Annual report – Executive Summary

Reporting months: July 2017 – June 2018

Photo: By & Havn / Rasmus Hjortshøj

Christoffer Greisen, corresponding author/editor
DTU Electrical Engineering
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Contributors:
Benny S. Hansen, ABB
Palle Holdt, Balslev
Magnus Klintström, DTU Electrical Engineering
Kristian Honoré, HOFOR
Poul Brath, Radius Elnet
Claus Bildsøe Astrup, CleanCharge
Jane Hegner Mortensen, By&Havn
Jan Eric Thorsen, Danfoss

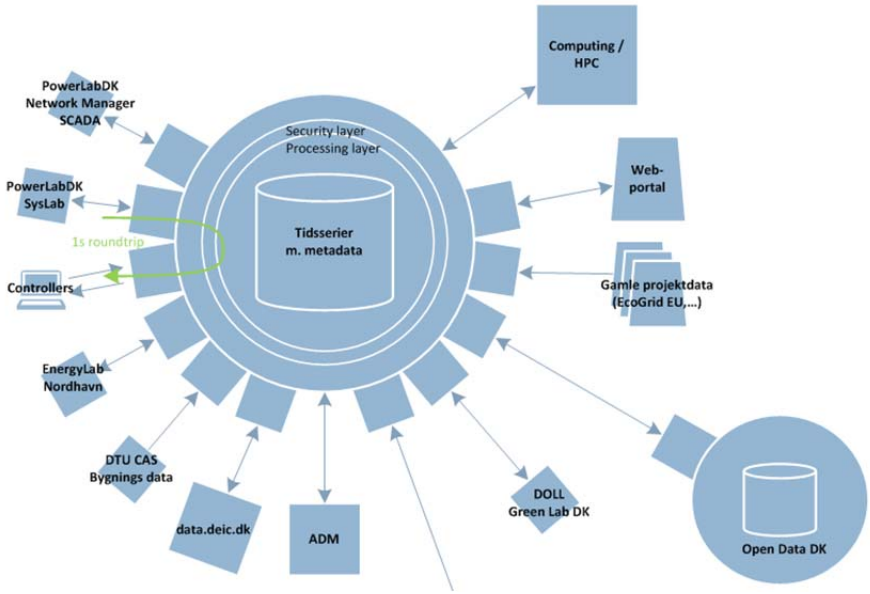
1. Introduction

This summary covers the progress in the project for the reporting period, covering all 10 work packages of the project under the two EUDP grants 64014-0555 and 64015-0055. For further details, please consult the individual WP reports

2. Selected activities and technical results in the reporting period

WP2 Data

The shared data system is centered on a Data Management System, DMS, operated by DTU PowerLabDK, aimed at providing data to and from infrastructures and other relevant sources to all participants in the project.



The DMS itself is now in operation, the interfaces are finalized for most of the installations and a plan for the remaining has been agreed. Metadata has still not been entered for all data streams, but work is in progress and there is a simple way to add metadata.

DTU is data responsible, and GDPR compliance is handled by the legal department at DTU. This includes consent declarations for residents and data processing agreements for relevant ELN partners.

Data validation and monitoring of interfaces are still not in place. Work is in progress. Some recently completed tests and data being received by the DMS are:

- End-to-End test between KNX home automation systems and the DMS
- Validation of data from a local weather station at CIS

- Connection of HOFOR data stream from heat meters by hourly sFTP[1] transfer to the DMS
- Sourcing of data from Radius RPM by sFTP is enabled, but frequency of data exchange is still being investigated
- Data from CleanCharge EV charging stations is being received by DMS.
- NordPool electricity prices are being received by DMS
- Agreement regarding weather data from a commercial supplier has been signed and data is now being received by DMS
- Agreement regarding live data on CO_2 emissions and production mix in the electricity grids and weather forecast for wind production has been finalized.

Extraction of data from the DMS is possible, but the user interface needs improvements.

WP3 Smart Energy Buildings

Installation of building automation systems has been completed. Work on structuring the data by adding metadata has been carried out in collaboration with WP2 in order to make the data accessible for the researchers. A PostDoc, several PhD and Master students are well integrated in the project, working on building modelling and the use of flexibility related to the consumption of heat and power in buildings. Studies of how thermal designs and occupants' behaviour in smart buildings influence the energy performance of the building have been carried out. The research has led to fourteen conference papers and eleven journal articles, along with participation in several conferences and seminars.
A dominating theme has been the possibility to adopt paradigms for flexible delivery of energy, particularly heat, to the buildings, and how it interacts with occupants' presence and use of buildings. In addition, technological themes such as the effect of thermal mass, ventilation and solar gains of buildings have been studied while considering possible simulation based means to predict the thermal indoor environment and patterns of energy use. So far, the studies seem to indicate that there is a good potential for adopting paradigms for flexible delivery of heat to buildings in Nordhavn without sacrificing the comfort of occupants. The best possible means to control such patterns (Demand Side Management) is still being studied, e.g. with variable tariffs.

Selected results and task activities in the reporting period

- The building recruitment process has been finalized
- The building automation system (KNX) has been successfully installed in all recruited buildings

[1] Secure File Transfer Protocol. API's (Application Programming Interface) is another data transfer method.

- A quantification of the flexibility potential in various generations of the building stock has been made available
- The findings are elaborated in 11 journal articles and 14 conference papers published or in pipeline
- Six B.Sc or M.Sc. theses have been based on WP3.

WP4 Smart Network services
This work package addresses the development of smart network services and demonstration on two technology platforms - one for shift in energy carrier and one for temporal decoupling of electrical heating and delivery of space heating.

The enrollment of residents for the fuel shift installations in *Frikvarteret* has started, and verification of the fuel shift controller and configuration settings is ongoing at DTU Risø SYSLAB. Work on defining and structuring measurement data has started in collaboration with WP2.

Fuel shift can provide substantial benefits in term of reducing peak boiler usage, managing network congestion and reducing CO_2 emission levels. According to a simulation-based study performed by DTU researchers, there is a potential of maximally reducing base and peak heat load by 15% and 48% respectively for the simulated DH system, when advanced coordination is conducted between a district heating operator and heat users installed with fuel-shift technologies. It can be doneat the modest penalty of an increase in electric power consumption by up to 4%. If well managed, this electricity consumption can avoid other peaks in the electrical grid.

With regards to the space heating application, a demonstration site for the Quantum Heater installations has been located and nine heaters have been installed at E-hub in Nordhavn. The specification and design of a Quantum smart controller have started and the plan is to demonstrate load scheduling (Electricity price response).

For the next steps, availability of other data sources in the DMS is crucial.

WP5 – District heating Infrastructure
During the past year several tasks, demonstrations, tests and analyzes related to the district heating infrastructure have been carried out. Furthermore, the first deliverables of WP5 have been completed.

The following activities and deliverables in Task 5.1 have all been reported and finalized:
- Optimized operation of a district heating network by including heat consumption data
- Value and added know-how from improved energy labelling and heat profiles of buildings for better operation of district heating substations as well as energy savings at customer level in the buildings.

Furthermore, the demonstrations on flexible customers; short-term heat storage in buildings in T5.2c have been carried out successfully and with promising results. It has

been demonstrated that significant energy flexibility can be achieved from activating the thermal mass in the buildings without compromising the customers comfort. The preliminary results are so promising that this activity has been adopted by HOFOR's regular project pipeline and will be scaled up outside the EnergyLab Nordhavn project.

The FlexHeat Nordhavn heat pump was commissioned in May 2018. It will be able to integrate the power and heat markets in an optimal way as the FlexHeat system includes a thermal heat store as well as electrical heaters to increase the potential for delivering flexibility to the electricity system.

WP6 – Electricity Infrastructure
Work in all tasks is aiming on the future load scenario with stochastic load profiles and increased loads from i.e. electric vehicles and heat pumps.

The grid-connected battery has been in operation since spring 2017. Minor shortages in the control algorithm have been corrected. The primary application tested is peak shaving of the general load on the 10 kV grid, but the battery is also designed to utilize the spare battery capacity for trading on the reserve market in order to demonstrate a positive business case. Since it was commissioned, the control algorithm has been adjusted and tested. Regarding peak shaving, an IT tool has been developed in order to predict which hours to peak-shave the following day and which hours to offer to the reserve market, in order to maximize income. Furthermore, State of Charge management has been tested. All the mentioned tests show correct functionality.

Radius and the other participants in WP6 are continuously expanding the scope of the work according to the learning obtained, including the research activities on load patterns and new grid design methods. A review of task and deliveries in WP6 is therefore foreseen.

WP7 Transportation Infrastructure
Two car share options with electric vehicles have been made available for the residents in Nordhavn and By & Havn has granted the car share companies access to the parking facilities in P-hus Lüders in Nordhavn. CleanCharge has installed two dedicated chargers and made an agreement with By & Havn to rent four dedicated parking spaces for the car share companies in a test period of six months.

A work-around has been made with one of the car share companies to utilize their existing RFID-chips in the cable to authorize and identify the charging sessions on the chargers.

Denmark's currently fastest DC quick charge with 150kW+ peak output and a 50kW DC charger have

been installed in P-hus Lüders in Nordhavn as a joint investment by By & Havn and CleanCharge. This signifies an important step toward mutual investments, responsibilities and understanding of a future with e-mobility at its core, where charging as a service is a vital component and offering of a modern urban parking facility.

The quick chargers have been put into operation and a profit and loss model has been developed with quarterly settlements based on the business case approved by By & Havn and CleanCharge.

In the past year, connections and coordination between WP6 and WP7 have been elaborated. The chargers are not directly connected to the battery, but the load onto the grid from several chargers already installed will generate a peak load that can be countered by the installed battery and its peak shaving mechanism.

Cars with the necessary functionality are expected to be introduced to market during the last year of the ELN project, at which point the active demonstration of grid services through protocol 15118 as described in Del. 7.1 will be demonstrated.

WP8 – Smart integrating solutions

This work package aims at integrating the work and physical demonstrations provided by the other technical work packages. The content has been restructured and a new complete description has been approved by the Steering Committee and by EUDP.

The new approach entails a structured process to define use cases, which in turn will lead to the demonstration of smart and coordinated operation of multiple ELN assets. Based on the previous and recent concept work, four use cases are now refined, adopted and anchored.

The first use case has been selected for implementation. It coordinates the smart operation of the large heat pump with a heat storage and the smart charging or discharging of the battery. It is now being planned how it can be implemented using ABB's MicroSCADA platform. The other three are:

- ELN XUC#25: Coordinated load shift in the power grid
- ELN XUC#26: Coordinated load shift in the district heating network
- ELN XUC#27: Distributed heat generation in the district heating network

Progress has been made on the development of a new coordinated, dynamic and time of use price and tariff structure for district heating and electricity. Actual demonstration sites selected for the first analysis are the fuel-shift demonstration in the *Frikvarteret* townhouses.

As for the wholesale market coupling, three different mechanisms for coupling heat and electricity markets have been compared: i) a traditional sequential market framework, ii) an integrated market framework, and iii) an improved (stochastic) sequential market framework. Uncertainty from wind production has been accounted for using stochastic programming.

Research on how to apply the improved sequential market clearing to large-scale energy systems is in progress. Focus is on the use of a tailored decomposition algorithm for large-scale optimization.

WP9 Visibility and Stakeholder Engagement
The past year, the focus has been on the opening of the showroom, identifying SME's and handling of delegations.

With the official opening of the Showroom in December 2017, a great milestone was reached. We succeeded due to an enormous effort from the partners and the possibility of using Pakhus 47 on Sundmolen owned by By & Havn, who also engaged Urban Help to operate the facilities.

The external visibility of the project is high, with attention from domestic and international media, from international delegations and invitations to expose the project internationally.

Until March 2018, the showroom has been visited by nearly 1800 people and is frequently used for meetings, conferences and other events. Furthermore, it has become the seed for an innovative co-working space for project participants as well as regular tenants.

A few examples: the Copenhagen Climate Solution Conference hosted by the City of Copenhagen invited participants to Nordhavn in August 2017, several Swiss and French utilities visited in the fall 2017 and winter 2018, the Ukrainian Minister of Energy visited the sites in May 2018 the same month as the EnergyLab Nordhavn project was main host of a full week program during the Nordic Clean Energy Week. As part of the program the Mission Innovation IC#1 working group had its public workshop in the showroom which showcased EnergyLab Nordhavn to a wide audience from both international research institutions and energy companies.

The coordination of the vast number of delegations and matching of their needs with the project partners has been carried out by the project secretariat. A handover of the activities from the secretariat to Københavns Kommune is in process and will take place during the remaining project period.

WP10 Smart Components

This work package aims at demonstrating a heat booster substation solution for ultra-low temperature district heating, activation of flexibility in apartments through the use of the Danfoss home automation systems and the flexible use of waste heat from a supermarket.

The Heat Booster Station (HBS) is in operation in *Havnehuset*, supplying 22 flats in a multifamily building with domestic hot water and domestic hot water circulation. Based on the first field experience of the HBS, it can be concluded that the HBS unit is successfully installed, commissioned and in operation.

Initial testing has shown that the electric power consumed by the two heat pumps amounts to a range of 11-17% of the total heat supply to the system, depending on the domestic hot water consumption. The electric load shift potential is limited to app.12 kWh/day, whereas the district heating load shift potential is app.120 kWh/day, which is in the same range as the load shift potential based on the buildings passive thermal capacity relating to the heating system.

As for the flexibility to be activated with home automation systems, challenges with realizing the load shift schedule principle for eight flats in *Havnekanten* has resulted in limited field test results so far. Focus is now on solving this and becoming ready for the coming heating season where load shift control will be applied.

For the demonstration of the recuperation of supermarket waste heat, a *Meny* store (Danish super market chain) has been enrolled and is expected to open at the end of 2018. Planning of the integration of the HOFOR district heating grid and heat recovery of the supermarket refrigeration system is currently in progress. A direct cooperation between Danfoss, *Meny* and refrigeration subcontractor Knudsen Køl has been established.

3. Follow up on milestones

Ye	Gra	2017												2018												2019			
Work packages/ tasks																													
Technical and commercial Milestones																													
M2b: Agreements are in place with sufficient amount of building owners to conduct the necessary demonstrations for the project, except those HOFOR demonstrations in buildings finished later than july 1, 2016.				X																									
M3: Showroom established	14									X	X																		
M4: Data management system in operation	14										X																		
M5: Battery in operation	14				X																								
M6: EV charging in operation	14											X					E												
M7: Smart building management demonstrated	14												X			E													
KM5: Styring af en stor varmepumpe og el-patron i forhold til varierende priser på el.	14																	X										E	
MP1: Contracts signed with building owners	15												X																
MP2: Heat boosters successfully installed in building	15									X				X															
MP3: Heat booster and circulation HP successfully demonstrated	15																X			E									
MP4: Living Connect successfully installed in 10 apartments	15	X																											
MP5: Living Connect successfully demonstrated	15																X											E	
MP6: Multi-purpose heat pump successfully installed in supermarket	15																			X									

In the reporting period, the following milestones[2] have been reached:
M3: The showroom was established and inaugurated in December. It offers an innovation hub for SME's, start-ups and project participants.
M4: The data management system is in operation. Data streams can now be collected as access to them is established and they can be extracted by the trained user through a simple interface. A user-friendly interface is being developed.
MP1: An agreement with *Meny* to carry out demonstrations in the supermarket on Southhamptongade in Nordhavn has been made and hence all necessary contracts with building owners for the Danfoss demonstrations are in place.
MP2: Heat boosters have been successfully installed in *Havnehuset* and have passed a site acceptance test. Hence this milestone was reached in March 2018.

The following milestones are delayed:
M6: (Smart EV charging) was expected to be completed by May 2018. At the milestone review, a discrepancy in the interpretation of requirements for milestone fulfillment has appeared and needs to be resolved before a new estimate can be made.
M7: (Smart building management demonstrated) requires a bit more documentation, since the team has decided to pursue the demonstration of the building management by using automation systems for private homes, controlled through the IT systems established in the project.
KM5: Originally, it was planned to establish and test the operation of two large heat pumps. It turned out to be practically impossible to establish the one planned at *Fisketorvet* and, instead, the ambition level for the large heat pump at the cruise terminal has been increased. It requires a few months of a heating season to reach the milestone and the plant was not ready before this spring. Hence, it is expected to be delayed until March 2019.
MP3: (Demo of heat booster) is delayed, since it requires a new developed circulation heat pump to be built and tested at DTU and subsequently installed in a reference building on

[2] Milestones of the form Mx and MPy are technical milestones under the two grants, whereas KMz are commercial milestones in the EUDP definition.

Strandboulevarden. Furthermore, load shift tests on the heat booster substation are still pending.
MP5: (Living connect) is expected for February 2019, since it requires demonstration of the remote set point shifting in a heating season, and this capability did not make it for the 2017/18 heating season.

4. Notes on the project management and governance

The Steering Committee has convened quarterly with excellent levels of appearance (>80%), proving a strong anchoring of the project with the partners. An important activity in this regard was the midterm review with the EUDP board, held in December 2017. The WP Leader group convenes once a month to follow up on cross-cutting issues and share progress across the project.

In the reporting period, six change requests have been submitted to EUDP. The following changes are the most important

Date (appr)	Topic	Justification
27/10-2017	Changes to deliverables in WP6	Primarily changes in the detailed plans for tests on the battery (task 6.3)
19/12-2017	Project extension by seven months with budget adjustments	A full heating season and time to test new roles and use cases.
2/5-2017	Change in HOFOR budget (equipment to man power)	More effort was needed in relation to the Flexheat heat pump at the cruise ship terminal
6/7-2018	New WP8 description and budget adjustments	More operational setup for WP8.

5. Dissemination and visibility

During the reporting period, the accumulated number of journal papers and conference presentations has reached 48. Furthermore, the showroom has proven to be a very powerful dissemination platform for formats such as presentations, workshops and informal meetings.

6. Comments on the upcoming phases

As for the data warehouse, focus will be on improving the user interfaces for the DMS, including data browsing and on improvements to the data validation processes. Furthermore, the ability to forward control signals will be implemented. Some of the data streams will be selected for visualization.

The energy flexibility of buildings will be activated through the installed home automation systems and further tests with Copenhagen International School will be carried out. The domestic hot water fuel shift solutions will be rolled out to *Frikvarteret* and *Sundmolehusene* and they will be included in demonstrations based on the tariff and pricing scenarios developed. The electrical space heating solution for load scheduling will be tested with respect to the same scenarios.

The FlexHeat including heat storage and balance of plant elements will be tested including its role on the market for ancillary services. The operation of the load shifting capability of the booster heat pump based on energy system needs will be demonstrated, and the supermarket heat recovery system will be added to the Nordhavn experiment portfolio.

The battery will be included in a number of integrated operation schemes, and scenarios for service stacking will be tested. For the EV charging, analyses of user patterns will be made and potential peaks identified. Pricing models for alleviating such peaks will be carried out and – when EVs with the necessary capability are available – the use of dynamic charge profiles for grid congestion management will be demonstrated. Through the realization of use cases, the concerted operation of many of these elements will be demonstrated. The project will put an increased focus on the uptake and anchoring of the developed solutions with project partners' development pipelines as well as with external stakeholders, such as consulting engineers, regulators, energy retailers and other service providers. Specifically, the results can be used for informing the development of the next phases of Nordhavn area.

Quality Assurance

Action	By	Date
Sent for review	Christoffer Greisen	July 4, 2018
Reviewed	SG members	July 11, 2018
Approved	SG/Christoffer Greisen	July 17, 2018

Author/Editor	Reviewer	Approver
Christoffer Greisen	SG members	Steering Committee

The project "EnergyLab Nordhavn – new urban energy infrastructures" will develop and demonstrate future energy solutions. The project utilizes Copenhagen's Nordhavn as a full-scale smart city energy lab and demonstrates how electricity and heating, energy-efficient buildings and electric transport can be integrated into an intelligent, flexible and optimized energy system. The project participants are: DTU, City of Copenhagen, CPH City & Port Development, HOFOR, Radius, ABB, Balslev, Danfoss, CleanCharge, METRO THERM, Glen Dimplex and the PowerLab facilities. The project is supported by EUDP (Energy Technology Development and Demonstration Programme), grants 64014-0555 and 64015-0055 and runs from 2015-2019.