Benchmark technical solutions and business models.

Deliverable 5.2 for the SmartCE2H project

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1. Introduction

The growing integration of renewable energy sources (RES) provides technical and economic opportunities to decarbonize the local energy systems. The district heating (DH) networks are delivering more than 64% of the Danish heating needs, however, over 40% of energy mix in the country's DH system constitute of fossil fuels, mainly coal and gas [1]. Furthermore, it is crucial to meet Denmark's political objective of reducing CO_2 emissions by 70% by 2030 with the help of renewable energy resources (RES). The closer integration of electricity, heating and transport (e.g. converting electricity to heat through heat pumps (HP), electricity to transport fuel through electric vehicles (EV)) can become key elements in this transition. This document reports the benchmark technical solutions for smart integration of electricity to heating systems and provides business models for stakeholders for reaping economic benefits in demand response (DR) programs.

1.1 Scope and objectives

The technical and business models will be developed to optimally aggregate flexibility from local energy systems in an integrated energy community considering consumer comfort preferences, local grid limits for optimizing the economic benefits to all the energy stakeholders. The specific objectives are as follows:

- Presenting benchmark technical solutions that can be used in creating a roadmap to integrated local energy systems in a Danish context
- Presenting benchmark business models that can support the roll-out of these technical solutions for integrated local energy systems in Denmark.

1.2 Partners contribution

AAU is responsible partner for this deliverable in coordinating and illustrating the benchmark technical models. While Neogrid and Skive Kommune describe various business models and societal issues that can applied to engage utilities as well as private customers in the real-world integrated local energy systems.

2. Benchmark framework

The framework for the smart integration of individual heat pumps or central heat pump system is shown in Figure 1. This framework gives the key technical features of an aggregator-based heat-pump pool utilizing the excess from the local renewable generation including Solar-PV or Wind units, located either on-site or within the community. Accordingly, two use cases are defined.

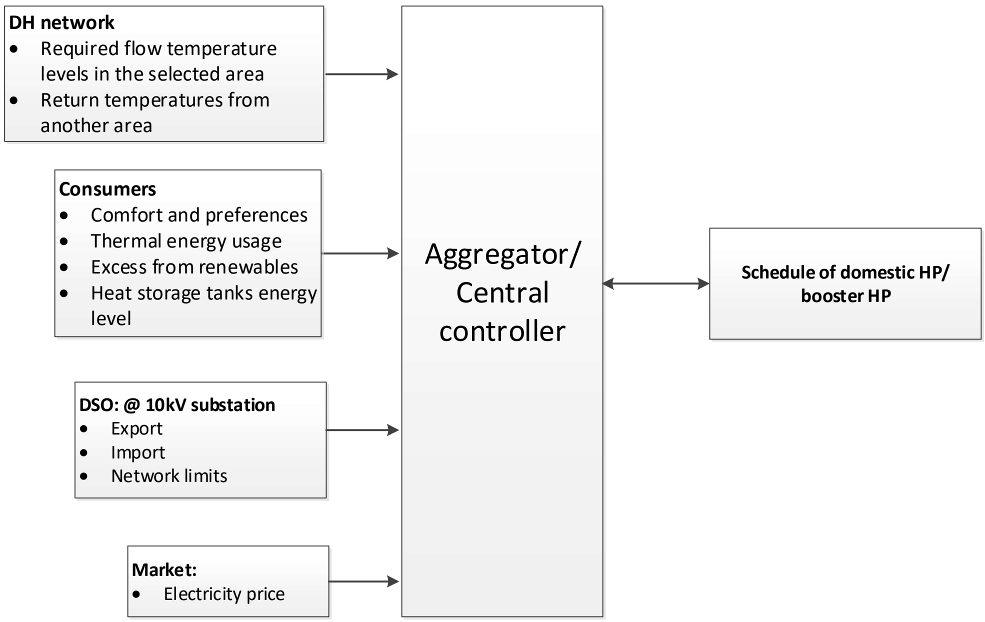

Figure 1: Flexibility framework for heating system/s control

The stakeholders in this framework are consumers, distribution system operator (DSO), electricity market and finally aggregator. Even though the DSO is not an active partner in the project, it is an important actor who provides guidelines towards network limits that needs to be strictly followed. Due to the unbundled system between DSO and energy trade the aggregator has to come into contract with a balance response party (BRP) to get third-party access, thereby, actively participate in the DR activity and take care of the sale of the energy flexibility.

3.2 Use-cases

The dominant use-cases for the given flexibility framework are derived considering on-site and community- based generation from renewable sources.

1. Optimizing the HP-based storage system's operation of households using the excess energy from the on-site renewable power generation.
2. Optimizing the HP-based storage system's operation of the household using the excess energy from the local community based renewable power generation.

These uses cases can be widely adapted to any integrated energy system with heating systems, electric vehicles, and renewable power generation capabilities. The aggregator (Neogrid) plays a major role in representing consumer flexibility in the demand response program towards grid services not only locally (DSO) but also in the balancing market (TSO). Nonetheless, the objective of this project is to provide services to DSO and a business model for aggregator through this flexibility framework.

3. Benchmark technical solutions

Energy sectors such as electricity and heat provide potential positive synergies and benefits through coupling, for example, power-to-heat, storages, and electrification. Sector coupling and integrated energy systems are the key concepts to overcome the challenges posed by future energy transition including the increase of decentralized energy systems. However, this shift can provide benefits to local energy communities from increased flexibility of their supply to direct involvement in the decision-making process. To take advantage of these opportunities, planning of flexibility provisions at a local level is required. In this project, the integrated energy systems include local solar-PV installations, heat pumps with thermal storages and electric vehicles, where it is required to know the available local generation, demand flexibility and heating, ventilation, and air conditioning (HVAC) systems set points. Accordingly, estimation of both local generation and demand flexibility along with appropriate market models constitute the main characteristics for deriving benchmark technical solutions for the local integrated energy systems.

3.2 Control of individual heat pumps

A first technical solution applies to the situation where the heat production is happening in the individual households themselves, based upon a common electricity supply.

The electrical grid layout of the corresponding Solbakken demonstration case is shown in Figure 2. There are several households that have installations of solar-PV, heat-pumps with phase change material (PCM) -based thermal storage tank and EVs. The shares of PV, HP and EV in the considered distribution network are given in Table I. From the simulations that are presented in D2.2, it is expected that the system experienced voltage limit violations due to uncontrolled operation of flexible loads. The derived framework has been applied to minimize the electricity price paid by flexible customers participating in the DR program and at the same time keeping the voltage within the limits set up by the DSO.

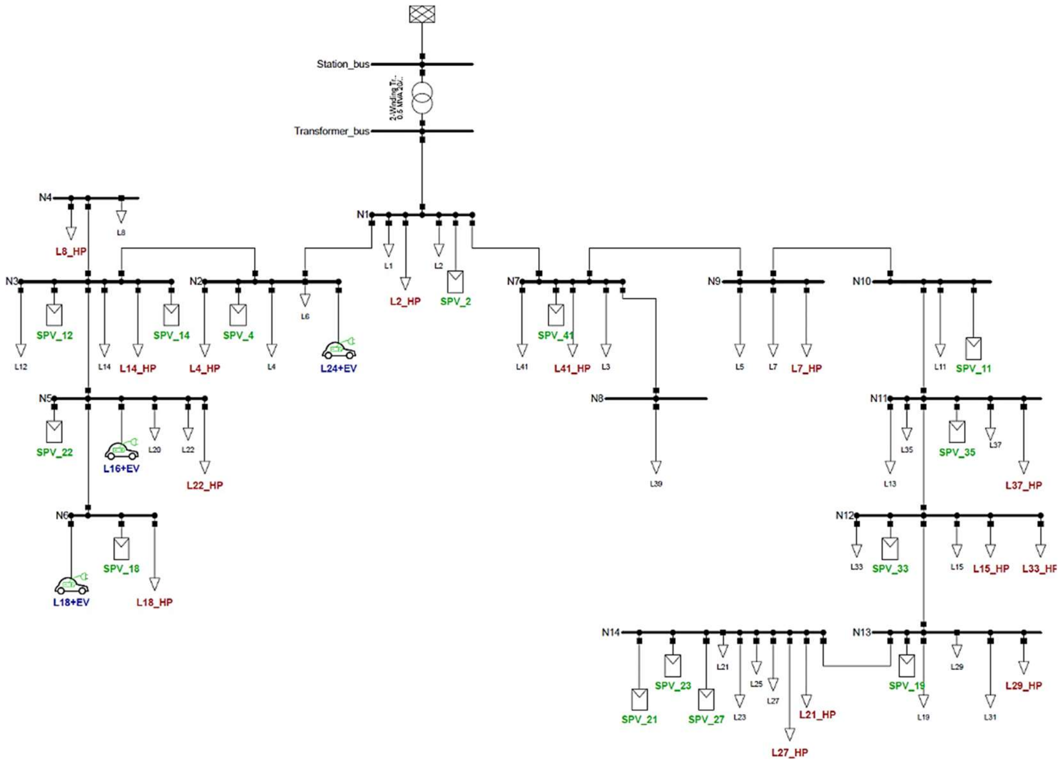

Figure 2: Solbakken demonstration site: DIgSILENT model

Table I: Percentage share of flexible loads and solar-PV generation

Component	Share of houses in area
Solar-PV	32 %
Heat pump	26 %
EV	9 %

The benchmark control algorithm for the optimal operation of individual heat pumps is as follows.

- Direct triggering of HP-start/stop considering the storage tank energy limits, thermal demand, electricity price and network limits.
- The objective is to reduce the cost of heating by shifting the demand from high electricity prices to the times with low prices, while taking the advantage of excess energy from local renewable energy generation, while keeping the voltage within network limits.

3.2 Control of booster heat-pump setup

A second technical solution applies to the situation where a common heat supply is viable for a group of closely located buildings. This can either be in an existing area with pre-existing district heating supply (typically in the far end of the network), or in areas where a new heating system needs to be installed in a group of closely-located buildings.

This demonstration provides technical solution to enhance the temperature level in the far-end of the local DH network. The booster heat pump with PCM based storage tank is tested to supply 20 households on Citronvej, Skive municipality. The low return temperatures (30-45 °C) from another area are stored in a mixer tank and given as input flow for the booster HP setup as shown in Figure 3.

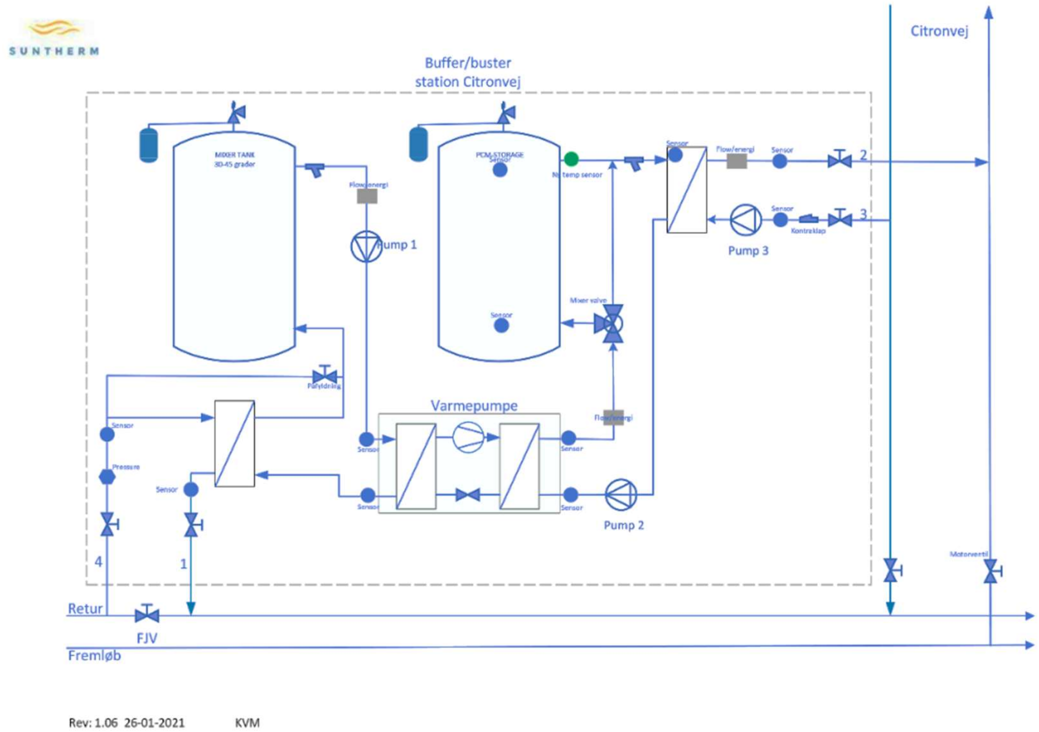

Figure 3: Booster HP setup

There are three high-level activation options for the booster HP including, supply temperature set point control, compressor control and complete shutdown of the installation. During the last activation option, the area is reconnected with the main DH network.

The benchmark control algorithm for the intelligent operation of booster HP is as follows.

- The objective is to supply heating at the required temperature level to specific area using booster HP along with its PCM-based storage tank by taking the return temperature from DH network in another area.
- Aggregator (central controller) gathers information about excess renewable production, temperature inside the PCM tank, state of energy of the PCM tank and electricity prices.
- Consumer preferences and electrical network operating limits will form the constraints.
- The PCM tank associated with booster HP,

- Charges when there is either excess production from RES, low electricity prices or it is low on energy.
- Discharges whenever there is a need to level off the flow temperature to the desired limits for the selected area's DH network.

4. Benchmark business models

In deliverable 7.1 – Exploitation of business strategies for individual heat pumps, we're going into more specific details on how Neogrid tend to exploit the results of the project.

4.1 Ownership models:

There're basically 2 ownership models for heat pumps in private houses.

Owning or renting. Each model is marketed in a wide range of flavors.

4.1.1 Owning:

When purchasing a heat pump, the market offers a huge range of different ways of purchasing it. Ranging from online stores that sell heat pumps, and leave it up to the customer to figure out how to install it. There's little support or after sales service.

Many plumbers (VVS) sell and install heat pumps directly to the end users, often with some sort of service agreement throughout the lifetime of the heat pump.

Specialized businesses focus their business to be one-stop-shop's for heatpumps. Offering a single point of contact for the enduser throughout the entire process. They support the customer in selecting the proper brand and model, apply for available subsidies, install or have 3rd party to install and offer a service contract with free repairs.

4.1.2 Renting:

When you choose to rent your heat pump, it's also possible in many different flavors. There's a handful of companies that offer a subsidized scheme called 'skrotningsordningen' where pre-approved companies follow a set of rules in order to pre-qualify for the subsidy. SUNTHERM had ambitions to become one of these companies, but did not manage to get approved due to the 'financial strength' metrics. Eventually SUNTHERM went bankrupt.

A central part of the scheme is that the service provider is taking the risk on heat pump performance, as the end-user pay the supplied heat energy.

When looking at the other companies on the list from Skrotningsordningen | Energistyrelsen (ens.dk), we see that about half of the companies seem inactive, the remaining offer one or more ways of getting a heat pump installed.
Only one company (EWII) state that they only offer heat pumps on the 'skrotningsordningen'-scheme.

Both OK and Nærvarme Danmark offer a leasing variant where the end user pays the electricity, and not the supplied heat. This approach is much cheaper to install, as it doesn't require heat energy meter the setup for reading it, and the provider is not exposed to the variances in COP that different installations will give.

4.1.3 Mainstream business models for heat pumps.

With the increased focus on transitioning from fossil fuels to green solutions, there financing options have also increased. Mortgage companies, banks and financing companies all offer attractive loans for energy investments.

5. Conclusions

The management of assets in the project is an important aspect, where the heating installations and communication setup requires maintenance. There is complexity associated with modeling the PCM based storage system and the PCM needs high supply temperature (which reduces COP of HP) to adequately activate the PCM in order to store/release energy. In addition, lower flow rates might require even higher temperature differences, as the heat transfer between the PCM shell and water would decrease with decreasing flow rate. For the booster HP demonstration, a specific challenge was encountered with the energy meters (SHARKY 775 from Diehl, a classic heat-meter in Denmark) which was that the temperature difference across the meter on the secondary side of the heat-pump was often too close to the meter's limit (3 K) given the high flow in the loop (in the range of 10 m3/h). The need for maintaining supply temperature above 50 °C requires adequate temperature difference between PCM melting point (58 °C) and supply temperature, where the margin is less in the current installations of this project. The use of data will need to be facilitated by tools for distributed data governance, data cleaning, and data integration. There are socio-technical challenges that are to be faced for successfully implementing the benchmark solutions. With the increasing penetration of distributed generation (electricity generated by micro-units and injected into the grid), the DSO has to take the responsibility of providing security and reliability of the overall system. Further, DSO has to promote localized trade of energy and grid services through interacting with prosumers and aggregators.

6 References

1. Gunnar Boye Olesen, “Energy Communities in Denmark: Good examples and concerns,” INFORSE-Europe, Webinar 9/9 2020.