Interim report – WP8

Reporting months: July 2017 – June 2018

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ABB A/S
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Overall progress of the work towards WP objectives

It was decided by SG to rewrite the WP8 description early 2018 and Christoffer Greisen and Benny Stougaard Hansen were given the task.
The new description and resource plan has been accepted by the Followgroup, the SG and has been presented to EUDP who has approved the change in WP8.

WP8 is now split into 6 tasks:

- Task 8.1: Support to demonstration of integrated energy solutions
  - **Task leader: Per Nørgaard, DTU CEE.**
- Task 8.2 Local optimized and coordinated asset operation
  - **Task leader: Henrik Vestergaard, ABB.**
- Task 8.3: Improved coupling of wholesale heat and electricity markets
  - **Task leader: Jalal Kazempour, DTU CEE.**
- Task 8.4 Energy prices and tariffs
  - **Task Leader - Kristian Honoré, HOFOR.**
- Task 8.5: Retail side: innovative business models
  - **Task leader: Pierre Pinson, DTU CEE.**
- Task 8.6: Simulation of (local) energy platforms
  - **Task leader: Henrik Vestergaard, ABB.**

The work in tasks 8.1, 8.2 and 8.4 has already started.
The first Use case from 8.1 is being evaluated and 8.2 is discussing and planning how to implement the use case into MicroSCADA.
Furthermore, 8.4 is working on a new price structure regarding DH prices to compare with the Electricity prices from Nordpool.

Status and activities in the WP tasks

Task 8.1: Support to demonstration of integrated energy solutions

The objective of task 8.1 is to support the realization of use cases, demonstrating smart and coordinated operation of more of the ELN assets.
Based on the previous work defining as series of use cases, three new use cases were developed, adopted and anchored at a use case workshop in March 2018:

- ELN XUC#25: Coordinated load shift in the power grid (lead: Poul Brath, Radius)
- ELN XUC#26: Coordinated load shift in the district heat grid (lead: Kristian Honoré, HOFOR)
- ELN XUC#27: Distributed heat generation in the district heat grid (lead: Jan Eric Thorsen, Danfos)

In addition, the original ELN XUC#01: 'HP and battery' has been selected as the first test use case to be implemented under task 8.2. A simple realisation of this is described (in folder 'Use case for WP8.2').
The use cases are documented at the SharePoint drive:
https://share.dtu.dk/sites/nordhavn_40150/Shared%20Documents/Forms/AllItems.aspx?RootFolder=%2Fsites%2Fnordhavn%5F40150%2FShared%20Documents%2FWork%20Packages%2FWP08%20Multi%2DCarrier%20Energy%20Systems%20Operation%20and%20Market%2FUse%20cases&FolderCTID=0x01200002BC6441F1F7F545BC6341F9D3BDE7D6&View=%7B7B0DA0A3%2D5CC0%2D486B%2DA43F%2D4595146562EE%7D

Task 8.2 Local optimized and coordinated asset operation
First Use case from 8.1 has been disussed already in 8.2 and basicly it involes heatpump and battery. How to co-ordinate thermal and electric storage, how to charge battery when electricity prises are low and use the battery power when prices are high.
Control will be at DTU PowerLab, using the ABB MicroSCADA system already installed at DTU PowerLAB.
There will still be some co-ordination between the DH and Power utillities agreeing about control exchange.
The Interface setup has been ordered to HOFOR Flexheat (Heatpump) facility at the cruice terminal in northern Nordhavn.
The Interface between WP2 DMS system and MicroSCADA system has also been startet.
Both interfaces are expected finalised before summer vacation.

Task 8.3: Improved coupling of wholesale heat and electricity markets
We have completed the comparison of three different mechanisms for coupling heat and electricity markets: i) a traditional sequential market framework, ii) an integrated market framework, and iii) an improved (stochastic) sequential market framework (journal paper in preparation). Uncertainty from wind production has been accounted for using stochastic programming.

The application of the improved sequential market clearing to large-scale energy systems is in progress. We are currently focusing on developing a tailored decomposition algorithm for large-scale optimization (journal paper in preparation).

Preliminary work on modelling flexibility in district heating networks has been completed. A convexification of the temperature dynamics and time delays in pipelines was developed (conference paper submitted) and integrated in an economic dispatch.

Based on this preliminary work, we are at the early stage of the development of flexible products to coordinate flexible sources in heat and electricity markets, and remunerate their flexibility. One Post Doc and one master student are currently working on policy-based reserve and financial storage rights.

Task 8.4 Energy prices and tariffs
Master student, Edoardo Bosco, from DTU-CEE is writing a report regarding international/national experiences, which already are known regarding prices and tariffs within the district heating market.
A synopsis for the work done in task 8.4 is in place. It will be updated as the results appear doing the project. As from a starting point the work will use the actual demonstrations in ELN and first analyze the fuel-shift solution in the row houses.
The analysis work has turned out to be very extensive but it is expected to be reused for other demonstrations e.g. the Heat Booster.
Activities regarding a new price and tariffs structure on environment aspects have started.
It is planed that activities for the second half of 2018 are substantially increased.

Task 8.5: Retail side: innovative business models
Last semester, a course at DTU for ten students was held, in which they had to come up with innovative business models. Most of them focused on distributed renewables plus battery (as in Nordhavn), considering energy communities or market participation (i.e., provision of ancillary

services). The results were good. Unfortunately, though, they could not use Nordhavn data, so the results are based on data from e.g. Australia, London, Texas. It is our plan to continue those works based on a number of MSc theses this and next semester, incl. one in collaboration with HOFOR. Finally, we are joining forces with the Interreg project, Smart Cities Accelerator, to analyze the possibility of having energy communities in Nordhavn with p2p electricity markets, this time based on Nordhavn data.

Task 8.6: Simulation of (local) energy platforms
This task has not yet started.

Status on PhD work regarding to WP8

PhD student: Lesia Mitridati

Period: 2015-2018

Title: Market Mechanisms for Integrated Energy Systems

Over the last period, a primary focus has been placed on approaches to model and operate district heating infrastructures in an integrated energy system framework. In practice, this results in a Combined Heat and Power Dispatch (CHPD) optimization model that aims at minimizing overall system operating costs, while accounting for operating and transmission constraints in both heat and power systems. Contrary to traditional economic dispatch approaches, this model provides a detailed formulation of temperature dynamics and time delays in heat pipelines. Allowing variable time delays in our model, allows us to exploit the operational flexibility of the district heating network, and, in terms, provide flexibility to the power system. In practice, the optimization model is quite complex and challenging to solve due to non-convexities in modelling temperature dynamics and transmission constraints in district heating networks. As a result, substantial efforts were placed in the proposal of efficient solving methods, e.g., with a dedicated convex relaxation of the original Mixed Integer Non Linear Problem (MINLP). The idea of such an approach is to transform the non-convex constraints using McCormick envelops, second order cone relaxation, and outer approximation methods, and to solve the resulting convex (relaxed) optimization problem. Although the original optimization problem is not of a form that can be handled readily, we showed that the convex relaxation approach provides an efficient and scalable solution method. In parallel to this main focus on the wholesale side, dedicated work concentrated on the development of dynamic prices for district heating markets. Locational Marginal Prices (LMPs) were derived from the wholesale heat market clearing, and different retail tariffs for heat consumers were proposed. Time-Of-Use (TOU), and hourly tariffs were compared to the current flat retail tariff. The aim of these new pricing schemes is to better reflect heat production costs, and provide appropriate price signals to harness end-users' flexibility.
Finally, numerous works were initiated in order to rethink the way energy may be exchanged within Nordhavn, possibly motivating numerous new business models. The core concept relates to coalition of prosumers (electricity and heat, possibly). This approach relies on cooperative game theory. The main challenge is the development of adequate remuneration mechanisms that incentivize collations formation, ensure stability

of such coalitions, and harness prosumers' flexibility. Scenarios were conceived for the forming of energy communities at the Nordhavn level, accounting for production, storage and flexible consumption. It is our aim to find ways to motivate and demonstrate such development in the coming period.

Deliverable status

Deliverable reporting has not started yet due to new WP8 description awaiting EUDP approval.

Dissemination

Name of Ph.D/Post Doc	**Area/Sector**	**Production. Paper, lessons** Only title.	**Innovation perspective** (where do we break new land?)	**Integration to ELN project** (implication to practice)
WP8				
Lesia Mitridati	Electricity and district heating	Towards fully renewable energy systems - experience and trends in Denmark. 2017. CSEE Journal of Power and Energy Systems	review the current trajectory of Denmark in going towards fully renewable based on an energy system integration approach - comparison of el-heat and el-gas opportunities	Generate base knowledge to map status and opportunities
	Electricity and district heating	Optimal coupling of heat and electricity markets - a stochastic hierarchical approach. 2016. PMAPS Conference	Proposal of a novel approach to couple heat and electricity markets to better utilise flexibility on the heating side to help integrate renewables on the electricity side	Could be considered and used as a new version of varmelast
	Electricity and	Power system	Develop a	Should be seen

	district heating	flexibility from district heating network. 2017. PSCC conference (submitted, to appear in 2018)	convex optimization approach for the joint operation of heat and electricity network. To be seen as an ideal benchmark that market-based operation would be trying to approximate	as a benchmark approach to assess how much flexibility could be used from the district heating

Next steps

Start working on the approved WP8 tasks and deliveries.

Quality Assurance

Status of deliverable		
Action	By	Date
Sent for review	Benny Stougaard Hansen	13-6-2018
Reviewed	Anders Kragh	14-6-2018
Approved		

Author	Reviewer	Approver
Benny Stougaard Hansen	Anders Christian Laage Kragh	Christoffer Greisen

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.