Interim report – WP4

Smart Network Technology

Reporting months: July 2018 – June 2019

Photo: By & Havn / Ole Malling

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V190621: Public, EnergyLab Nordhavn

Work package aims and objectives

The objective of WP4 is to develop, experimentally verify and evaluate various control-based enabling technologies, (e.g. electric storage radiators and electric heat boosters) and solutions for smart networks services with high efficiency and promising business potential, and provide elements for a smart energy infrastructure design and operation.

Overall progress of the work towards WP Objectives

Until the moment of reporting, WP4 has met almost all the expected objectives, including:

1. Identification and characterization of smart energy network services for urban operation in T4.1 (completed)

2. Design of advanced situation-aware control algorithms for using smart energy components to provide smart network services in T4.2. (completed)

3. Design development and testing of smart controllers for distributed energy resources in T4.3, wherein a portfolio of electric storage radiators were installed at Nordhavn, controlled to support power balancing. (completed)

4. Design, development and testing of low-cost controllers for fuel-shift technologies and/or low temperature district heating in T4.4, wherein a portfolio of electric heat boosters (with 110L storage capacity) were installed at Nordhavn and controlled to offer multi-smart network services, i.e. meeting end users' energy requirements, enabling LTDH, offering peak reduction services to the DH system, offering frequency support to the power sector. (almost completed, with only one remaining task, i.e. to test and demonstrate the potential of using electric heat boosters with 160L storage capacity to support ultra-low temperature district heating)

5. Demonstration, evaluation and comparison of control solutions for using smart energy components to provide smart network services in T4.5, wherein solutions developed in T4.3 and T4.4 have been demonstrated and evaluated. Remaining work of T4.5, including comparison of the control solutions and detailed analysis of the business potential, are currently under investigation.

Status and activities in the WP tasks

Task 4.1 Identification and characterization of smart network services for urban network operation
Already reported in 2017.

Task 4.2 Design of advanced situation-aware control algorithms for using smart energy components to provide smart network services

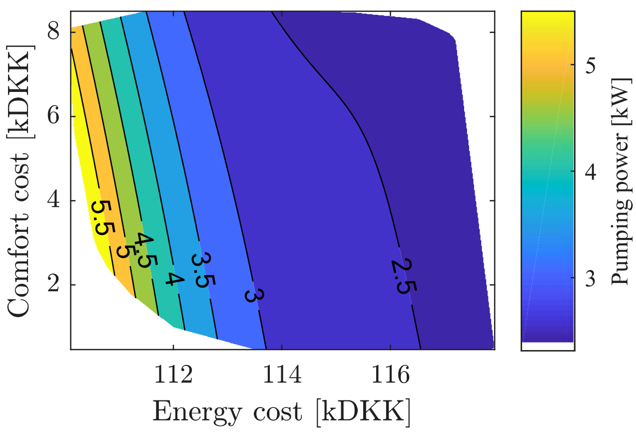
In additional to result documented in previous interim report, a realistic demand side management mechanism has been proposed for Nordhavn district heating network to improve system efficiency and manage congestion issues.

Comprehensive models including the circulating pump, the distribution network, the building space heating (SH) and domestic hot water (DHW) demand were employed to support day-ahead hourly energy schedule optimization for district heating substations. Flexibility in both SH and DHW were fully exploited and the impacts of both weekly pattern and building type were modelled and identified in detail.

A case study was performed based on Nordhavn energy system. Results show an up to 11% reduction of energy costs. The results were obtained based on a district heating marginal cost profile in a winter week in 2016. For more details, please refer to "Cai, Hanmin, Charalampos Ziras, Shi You, Rongling Li, Kristian Honoré, and Henrik W. Bindner. "Demand side management in urban district heating networks." Applied energy 230 (2018): 506-518."

A sensitivity analysis was conducted, which provides decision makers with insights into how sensitive the optimum solution is to any changes in energy, user comfort or pumping costs.

The figure shows the results are in three perspectives, the total energy costs of weekly heating consumption, the total virtual costs of comfort deviations and the corresponding pumping powers. In other words, these three metrics represent the flexibility level, the CO_2 emission reduction and the level of concurrent load. When a pumping power capacity is specified or for existing infrastructure, the comfort cost increases dramatically as the energy cost is lowered.



Task 4.3 Design development and testing of low-cost controllers for distributed energy resources

In 2018, WP4.3 experimentally evaluated demand response potential of aggregated high-temperature storage radiators to support intermittent solar photovoltaic (PV) production. Nine storage radiators in showroom were aggregated.
The demand response potential to compensate the forecast error of the production from large-scale PV installation in the neighborhood was analyzed.

From the experimental results, it was found out that the aggregated storage radiators have an activation time of 15 seconds and could provide significant energy capacity while the end-users' comfort were maintained. The electrical box as shown in Fig 2 was installed in showroom to support all the autonomous and aggregate control. Fig 3. shows the implementation and live visualization in showroom.

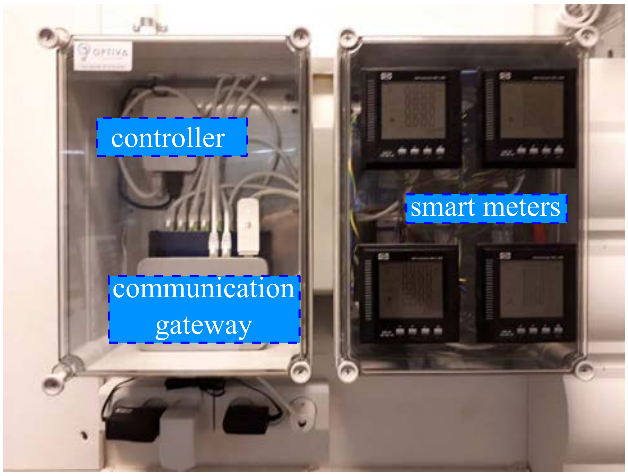


Fig 2. Electrical box in showroom

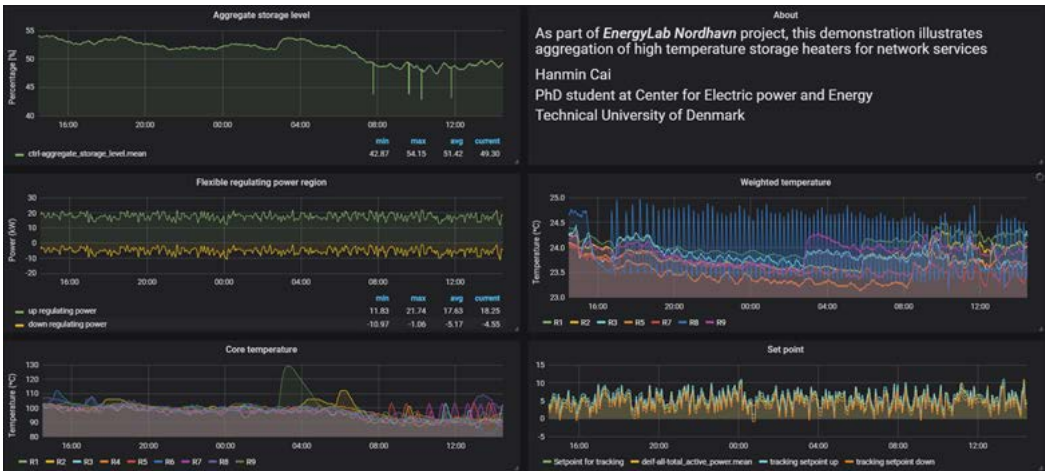


Fig 3. Demonstration in showroom

The demonstration was arranged on 12th December 2018. The deliverable for WP4.3 has been approved. Thus, this WP4.3 is considered to be completed.

Task 4.4 Design, development and testing of low-cost controllers for fuel-shift technologies and/or low temperature district heating

Installations

Domestic Water Heater – Combitank

Five residencies at Frikvarteret and two residencies at Sundkajen have been equipped with a 110L resp. 160 L Domestic Water Heater (DHW) system to support Fuel-Shift by using District Heating (DH) or Electrical Heating (EH) or a combination of both.
Metro Therm has delivered the system, which also includes a Fuel-Shift Controller from DTU.
The installations in Sundkajen have also been equipped with a mixing loop to be able to run with Ultra-low Temperature District Heating (ULTDH).

DTU together with METRO THERM have carried out a number of tests to map the possibilities, for switch between normal district heating operation (> 60°C), and Fuel Shift.

At the test facilities at METRO THERM, in addition to Fuel-Shift, the 160L unit was also tested for the possibility to use ultra-low district heating (ULDH), with a forward temperature of 45°C.
During testing it was shown that the unit can comply with the water norm DS439, tapping requirements for shower. With a share of district heating = 66,5%, and electricity = 33,5%, of the total energy consumption for the DHW heating.

The flexibility in fuel shift that the system provides, hereby also gives the possibility for peak shaving and for energy balancing services.

Domestic Heat Water Heat Pump

As part of the EnergyLab Nordhavn project, METRO THERM and partners have installed a domestic hot water heat pump (DHWHP) in the EnergyHub/Energylab Nordhavn showroom.

The unit has been installed as an exhaust air heat pump supplying domestic hot water for kitchen, toilets and bathroom while ventilating the showroom or the meeting room next to the kitchen.

It can be concluded that the unit is producing sufficient domestic hot water while also having significantly improved the air quality in the showroom.

Demonstrations

An integrated demand response program has been implemented in Nordhavn with the fuel shift equipment in Frikvarteret. The demonstration shows how fuel shift equipment could support the next generation of district heating and a power system with a high share of wind power, through a multi-service and cross-sector design.

It was shown that a frequency normal-operation reserve (FNR) service with a symmetric reserve of 7.5 kW could be delivered with an activation time of 4 seconds while delivering a peak shaving service at the same time to the DH system. An analysis of the temperature distribution during the test period shows that end-user comfort was maintained while services were provided.

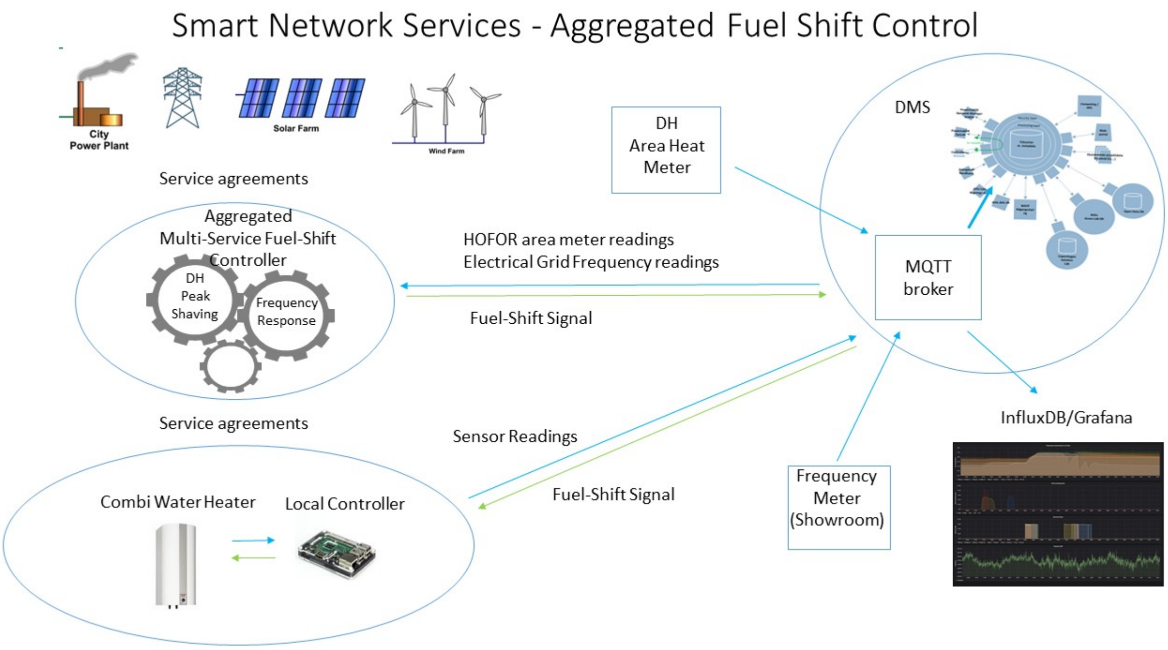


Figure **4**. WP4.4 Aggregated Fuel-Shift Control Demonstration

Task 4.5 Demonstration, evaluation and comparison of control solutions for using smart energy components to provide smart network services

Demonstrations for smart network services have been done in T4.3 and T4.4.

Task 4.6 Development of public fuel-shift catalogue

The work concerning the development of a fuel-shift catalogue changed from specific modelling of each considered fuel-shift technology, to a preliminary economic feasibility analysis, a list of technically, economically feasible fuel-shift technologies, and a multi-objective analysis of a specific technology. The change to the task was a consequence of a too high initial expectation to the outcome.

The results corresponding to the three individual tasks were finalised, but at the time of writing not reported in appropriate details. The reporting of the analysis is expected to finish in the weeks to come. The third task has some overlap with other work performed in WP, and will be reported in short form.

The participation in T8.4 has resulted in co-creation of a deliverable D8.4.A (lead by HOFOR), which will be reported along with the rest of D8.4. The analysis focusses on the possible changes in tariffs for electricity and heat, which may change the business-case for fuel-shift technologies. The results presented in D8.4.A matches well with the results to be reported in D4.6.

Deliverable status

D #	Deliverable title	Planned completion month	Status **1** = on schedule **2** = completed **3** = delayed
D4.2	Situation-aware control algorithms for using smart energy components to provide smart network services with software-based verification report	March 2019	**2**
D4.3a	Installation and SAT test report on Glen Dimplex storage space heating technology installed	August 2018	**2**
D4.3b	Low-cost controllers specification, design and test report.	April 2019	**2**
D4.3c	Validation document on field-data collection from storage heaters	April 2019	**2**
D4.4a1	Installation and SAT test report on 11 installations of district heating units with hot water tank (small tanks)	January 2019	**2**
D4.4a2	Installation and SAT test report on 11 installations of district heating units with hot water tank (big tanks)	June 2019	**3**
D4.4b	Installation and SAT test report on one booster heat pump installations: air/water or water/water	June 2019	**3**
D4.4c	Installation and SAT test report on 2 domestic hot water heat pumps with integrated water tank	May 2019	**2**
D4.4e1	Validation document on field-data collection from 110l DHW appliances (small tanks)	June 2019	**2**
D4.4e2	Validation document on field-data collection from 160l DHW appliances (big tanks)	June 2019	**1**
D4.5a	Validation document on field-data collection from demonstration		
D4.5b	Report on demonstration, evaluation and comparison of enabling smart network services through autonomous control solutions and coordinated control solutions	Mid- 2019	**1**
D4.6	Public fuel-shift catalogue and their role in the smart energy system	June 2019	**1**

4.5a - The task will be devided into two smaller tasks and will be placed in T4.3 and T4.4. So that the task responsible for making the controller, will also be responsible for validation the collected data.

Dissemination

Journal:
Cai, Hanmin, Charalampos Ziras, Shi You, Rongling Li, Kristian Honoré, and Henrik W. Bindner. "Demand side management in urban district heating networks." Applied energy 230 (2018): 506-518.

Cai, Hanmin, Shi You. "Distributed demand response in district heating systems: design and implementation." Submitted to Applied energy

Cai, Hanmin, Andreas Thingvad, Shi You, Mattia Marinelli. "Experimental evaluation of an integrated demand response program." Submitted to Applied energy

Conference:
Cai, Hanmin ; You, Shi ; Bindner, Henrik W. An Experimental Setup for Investigating Flexibility of District Heating with Fuel Shift, Presented at: International Conference on Smart Energy Systems and 4th Generation District Heating

Cai, Hanmin; You, Shi , Improving urban energy system operation with flexible heat and power coupling, Presented at: Sustain conference 2018: Creating Technology for a Sustainable Society

Cai, Hanmin, Meysam Qadrdan, Muditha Abeysekera, Shi You, Jianzhong Wu , Henrik w. Bindner. Optimal operation of a multi-energy system: a case study of warwick university campus, accepted to present at: the 11th international conference on applied energy (icae2019)

Cai, Hanmin, Rongling Li, Shi You, Jan Eric Thorsen, Kristian Honoré. Flexibility in integrated energy system: experimental insights from EnergyLab Nordhavn project, accepted to present at the 5th International Conference on Smart Energy Systems, Copenhagen, 10-11 September 2019

Cai, Hanmin, Shi You, Sergey Klyapovskiy and Henrik W. Bindner. Demand Response Potential of Aggregated High-Temperature Storage Radiators, accepted to present CISBAT 2019 – International Scientific Conference 4-6 September 2019, EPFL Lausanne, Switzerland

Presentation:
WP4.3 demonstration in Energylab Nordhavn showroom, public event on 2018 December 12th

Presentation of GlenD demo for partners from GlenD, January 2019

WP4.4e1 demonstration in Energulab Nordhavn showroom, public event on 2018 June 4th

Presenting EnergyLab Nordhavn project at Cardiff University, April, 2019

Next steps

- Live test with ultra-low temperature district heating using 160L combitank in Sundkajen
- M8 review planned June 2019
- KM1 review planned June/July 2019
- T4.4 Finalize reporting of deliverable D4.4a2 June 2019. Writing ongoing.
- T4.4 Finalize reporting of deliverable D4.4b June 2019. Ready for review.
- T4.4 Finalize reporting of deliverable D4.4e2 June 2019. Not started. (Part of a MSc project)
- T4.5 Finalize reporting of deliverable D4.5b mid-2019. Writing ongoing.
- T4.6: Finalize reporting of deliverable D4.6 June 2019. Submit for review.

Quality Assurance

Status of deliverable		
Action	By	Date
Sent for review	Magnus Klintström, DTU	7-6-2019
Reviewed	Jan Eric Thorsen, Danfoss	12-6-2019
Approved	WPL Approved	21-6-2019

Author	Reviewer	Approver
Magnus Klintström, DTU	Jan Eric Thorsen, Danfoss	WPL

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), grant 64014-0555 and runs from 2015-2019.

Version Control

Version	Date	Author	Description of Changes
1.0	6-6-2019	Magnus Klintström	Preparation
15.0	12-6-2019	Jane Eric Thorsen	Review with comments
16.0	14-6-2019	Magnus Klintström	Updated
17.0	21-6-2019	Magnus Klintström	Approved document