Final report

1.1 Project details

Project title	**IEA EBC – Annex 64: LavEx Samfund ”Low exergy community”**
Project identification (program abbrev. and file)	**64014-0540**
Name of the programme which has funded the project	**EUDP**
Project managing company/institution (name and address)	**Technical University of Denmark** **Anker Engelunds Vej 1. Building 101A 2800 Kgs. Lyngby**
Project partners	**Danfoss**
CVR (central business register)	**30060946**
Date for submission	**2018-03-27**

1.2 Short description of project objective and results

Engelsk version

The aim was to develop solutions that include holistic exergy principles applied on a community level. Different types of supply systems require different supply temperatures. To obtain the maximum output from a primary energy flow, different temperature levels can be cascaded according to the requirements of the building typology and technology.

Results are mainly based on case studies:
In case 1 in Bjerringbro the use of a central heat pump as the heat source for ultra-low-temperature district heating resulted in improved system exergy efficiency and reduced distribution heat loss. In case 2 in Frederikssund the space heating demand of a low energy house was supplied by the heat stored in the building mass based on direct electrical floor heating during off-peak hours, which is a good integration of different energy resources. In case 3 in Odder the Domestic Hot Water, DHW, was supplementary heated by instantaneous electrical heater, so that ultra-low-temperature district heating could be used to preheat the DHW

Dansk version

Formålet var at udvikle helhedsorienterede løsninger baseret på exergi principper anvendt på regionale niveauer. Forskellige typer af forsyningssystemer kræver forskellige forsyningstemperaturer. For at opnå maksimale output fra forskellige primære energi flow kan forsyningstemperaturerne sammensættes alt afhængigt at bygnings typologi og teknologi.
Resultaterne er især baseret på case studier:
I case 1 i Bjerringbro blev en central varmepumpe anvendt som varmeforsyning til et ultra-lav-temperatur fjernvarmenet. Der førte til forbedrede exergi effektivitet og reduceret varmetab fra nettet. I case 2 i Frederikssund blev der benyttet et elektrisk gulv-

varmesystem i et lavenergihus. Ved at udnytte lagringen i det tunge betongulv kunne huset opvarmes alene ved brug af nat-el. Dermed kan bygningen fungere som en fleksibel elforbruger. I case 3 i Odder blev et ultra lavtemperatur fjernvarmenet afprøvet med supplerende opvarmning af det varme brugsvand baseret på en elektrisk gennemstrømningsvandvarmer.

1.3 Executive summary

Exergy describes not only energy flow, but also energy quality through energy delivery process. Therefore, this project aims at developing the technologies and operation methods that can improve the overall exergy performance of the energy system integrating different energy resources.

As an active participant of IEA EBC Annex64, we documented the most representative Danish examples with the strongest relevance and novelty.

The overall results of the project are based on an overall evaluation of the energy and exergy performances of different new solutions, as well as the possibility of the achievement of phasing out fossil from energy and economy point of view. The concrete case studies have shown that new solutions with energy benefits can be developed into buildings with low energy consumption and low-temperature heating systems if electricity is used to supplement the heat supply. However, the economy in the solutions depends on the prices and, in particular, the taxes on electricity consumption.

1.4 Project objectives

From exergy point of view, the exergy quality of the energy supply should match the exergy quality of the demand, to avoid the destruction of the useful work. Therefore, the main objective of this project is to find alternative solutions to establish better match of exergy quality between the supply side and consumer side, which is reflected by the temperature level. The hypothesis is that the exergy approach will help to identify the optimal solution to save green house gas (GHG) emissions, energy and costs with long-term vision. For some solutions it is difficult to determine the economy in the future before they are standardized. Therefore by taking an exergy approach it can be used as basis to assess the future solutions economy.

During the implementation process, the project worked cohesively with three main areas where exergy concepts strongly can be addressed:

1. Low temperature district heating for new and existing buildings

2. Electricity use for heating in off-peak hours in non-district heated areas

3. Exergy analyses for energy savings versus energy supply - to which extent should we save energy and to which extent should we supply energy.

Different case studies are used to investigate the different technologies. Adjustments of the work content were continuously conducted, in order to ensure the core objective of the project can be met. Some of the planned milestones were replaced by other case studies with closer connection. The most relevant and representative Danish good examples are documented. The project followed the time schedule. For more information on the implementation of project and the milestones see 1.5.

1.5 Project results and dissemination of results

Brief introduction of the results from the included case studies:

In case study in Frederikssund, the feasibility of using heat storage in the building mass to cover the space heating demand by transferring surplus electricity was tested. A predictive control model was developed for the case with consideration of the comfort requirement and weather condition. The thermal comfort can be achieved without problem using this solution.

The case study in Bjerringbro utilizes a combination of ground water cooling and heat pump heating. The ground water is heated by the cooling load in the summer period and is being cooled by a heat pump in the winter period. The ground water heat pump supplies heat to an ultra-low-temperature district heating (ULTDH) grid. This case study was in collaboration with Bjerringbro DH company. The ULTDH system was operated with 46 °C supply temperature most of the year without any discomfort at the consumer side. The heat extracted from the ground water was able to cover most of the heating load, which reduced the heat production by conventional fuel. The exergy efficiency of the renewable based ULTDH system is also higher than the conventional system.

Case study in Odder, which added a supplementary electrical heater for domestic hot water preparation to realize the ultra-low-temperature district heating. This use case was in collaboration mainly with Danfoss. On-site experiments were performed in five single-family houses. Based on one-year measurements, the installation of electrical heater can guarantee comfortable temperature of domestic hot water with small electricity consumption and heat losses.

The collection of project activities and dissemination are listed below:

In the period of 2015
Activities:
• The start-up meeting was held in June 2015, which defined the work plan of the project and the case studies should be included. Afterwards, we (Danfoss and DTU) participated in an Annex 64 meeting in Delft, where the different working groups were established and defined.
Disseminations:
• Hosted an Annex64 workshop meeting in Vejle, Denmark to exchange information and update the status of the project.

In the period of 2016
Activities:
• Adaption of the content of the technical report of the Danish case studies based on what was possible to be implemented and the relevance to the core purpose of this Annex.

• The technical solutions and performance analyses for the selected case studies were carried out in this phase with collaboration with the industrial partners.

• Organized a workshop meeting for the Annex64 group in Aalborg during the "Clima world congress" period.

Disseminations:

• Presentation based on case study 2 in "CLIMA 2016- the 12th REHVA World Congress" about heating buildings with direct electrical heating by storing heat in the thermal mass during off-peak hours using predictive control.

• Participation in the Annex64 workshop meetings in Princeton, USA, in October 2016 to exchange the information and update the status of the project.

In the period of 2017

Activities:
• The work on case studies has been completed and reported for use in the overall final report of the Annex.

Disseminations:
• Participation in the Annex64 workshop meeting in Darmstadt, Germany, in March 2017 to finalize the structure and content of the final report.

1.6 Utilization of project results

In IEA EBC Annex64, we investigated the possibility of storing surplus electricity by the form of heat in the building mass and release it when necessary for space heating demand. A predictive control method for the electrical heating is also developed. The result from this project can be seen as a good solution for supplying heat to energy efficient buildings in the low heat density area. Moreover, the performance of local electrical booster for supplementary heating for domestic hot water was also investigated, which can be seen as a solution for securing the supply safety of ultra-low-temperature district heating system.

Danfoss, as the industrial partner, agrees on that the investigations from this project has constructive meaning for developing the products meeting the needs of the future market. With the context that renewable energy will play a more and more important role in the future energy system, the integration of the electricity during the off-peak demand hours is helpful to stabilize the fluctuation of the renewable energy system, and could be more efficient from economy point of view. Considering those, the target market can be in the countries with high share of renewable based electricity generation, such as wind power or solar PV.

To a broader scope, this project proves the possibility of realizing low-temperature district heating (LTDH) and ULTDH in practice by providing tested solutions and demonstrations. The knowledge and experience shared can be utilized by the utilities, industrial companies and policy makers to establish a more efficient energy system.

1.7 Project conclusion and perspective

The key motivation of this project is to utilize the energy more efficiently both in single buildings, and in a group of buildings, by the means of integrating the distributed energy resources smartly. By integrating the surplus electricity into the district heating system, it is possible to optimize the energy supply from electricity and heat of district heating, thereby realizing the ultra-low-temperature district heating. From the results of the case study with electrical floor heating, the surplus electricity during night periods can be stored in the form as heat and released for covering the heat demand during the following day, which increase the flexibility of the integrated energy system. Electrical water heaters as a local supplementary heating solution to ULTDH, makes it possible to reduce the district heating operating temperature, thereby reducing the distribution heat loss and utilize low exergy heat sources as e.g. waste heat. From the demonstrated case study, by such integration, it is possible to supply the low heat density area with ultra-low-temperature district heating with good energy and exergy efficiency.

It is expected that, the future energy system can be more flexible and efficient by integrating the electricity supply and district heating supply. With the improvements in the operation and demand side energy management, the distribution of the energy from corresponding resources can be optimized. As a result, the optimal operating temperature level of district heating can be confirmed considering the specific situation locally.

The renewable energy resources will be utilized utmost within the extent, so that to phase out the fossil fuels. The total energy input to the community will be minimized.

The technical solutions and experience from the case studies provide solid support for industries to develop their products fitting into the future market and also operation method for future energy system.

Final reports from IEA EBC Annex64 will be available in 2018 on:
http://www.annex64.org/