheim	Multi-family building	
6	Germany	Nürnberg, Bavaria	Multi-family building	

Number of case	Country	Site	Building Type	Pictures
7	Germany	Ostfildern	Gymnasium	
8	Germany	Baden-Württemberg	School	
9	Germany	Osnabrueck	School	
10	Germany	Olbersdorf	School	
11	Germany	Darmstadt	Office building	
12	Germany	Town Hall- Baviera	Office building	
13	Germany	Nordrhein-Westfalen	High school	
14	Ireland	Dun Laoghaire Rathdown	Social Housing	
15	Latvia	Riga	Multi-family building	
16	Montenegro	Plevlja, Montenegro	Primary School	

Number of case	Country	Site	Building Type	Pictures
17	Montenegro	Kotor, Montenegro	Student Dormitory	
18	The Netherlands	Leeuwarden	Shelter home	
19	UK	London	Mildmay Center	
20	USA	Grand Junction, Colorado	Office Building / Courthouse	
21	USA	Silver Spring and Lanham, Maryland	Office/Federal Building	
22	USA	Bethesda-Maryland. DIA ICC	Intelligence Community Campus	
23	USA	Seattle WA. JBDG	Office	
24	USA	Priest River, Idaho	Beardmore Building Office	
25	USA	435 Indio, Sunnyvale, CA	Office/Warehouse	
26	USA	Byron Rogers Federal Office Building, Denver, Colorado	Office	

As subtask leader of Subtask A Cenergia has been responsible for putting together the Case Studies report and writing the Guide for decision makers.

Subtask B: Business Models for Market Implementation

The objective of Subtask B was to develop business models for DER/refurbishment of buildings and building groups using public or private funding or their combination. The business model determines and describes the relationship, services, obligations, and financial streams between the participating parties of a DER project.

Deliverables

- Deep Energy Retrofit Business Model Guide

Initial tasks have centered on the analysis and comparison of the business and regulatory climates that exist at various levels of governments in the five participating countries (Austria, Denmark, Estonia, Germany, and the United States), and business models existing under these framework conditions. In this context, the experiences from the use of different business models such as the “owner-directed” and the Energy Savings Performance Contract (ESPC) business model have been compared between the United States and European Union (EU) countries.

During the reporting period, members of Subtask B have been analyzing several different financial sources, financing mechanisms, and business models for achieving deep retrofits: (1) using private funding sources (e.g., in an ESPC alone), (2) combining private funding sources such as ESPC with public money available for Major Building Renovation, and (3) integrating DER into a major renovation and executing the project under a single general contractor.

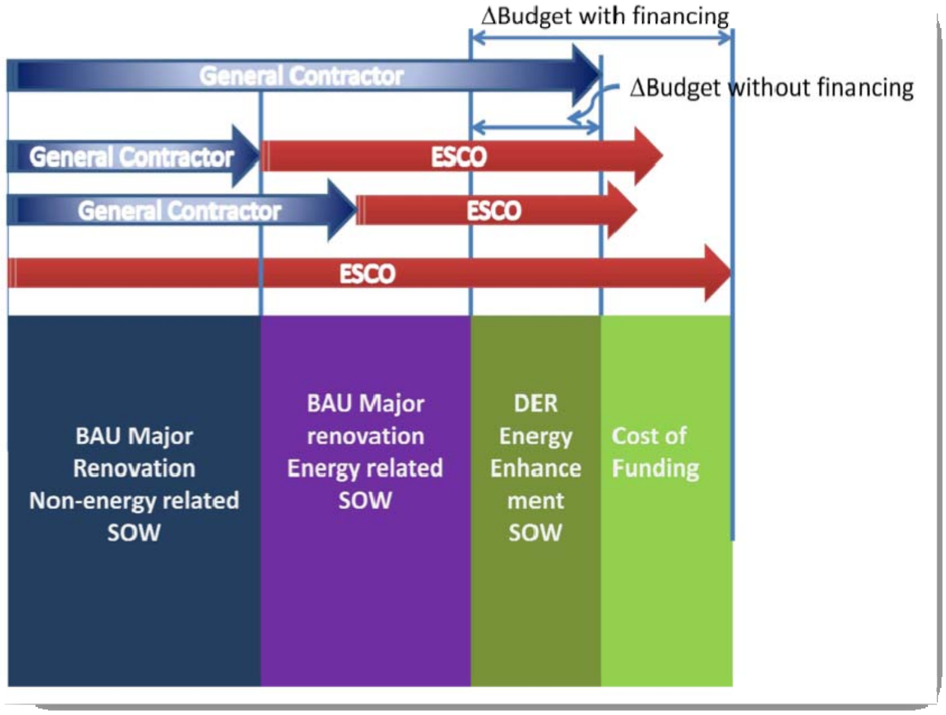


Figure 1: DER Financing Sources Models. (Note: BAU = Business as usual, SOW=scope of work).

Deep retrofits can be achieved through EPC alone when energy prices are high, when significant savings are available by implementing low-cost measures, and/or when large contributions of funds for energy related scope of the major renovation projects are budgeted. Such projects have been implemented in Europe where energy prices permit. High energy savings have been documented using public funds only (e.g., energy projects managed by the US General Services Administration [GSA] using American Recovery and Reinvestment Act funds, or the ongoing US Army project at the Presidio of Monterey, CA). Those projects are expected to achieve energy savings (site energy reduction) of up to 80%.

When public funds are limited, different combinations of these two strategies can be used to achieve DER during major renovation project. Members of Subtask B see the necessity to combine private funding sources such as ESPC with a major building renovation. In this case, the public funds contributed for the building renovation serve the combined purposes of reducing the cost of energy conservation measures, increasing the level of building energy efficiencies beyond the current building standards, and achieving the renovation itself. An example would be a renovation that includes funding for removing existing single-pane windows and installing new double-pane windows. In this case, private funding could contribute the incremental funding necessary to install triple-pane windows. This approach has the potential to reduce energy use by 60% or more without accruing additional costs for the public building owner.

Under certain given conditions (high energy prices, low specific DER investment bundle costs, and eligible project financing periods), a privately funded ESPC can even contribute to the public fund for a major building renovation; cost savings achieved in a privately funded highly efficient energy bundle that contain, e.g., lighting, building controls, and some roof insulation, may pay off the renovation after 12 years in energy savings alone. If the time frame for the project is expanded to 20 years, the savings that accrue over the additional 8 years may be used to refund a part of the major renovation costs. In that case, the public building owner will be able to use this “avoided spending” for major renovation as seed money to start another project.

Financing Mechanisms The funding mechanisms consider the way in which the DER investment costs (either delta-costs for different energetic scenarios or global investment costs) can be recovered by monetizing the benefits induced by the DER. During the reported period, Subtask B team members have developed a concept in which the DER Life Cycle Cost (LCC) analysis is conducted based on the “delta cost” of the project budget allocated for the construction and energy-related scope of the project designed to meet only the minimum building code requirements. To be cost effective, a DER needs to generate savings in operating costs (e.g., energy, maintenance, and insurance), and/or to generate additional revenues from higher profitability and lease rates of renovated buildings that will have a Net Present Value over the life of the project that will exceed the DER “delta cost.”

The maximum budget increase (or “delta cost”) can be calculated using the following equation:

$$\Delta \mathit{Budget}, \max = \mathrm{NPV}[\Delta\ \mathrm{Energy}(\$)] + \mathrm{NPV}[\Delta\ \mathrm{Maintenance}(\$)] + \mathrm{NPV}[\Delta\ \mathrm{Replacement\ Cost}(\$)] + \mathrm{NPV}[\Delta\ \mathrm{Lease\ Revenues}(\$)]$$

which can be presented using scalars and scalar ratios:

$$\Delta \mathit{Budget}, \max = \mathrm{SR}_{\mathrm{E}}[\Delta \mathrm{Energy}(\$)] + \mathrm{S}_{\mathrm{M}}[\Delta \mathrm{Maintenance}(\$)] + \mathrm{S}_{\mathrm{L}}[\Delta \mathrm{Lease\ Revenues}(\$)]$$

where S_M and S_L scalars can be calculated and are the uniform present worth factor series that use the discount rate, the same way as SR_E with the escalation rate e=0%.

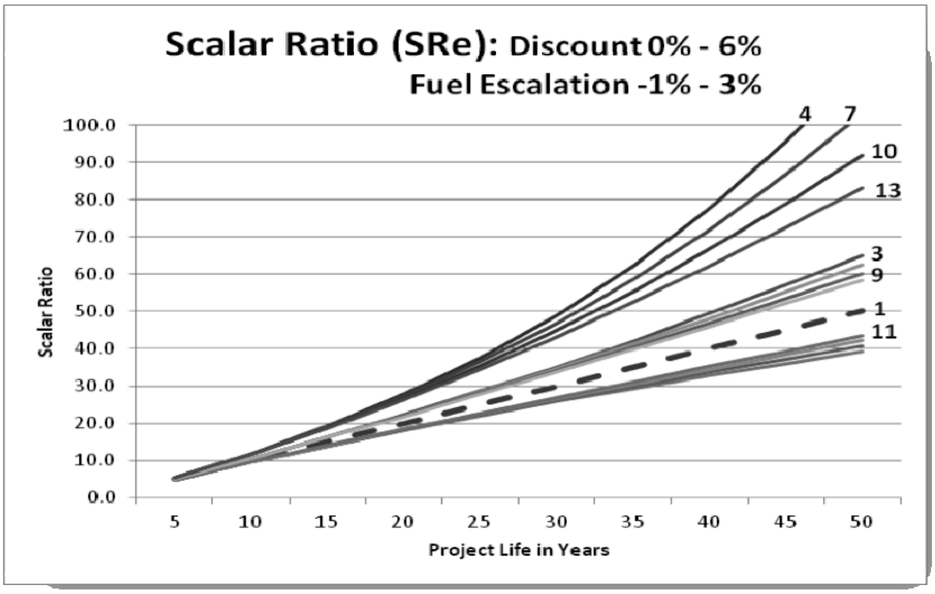


Figure 2. Scalar Ratio for Fuels at: (a) varying Discount and Fuel Escalations Rates SF

Subtask members are planning to further assess non-energy related benefits and monetary and non-monetary values resulting from DER by focusing on the following topics:

1. Non-energy components of operating costs such as reduced costs of maintenance, insurance, and water/sewage
2. Increased value of the building as the building users start to account the for additional values of "green" buildings with lower heating and electricity costs and avoided CO_2 emissions
3. Increased potential for marketing and promotions of the refurbished building
4. Increased net floor area (useable area)
5. Decreased health, employee absenteeism, and monetary compensation due to increased indoor air quality.

Business Model The business model integrates funding sources and financing mechanisms with the responsibilities of the involved parties. The working group compares two competing business models:

1. In the business-as-usual model, the architect, contractors, and tradesmen take responsibility for the implementation of DER measures, but the building owners remain in charge for the performance of these measures.
2. In the advanced ESPC business model, the Energy Service Company (ESCO) takes responsibility for the implementation, operation, and performance of the DER measures. ESPC often means that the ESCO guarantees the performance and the bankability of the life cycle cost benefits. With regard to the bankability of the business model and its funding mechanisms, Subtask B has also established a formal agreement with the Investor Confidence Project (ICP) Europe project, which is a high level research project funded by the EU commission to develop technical, process and financial quality assurance mechanisms for energy efficiency investments. This program was developed in California 2 years ago and provides a certification methodology for energy efficiency investments in the US market. By 2017, this methodology will be ready for application in the EU. The collaboration provides benefits for Annex 61 as it integrates the perspective of private investors into the results of Subtasks B and C.

Subtask B has tested the market applicability of the Annex 61 results in different ways. In some participating countries such as the United States and Germany, stakeholders from the public building sector, ESCOs, financing institutions and policy makers are involved in the working process. One main EU and US activity during the reporting period has been the documentation of findings from the First Investor's Day conducted on November 6, 2014 in Brussels, which was attended by more than 80 participants.

The Investors Day participants emphasized that increasing energy efficiency in the built environment is a key to reaching European's energy goals in regards of energy security, climate change, and economic growth. After the energy sector itself, buildings provide the second largest untapped and cost-effective potential for energy savings. Nevertheless, only a few profit-led energy services providers, private banks, or investment funds have identified energy efficiency as an attractive business. To change perceptions and stimulate private investor's appetite, existing success stories must be significantly better documented, publicized, and promoted. As yet, several important questions remain, e.g., how utility bill savings translate to attractive projects, and what needs to be done in the next decade to meet the European Union targets for energy savings.

Subtask C: Demonstrate Selected Deep Energy Retrofit Concepts

The objective of Subtask C is to demonstrate selected DER concepts using combined government/public and private funding and to prepare case studies of these projects. The goal is for each participating country to implement at least one DER project that would illustrate how the regulatory and economic environment (i.e., energy prices, construction costs, etc.) encountered in each country shaped the particular business and technical model used.

Deliverable

- Lessons Learned from Deep Energy Retrofit Pilot Projects

Subtask C participants have also developed a standardized case study template. This is similar to the format developed for Subtask A, and includes the following information:

- Short description of the project: building type, location
- Scope of work and description of technologies installed
- Baseline energy use and costs before the project
- Cost of the project, and predicted site and source energy and cost savings
- Results achieved (if the project has been constructed)
- Method of finance (directly funded, EPC, etc.)

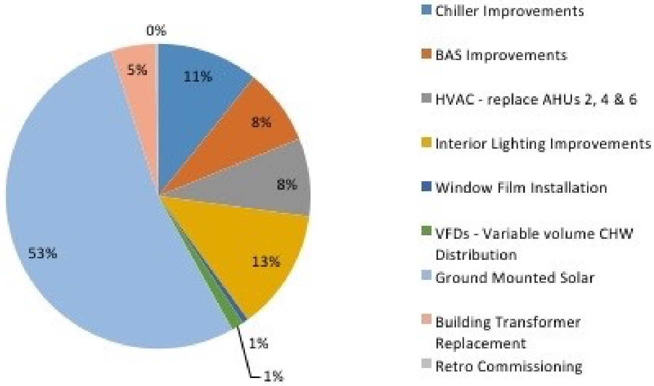
The following shows some examples:

GSA National Deep Energy Retrofit Program – St. Croix, US Virgin Islands First "Net Zero" Building Achieved Through ESPC

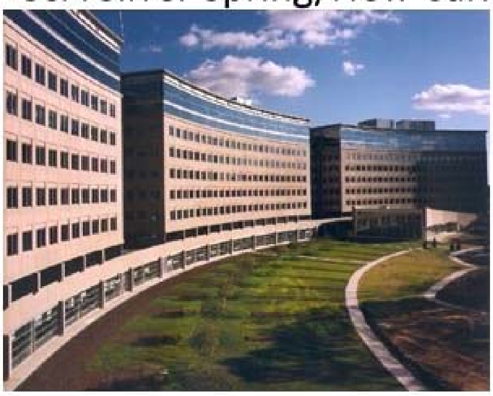
- Project Facts:
  - **Square Footage**: 76,227
  - **Investment Value: $6,372,000**
  - **Annual Energy Cost Reduction**: $509,777
  - **Payback Period** – 19 years plus 13-month construction
  - **M/BTUs/year**: 3,286
  - **Energy Reduction Percentage**: 100%
  - **Appropriated Funds included**: $118,750
  - **ESCO:** Schneider Electric
  - **ECMS based upon Investment Value:**

Buildings Included:

Almeric Christian Federal Building



GSA Silver Spring/New Carrollton Project



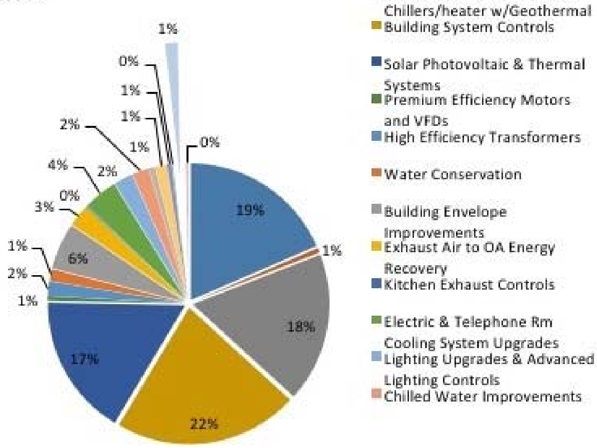
Project Facts:

- **Square Footage**: 2112664
- **Investment Value**: $44,633,045
- **Annual Energy Cost Reduction**:
- **Payback Period** – 22 years with 2-year construction period
- **M/BTUs/year**: 94588
- **Energy Reduction Percentage**: 60%
- **Water Reduction Percentage : 56%**
- **Appropriated Funds included**: $586,172
- **ESCO:** Ameresco

Buildings Included:

Silver Spring Metro Center 1 (MD0205ZZ)

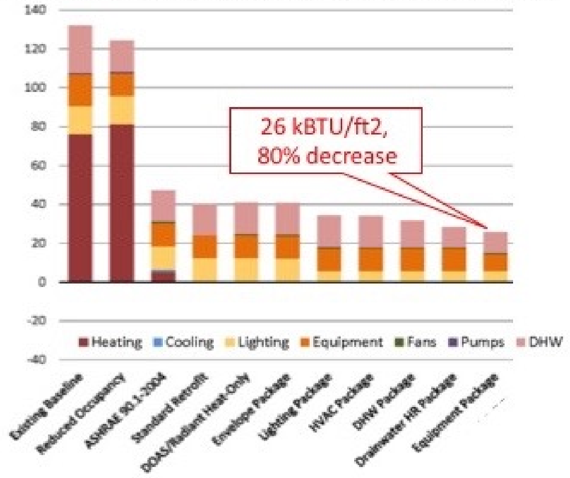
New Carrollton FB (MD0278ZZ) (pictured)



Renovation of the Barracks Building at Presidio of Monterey AG

Barracks before renovation (top and side views)

Major EEMs: Building envelope insulation: walls R-12. roof R-25, windows R=3 W/W ratio reduction, air tightness 0.15cfm/ft2 @75PA; lighting upgrade and controls, radiant heating, SWH: 70% of space heating and HW needs, return air HR; graywater heat recovery, high efficiency equipment.



Barracks building built in 1968
Total floor area 63,840ft2 (5746 m2)
Current energy use: Site 131.4 kBTU/ft2 yr (427 kWh/m2 yr)
Energy targets: Site 26 KBTU/ft2-yr (84kWh/m2 yr);
Source 60 KBTYU/ft2 (220 kWh/m2 yr)
Planned site energy use reduction: 80%
Project scope: Repair of dwelling units and administrative spaces, on-site greywater treatment, replacement of parking, courtyard hardscaping, exterior landscaping, and solar thermal roof-top panels.
Project budget: $23,355,492

Renovated barracks façade (rendering)

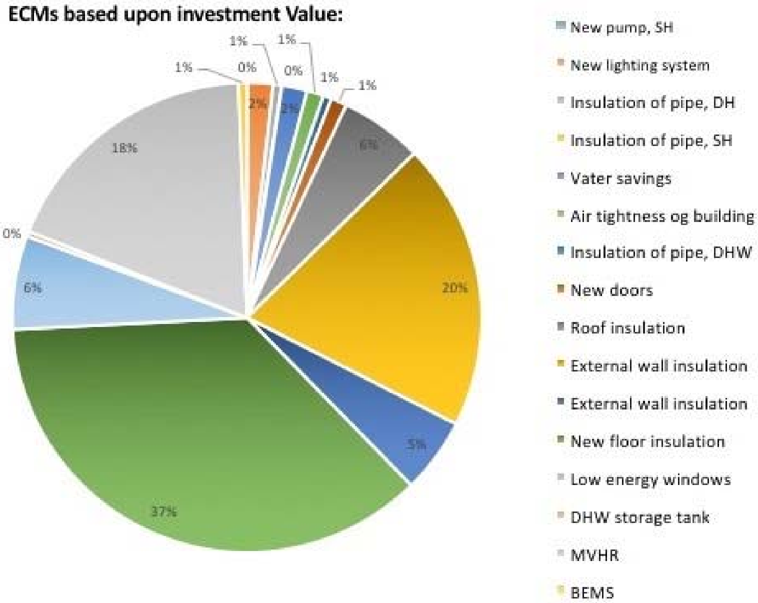
One wing has been gutted

Window replacement mock-up

Denmark: Grønne Etablissementer – Almegårds Kaserner

Project Facts:

- **Square Footage: 1411 m2**
- **Investment: 9.680.000 DKK**
- **Annual Energy and water cost reduction: 126.000 DKK**
- **Payback Period: 69 years**
- **Thermal energy savings percentage: 73 % (47 % RE)**
- **Electricity savings percentage: 53 % (65 % RE)**
- **Water savings percentage: 48 %.**
- **ECMs based upon investment Value:**



Buildings included:

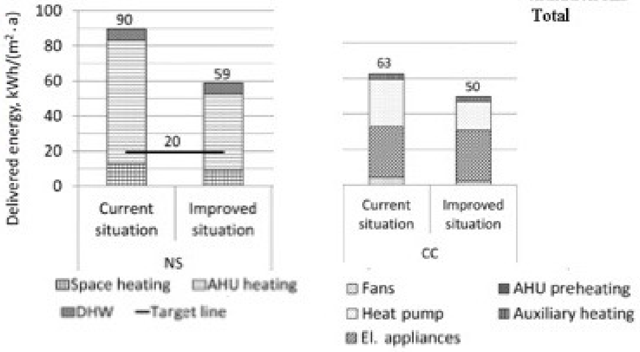
- Military barracks

Kindergarten in Valga, Estonia

- **Project Facts:**
  - Initial goal was to reach the level 20 kWh/m^2 a net space heat demand.
  - The building shell and the HVAC systems were replaced completely. The building has an additional "new building" part connected to the old one.
  - The study revealed many new aspects that should be taken into account in the future projects, and numerous new issues that are not considered as important in the regular building design became apparent.

Service system	Nursery school		
	Net energy		Real delivered energy
	Targeted value	Real consumption	
Space heating	3.9	13	13
Ventilation	4.0	71	71
Hot water	12	6.4	6.4
Total	20	90	90

Service system	Nursery school	
	Targeted value [4]	Real consumption
Electrical appliances and lighting	6.6	15.0
Ventilation fan	5.3	25.7
Total	11.9	40.7



Buildings Included:

- Built: 1960; Renovation: 2009
- Total floor area: 1156 m^2

Read more:

Raide, I.; Kalamees, T.; Mauring, T. (2015). Lessons learnt from the first public buildings in Estonia intended to be passive houses. Proceedings of the Estonian Academy of Sciences, 2, 157 - 167.

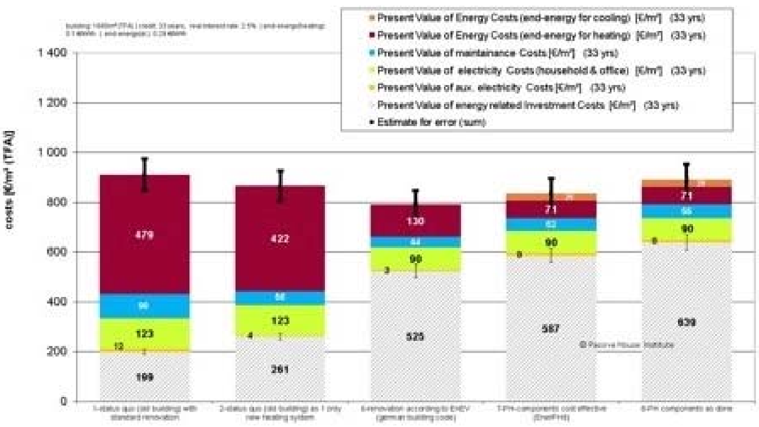
IWU office building, Darmstadt, Germany

Project Facts:

- **Square Meters useful area:** 1680 m^2
- **Investment Value:** 1 073 558 € (640 €/m^2)
- **Annual Energy Cost Reduction:** 36 800 € (22 €/m^{2}a)
- **Payback Period –** about 25 years
- **Energy Savings/year:** 315 430 kWh/a (183 kWh/m^{2}a)
- **Energy Reduction Percentage:** 87%
- **ESCO:** HSE Darmstadt
- **ECMs based upon Investment**

Buildings Included:

- IWU office building



Subtask D: Develop an IT-tool for Decision Makers and ESCOs.

Subtask D will integrate results of Subtasks A, B, and C and will develop a framework and models for government/public-sector decision makers and ESCOs, with a focus on the early stages of project identification and determination.

Deliverable

- DER IT-Tool-kit

The data and schemes may be provided as an intuitive electronic interactive sourcebook that provides holistic guidelines for implementing deep energy retrofit of buildings and building communities using innovative business models. The sourcebook will allow decision makers to obtain extensive general information on the technical, business, legal, and financial aspects of building and building community renovation projects that have achieved significant energy use reduction using a combination of public and private funds under their national frameworks.

Users who need information on energy-saving potentials and requirements for their individual building will be able to access different retrofit design and framework scenarios, descriptions of benchmark buildings, and the pool of experience gained in the best practice examples. The tool will allow building owners to define the scope of the deep retrofit project for their buildings based on the desired energy target for the building, available project funds, and a cost analysis of third-party funding.

Subtask D has collect, summarize, and present information on:

- Establishment of Retrofit Programs for DER
- DER case studies
- ECM bundles based on building type and climate
- DER project structure
- Input and structure for the intuitive sourcebook
- Decision-making models focusing the early stages of the project identification (included in a Guideline document)
- Distributed Energy Retrofit Guides developed in subtasks A and B

Dissemination of results

The deliverables described above will be uploaded on the website as soon as approval from the EXCO exists: http://iea-annex61.org/#

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.

SB13 conference December 8 – 10, 2013, Dubai

- Ove Mørck & Kirsten Engelund Thomsen. *"Analysis and Monitoring of Energy Use and Indoor Climate in Two Schools Before and After Deep Energy Renovation".*

2015 ASHRAE Winter Conference (January 24-28, 2015, Chicago, IL) and Annual Conference (June 27 - July 1, 2015, Atlanta, GA)

- Alexander Zhivov, Ruediger Lohse, John Shonder, Cyrus Nasseri, Heimo Staller, Ove Moerck, and Marko Nokkala. *Business and Technical Concepts for Deep Energy Retrofit of Public Buildings.*

- Jørgen Rose, Kirsten Engelund Thomsen, Niels C. Bergsøe, and Ove Christen Mørck. *Analysis and Monitoring of Energy Consumption and Indoor Climate in a School Before and After Deep Energy Renovation.*

2016 ASHRAE Winter Conference IEA Annex 61 Deep Energy Retrofit, Part 1: International Energy Efficiency and IEA Annex 61 Deep Energy Retrofit, Part 2: The Path to Net Zero

- Alexander M. Zhivov, Richard Liesen, Rüdiger Lohse, and Ove C. Moerck. *Core Bundles of Technologies to Achieve Deep Energy Retrofit with Major Building Renovation Projects in Europe, the United States and China.*

- Jørgen Rose, Kalle Kuusk, Kirsten Engelund Thomsen, Targo Kalamees, and Ove Mørck. *The Economic Challenges of Deep Energy Renovation: Differences, Similarities, and Possible Solutions in Northern Europe—Estonia and Denmark.*

- Heike Erhorn-Kluttig, Hans Erhorn, Stephan Kempe, Christoph Hofle, Jurgen Gorres and Kirsten Engelund Thomsen. *EU Project "School of the Future": Refurbishment of School Buildings towards Zero Emission with High Performance Indoor Environment.*

CIBSE Technical Symposium in Edinburgh, Scotland 14.-15. April 2016.

- Mørck, O. and Sánchez-Mayoral Gutiérrez, M. *"Deep Energy Retrofit of Buildings in Europe and the USA – Analysis of Case studies".*

12th REHVA World Congress Clima 2016 (May 22-25, 2016, Aalborg, Denmark)

- Ove C. Mørck, Miriam Sánchez-Mayoral Gutiérrez, Alexander M. Zhivov, Ruediger Lohse. 2016. *Best Practices of Deep Energy Retrofit Building Projects from Around the World*. Published in Heiselberg, P. K. (Ed.) (2016). CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 10. Aalborg: Aalborg University, Department of Civil Engineering.

- Jørgen Rose, Kirsten Engelund Thomsen, Ove C. Mørck. 2016. *Passive House Renovation of an Old Multi-Storey Office Building - Analysis and Monitoring*. Published in Heiselberg, P. K. (Ed.) (2016). CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 10. Aalborg: Aalborg University, Department of Civil Engineering.

The following IEA Annex 61 report is in press:

Mørck, Ove & Miriam Sánchez, Cenergia Energy Consultants, Herlev, Denmark, Lohse, Rüdiger & Martina Riel, KEA, Karlsruhe, Germany and Alexander Zhivov, US Army Corps of Engineers, Engineer Research and Development Center, U.S.A. : *"Deep Energy Retrofit - Case Studies, Business and Technical Concepts for Deep Energy Retrofit of Public Buildings - Annex 61".*

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 results from the project is the comprehensive case study template to be used for collecting information on accomplished DER case studies. The collected information was used to develop the decision-making guide.

The experiences and lessons learned from all the case studies have been grouped with respect to energy, use and comfort or to user-behaviour and acceptance. The heating energy consumptions were halved by the refurbishment of the building envelope and overall heating energy savings or 80 to 90% have been achieved by the combined building and systems renovation combined with change of supply (e.g. change district heating or heat pump). The indoor air quality increased strongly and a more stable humidity and a lot less pollution was achieved. However, it turned out that high ventilation rates would sometimes lead to very dry indoor air. The human behaviour plays a key role in the energy consumption: The energy consumption & Indoor comfort decreased significantly by carrying out a user training programs and improved documentation for common IT control equipment. Heating consumption is higher than calculated due to user behaviour. Therefore, occupant behaviour should be documented.

Furthermore, Annex 61 has been analyzing several different financial sources, financing mechanisms, and business models for achieving deep energy retrofits: (1) using private funding sources (e.g., in an ESPC alone), (2) combining private funding sources such as ESPC with public money available for Major Building Renovation, and (3) integrating DER into a major renovation and executing the project under a single general contractor.

The evaluation of the overall solutions of the case studies and the business models for extensive energy retrofit of existing buildings will help to form the future renovation projects. This allows the results of the project to help reducing the gross energy consumption in the existing building mass, so that the overall energy policy goals can be obtained.

Annex

Link for the webpage: http://iea-annex61.org/#

Annex 61 Business and Technical Concepts for Deep Energy Retrofits of Public Buildings