EBC

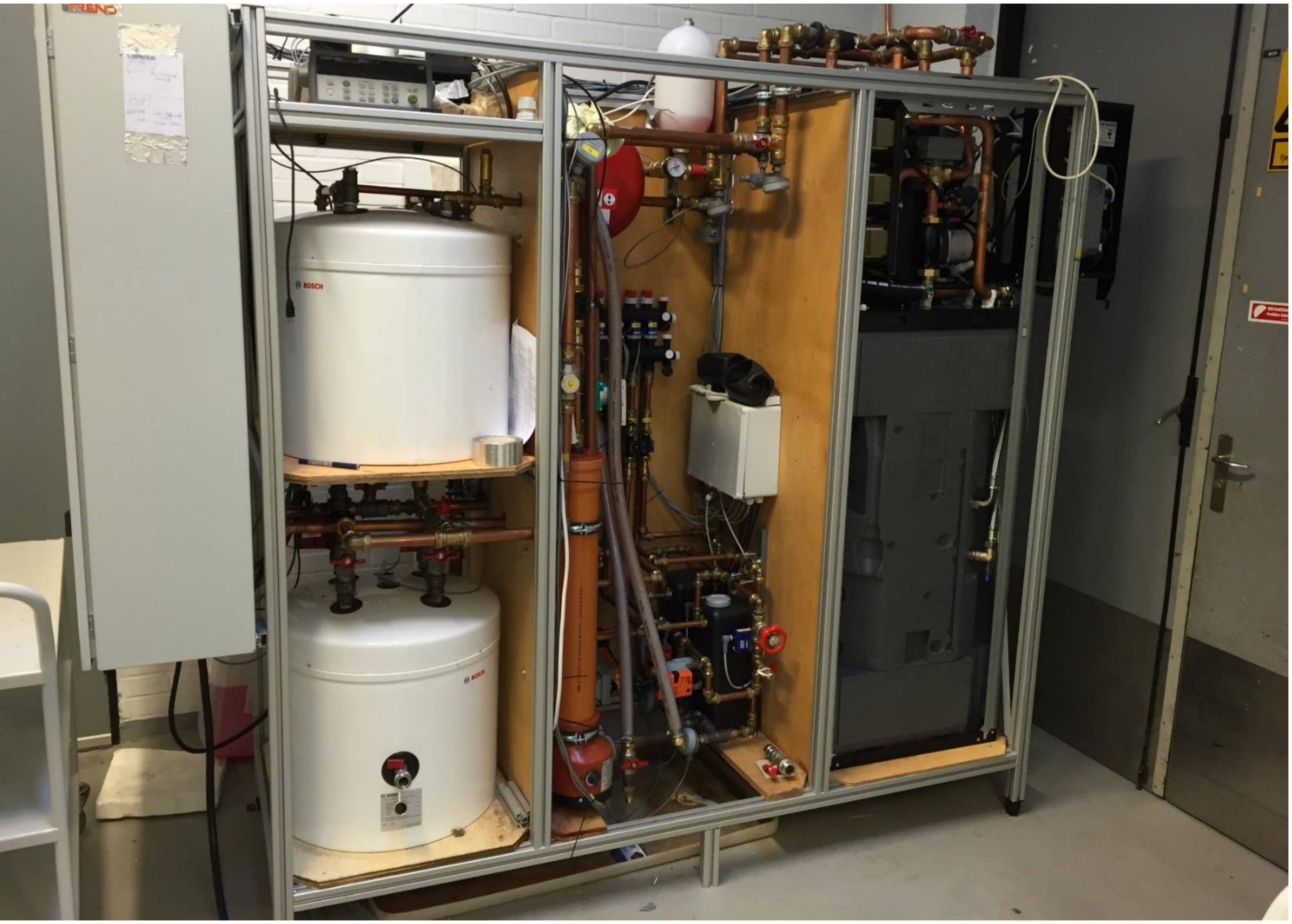
Energy in Buildings and Communities Programme

iea Energy Technology Network

ANNEX 67 NEWS

Newsletter 7 | July 2019

Content



The OPSYS test rig at Danish Technological Institute
Photo by Søren Østergaard Jensen

Brief from the 8th Annex 67 working meeting

By Søren Ø. Jensen, DTI & Anna Marszal-Pomianowska, AAU

An eight working meeting took place in Aalborg, Denmark on April 3rd-5th, 2019. The meeting was attended by 37 participants from 15 countries. The meeting was hosted by Aalborg University.

Since it was the last experts meeting, the first day of the meeting was used to focus on finalizing the content of the Annex 67 Deliverables. The editors of all deliverable have reported that the major part of the work is finished and only the final adjustments and corrections are still to be included. Yet, the original time plan had to be adjusted a bit. Five of the seven deliverables are to be finalized during May and afterwards sent to the Excusive Committee of IEA EBC (ExCo) for the final review. The two remaining deliverables will be finalized in the fall of 2019. The seven deliverables from Annex 67 are:

- Principles of Energy Flexible
- Characterization of Energy Flexibility in Buildings
- Stakeholder perspectives on Energy Flexible buildings
- Control strategies and algorithms for obtaining Energy Flexibility in buildings
- Experimental facilities and methods for assessing Energy Flexibility in buildings
- Examples of Energy Flexibility in buildings
- Project Summary Report

Many other publications (reports, articles, papers and a calculation tool) may already now be found on **annex67.org/Publications**

The second day was used for a public seminar on energy flexible buildings. A Summary from the event can be found in the section Public Seminar.

During the last day, a follow-up to Annex 67 was discussed. Based on the input from presentations and the interests of the Annex 67 participants it was decided that the follow-up of Annex 67 should have the following focus areas:

- Scaling from single buildings to clusters of buildings
- Flexibility in a multi carrier energy system
- Multi stakeholders acceptance/engagements
- Costs and business models

A concept proposal for a follow-up annex to EBC ExCo to their meeting in June. If EBC ExCo is interested, it is the intention to have a preparation workshop in September, possible in connection with the IBPSA BS conference in **Rome September 2-4**, to further refine the content of a new annex.

If you are interested in the possible new IEA EBC annex on energy flexibility in buildings please contact your IEA EBC ExCo member http://www.iea-ebc.org/contacts.

The participants of the 8

Public seminar Aalborg, Denmark

By Søren Ø. Jesnsen, DTI and Anna Marszal-Pomianowska, AAU

A public seminar was organized at Aalborg University. The full-day seminar took place on Thursday April 4, during the 8th working meeting. The objective was to provide an overview of EBC Annex 67 deliverables and achievements to a broader Danish audience, and to give an opportunity to Danish and international experts to present their activates related to energy flexibility. The event attracted a wide audience from universities, public and private research laboratories, energy services companies and utilities, consulting engineering firms, among others.

Per Heiselberg, Aalborg University started the seminar with an introduction to the International Energy Agency´s Technical Collaboration Program Energy in Buildings and Communities (http://www.iea-ebc.org) and the ongoing annexes.

Søren Dyck-Madsen from the Danish Ecological Council gave an overview of the energy situation in Denmark and the foreseen development until 2040. A large increase in renewable energy sources (RES) primarily wind is planed together with a transition from fossil fuels to electricity as main energy carrier. Denmark is special in the sense that 64 % of the buildings are heated by district heating. He also pointed out that the incentives for utilizing the energy flexibility in buildings is not present.

Christian Byrjalsen from the Aalborg Forsyning utility company (district heating (DH)) in Aalborg explained the plans for making the district heating in Aalborg entirely based on RES, waste heat for the industry and waste incineration. He further told about a new district heating unit, what may enable utilization of the energy flexibility at customer level. Helle Juhler-Verboner from The Danish Intelligent Energy Alliance reported among others about ongoing work on developing a market model for aggregators thus that energy flexibility for buildings may be utilized.

The seven deliverables from Annex 67 was presented. Several of the deliverables are close to be finalized. The deliverables will successively during 2019 be made available via annex67.org. The deliverables from Annex 67 is briefly described on page one.

The national perspective towards energy flexible buildings in France, Austria, Canada and China was presented. The situation is these countries are very different and also different from Denmark. The electricity production in France is mainly base on nuclear plants. France utilized different time-of-use tariffs for obtaining flexibility. Austria has a lot of hydropower, which at the moment delivers the necessary flexibility, but this cannot be expanded anymore. The situation in Canada is different in the different regions: Quebec has hydropower, Ontario has nuclear power, while the energy supply in Alberta mostly is based on coal and oil. Canada has mainly problems with transport of electricity over long distances.

The public seminar took place in the Department of Civil Engineering at Aalborg University. Photo: Vivi Søndergaard

80 % of the electricity production in China is today based on coal. There is a roadmap without year with the aim to reduce this to 45 %, while 50 % will come from RES and 15 % from nuclear. China has, however, the problem that there is lot of RES in the east part of the country, while the main demands is in the western part of the country.

Kirsten Gram-Hanssen, Danish Buildings institute warned that the end-users need to be heard and that comfort also include "being in control" for the user. Anna Marszal-Pomianowska, Aalborg University stated that there is a need to split measured heat demand into space heating and domestic hot water, as these two demands are very different also from a flexibility point of view. And further that a higher resolution of the measurements than hourly often is necessary. Christina Corchero Carcia, IREC, Spain presented the role of aggregators and business models for aggregation services.

Per Dahlgaard Pedersen, Neogrid Technologies presented the business model for their product PreHEAT, which is a cloud based data-driven manage system for monitoring, control and visualization of DH and heat pumps in buildings. He further presented their aggregator solution SWARM for pools of heat pump. Finally, Peter Sorknæs presented the energyPRO tool, which is mainly for modelling of DH plants but possible also may be utilized for investigation of Energy flexibility in larger areas.

The public seminar presentations are available at:

http://www.annex67.org/publications/seminar/

Danish perspective on energy flexibility

By Anna Marszal-Pomianowska and Søren Ø. Jensen, DTI

National goals

Denmark is at the global forefront of environmental policy and a front-runner in green initiatives. The Danish 2050 Energy Strategy [1], singed in February 2011, set the long-term climate goal for Denmark to be the climate-neutral society by 2050, with the intermediate goal of at least 50% Denmark's energy needs covered by renewable energy in 2030. In 2017, the share of renewable energy in the total energy consumption was 33%, and in the electricity mix. 43.2 % of national demand was supplied by wind and the CO_2 intensity was 291 g/kWh [2]. Figure 1 shows that due to fluctuating energy production from renewable sources, predominantly from wind, the need for flexibility, either upwards or downwards regulation, on the demand side is high. However, there is yet no business model for flexible buildings (individual customers), which makes it rather difficult for private building owners to become an active part of the energy system.

National Initiatives

In order to speed up the green transition the Danish government has signed in 2018 an energy agreement with following key initiatives [4]:

- **Greener heating.** It aims at providing greater freedom for district heating plants and customers. Regulatory constraints on the heat production of district heating plants will be eliminated, giving them the freedom to invest in transitions to greener energy, e.g. heat pumps, biomass and geothermal systems, thus enabling the transition towards a renewable energy system. The power to obligate consumers to be connected to the collective heating system will be abolished. This will allow for investment in other individual heating solutions, e.g. heat pumps for single homes.
- **Cheaper green electricity**. The reduction of electrical heating tax by 50% and electricity taxis by 15% is expected to trigger a rise in electricity consumption. Electrification of the energy system is a cornerstone of the green transition.
- **CO_2 impacts.** The energy agreement's initiatives will reduce carbon emissions from the sectors outside of the EU Emissions Trading System (non-ETS) by approximately 1.1 to 1.5 million tonnes in the period 2021-2030.
- **Efficient use of energy.** Introduction of new tender-based scheme with subsidies for energy efficiency improvements in businesses and buildings from 2021-2024. This includes:
  - new support scheme for replacement of oil-fired boilers with heat pumps
  - loans to finance energy renovations in buildings owned or operated by municipalities and regions
  - web-based information activities relating to energy savings and the utilisation of data to promote energy efficiency
- **More offshore wind.** This includes the establishment of three new offshore wind farms that will supply at least 2,400 MW of green electricity to the energy system by 2030 (more than the total combined electricity consumption of all Danish households).
- **Energy and climate research.** Up to 1 billion DKK annually for energy and climate research from 2024.

Denmark has just got a new social democratic minority government. Together with the three centrum-left supporting parties the government has agreed to reduce the CO_2 emission in 2030 with 70 % compared to 1990, which is a considerable increase compared to the former government's goal of an only 40 % reduction.

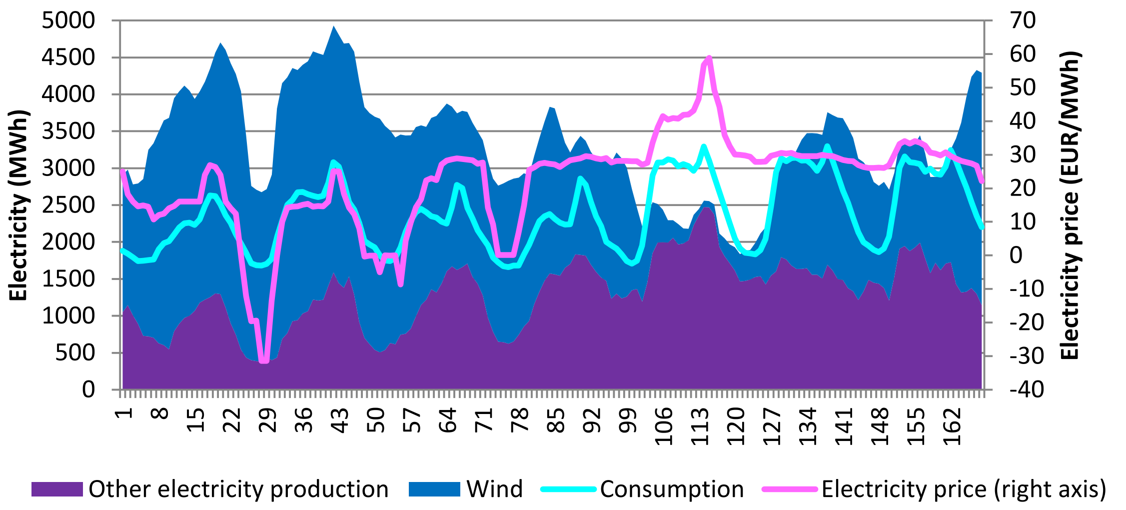


Figure 1. Electricity - Production, Demand and Price, for Denmark West. First week in 2015 [3]

Role of the buildings

Due to number of governmental energy savings initiatives and tightening the building codes, the building stock become more energy efficient. As mentioned before there is neither regulation to evaluate nor business models or tariff-structure to utilize the energy flexibility available in the building sector yet in place. Though, there are few national research projects, which aimed at investigating the flexibility potential of households' heat pumps at the local low-voltage network and hence push the market to visialize the positive energy flexibility potential of building buildings: iPower [5] Styr din varmepumpe or (control your heat pump) [6]. As 80% of the household energy demand is used for space heating and domestic hot water and 64% of Danish households are connected to district heating, the research initiatives are targeting this segment of the energy system, e.g. EnergyLab Nordhavn [7], HEATman [8] , InterHUB [9].

References:

[1] The Danish 2050 Energy Strategy

[2] Annual Energy statistics https://ens.dk/service/statistik-data-noegletal-og-kort/maanedlig-og-aarlig-energistatistik

[3] Presentation by Søren Dyck Madsen at Public Seminar Public seminar Annex 67 - Energy Flexible Buildings, April 4, 2019 Aalborg, Denmark

[4] Energy Agreement https://en.efkm.dk/the-ministry/publications/

[5] iPOWER https://ipower-net.weebly.com/

[6] Styr din varme pumpe https://www.energiteknologi.dk/sites/energiteknologi.dk/files/slutrapporter/12075_sdvp2.pdf in Danish

[7] EnergyLab Nordhavn http://www.energylabnordhavn.com/

[8] HEATman https://www.niras.dk/nyheder/naeste-generation-fjernvarme/

[9] InterHUB https://www.interhub.aau.dk/

Flexibility-Evaluation-Tool (FET)

By Tobias Weiß, AEE INTEC; Daniel Rüdisser, AEE INTEC; Glenn Reynders, VITO

The Flexibility-Evaluation-Tool (FET) developed within Annex 67 is an Excel-based tool to uniformly visualize, characterize and evaluate flexibility for different data input sources. The excel workbook comprises two worksheets:

- Energy Flexibility Evaluation
- Boundary Conditions

The worksheet "Energy Flexibility Evaluation" collects the input data and also reports results. For the evaluation at least three inputs are needed:

- Reference load without flexibility
- Load with flexible operation
- Cost function

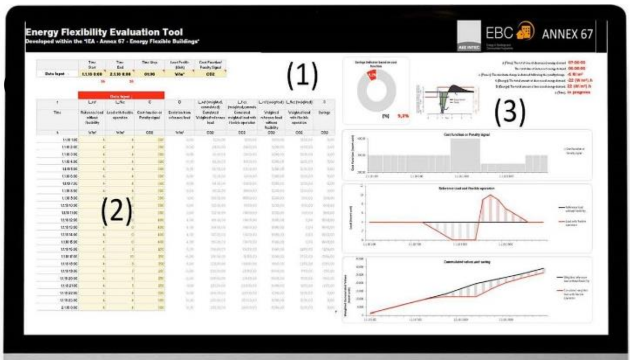
Within the worksheet "Boundary conditions", boundary conditions for the entered data like out-door temperature, global horizontal irradiation on horizontal plane, minimum comfort temperature, maximum comfort temperature e.g. can be documented. The inputs in this worksheet are for documentation only and do not affect the results in the "Energy Flexibility Evaluation" worksheet but aims to make results more comparable.

The tool includes two indicators for Energy Flexibility:

Efficiency of flexible operation (E-Flex) - it is a percentage value of the savings in terms of costs, CO_2 or primary energy, which can be achieved, compared to a baseline load profile without flexibility.

Flexibility (S-flex) - is a deviation of a flexible load profile from a baseline profile without flexibility.

A brief overview of the tool is given in the following.



(1) Overall inputs for timespan, timesteps, cost-function/penalty function and units.

(2) Input data about a buildings load profile, a flexible load profile and a cost function based on the timesteps, timespan and units.

(3) Evaluation charts and characterization.

Figure 2. Overview of the interface

① Cost function:

Definition of the cost function based on the objective - e.g. external signal: carbon emissions (gCO_2/kWh), costs (€), residual load (MW)

② Boundary Conditions/User Restrictions:

Definition of boundary conditions – e.g. times of flexible operation, expected comfort requirements, battery storage capacity

③ Control strategy:

Definition of the controller's ability to respond to the cost function/external signal.

④ Reference Load & Flexible Operation - Simulation:

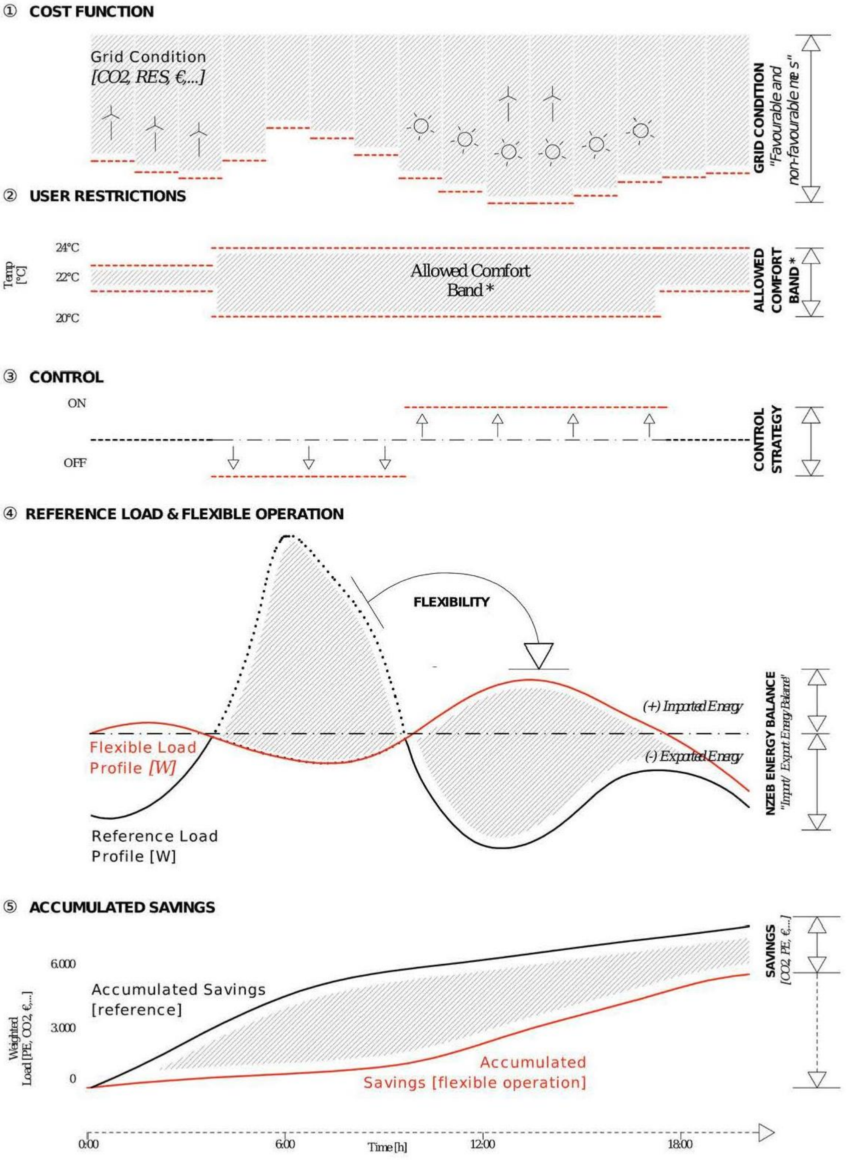
Lref: Simulation of the buildings without flexibility, which means a simulation without considering a flexible control strategy – reference load profile

Lflex: Simulation of the buildings load over a given time with flexibility - simulation where the new control strategy is considered – flexible load profile

The deviation of the two resulting profiles will be referred to as »flexibility« in the following definition of the indicator.

⑤ Accumulated Savings:

The load profiles (Lref) and (Lflex) are weighted and accumulated over time with the values derived from the cost function, e.g. external signal: carbon emissions (gCO_2/kWh), costs (€). The difference between the cumulated results of the two weighted cases at the end of the simulation period are called »savings«.



*User restrictions could also be defined as allowed hot water temperature, thermal comfort, demand management times for flexible services, etc.

Figure 3. Evaluation procedure for energy flexibility within the tool.

The full manual "Tool to evaluate the Energy Flexibility in Buildings – A short manual" and the tool can be found at http://www.annex67.org/publications/software/

OPSYS test rig

By Søren Ø. Jensen, DTI

The OPSYS test rig is a hardware-in-the-loop test facility for testing the combined control of a heat pump and a heat emitter system. The OPSYS test rig has been developed by the Danish Technological Institut – the picture at the front of the Newsletter shows the OPSYS test rig. Figure x shows schematically the set-up of the test rig with a physical part and a virtual (simulated) part. The heat pump and the valves of the heating system are physical components. The heat demand of the house is continuously calculated by a simulation program, which also controls a number of heat exchanges in order to emulated the heat demand of the different rooms of the house. The combined control of the heat pump and the heat emitting system can either be a physical controller or a virtual controller imbedded in the control system of the test rig.

The hardware-in-the-loop concept offers a bridge between laboratory tests of single components and tests in real buildings. Having the heat demand emulated by a simulation program offers the advantage that the performance of the system may be investigated during any time of a year without being dependent on the actual weather at the time of testing. The tests are further reproducible, which means that e.g. different control possibilities can be tested under the same conditions. The OPSYS test rig is described in [1] and [2]

The OPSYS test rig was originally designed for developing controls for traditional heat pump installations as the efficiency of these have been proven to be far less efficient that they are assumed to be. A major part this often poor performance is due to a poor control. Therefore,

the aim was to develop new controllers, which automatically can tune the operating of heat pump installations toward a much higher efficiency. In order to obtain this, there is a need for more advanced control of the heat pump installations including some sort of forecast of the heat demand of the house e.g. in the form of model predictive control. Such controllers have been investigated [1], but as these controllers incorporate much more intelligence than traditional heat pump and heat emitter control, they can easily also be used for obtaining energy flexibility. The ability of the test rig to test control options for energy flexibility has been demonstrated in a case, where the heat pump was prevented to run during the co-called cooking peak in Denmark. The cooking peak is the highest peak in the Danish power grid and occurs between 17:00 and 20:00 due to people coming home from work and start appliances in their homes – especially start cooking. It was demonstrated that heating up the house a bit more just before the cooking peak allowed the heat pump to following be switched off for a longer period without jeopardizing the comfort in the house compared to a situation where the temperature of the house was not raised before the cooking peak. The test is documented in [1] and [3].

[1] Combined optimization of heat pumps and heat emitting systems. Søren Østergaard Jensen (ed.). Danish Technological Institute. 2018. www.teknologisk.dk/39663.

[2] Laboratory facilities used to test energy flexibility in buildings. Thibault Péan and Jaume Salom (eds). IEA EBC Annex 67 technical report. 2019. www.annex67.org/publications/reports/

[3] Experimental facilities and methods for assessing energy flexibility in buildings. Jaume Salom and Thibault Péan (eds.). IEA EBC Annex 67 deliverable. Will be located at www.annex67.org/publications/deliverables.

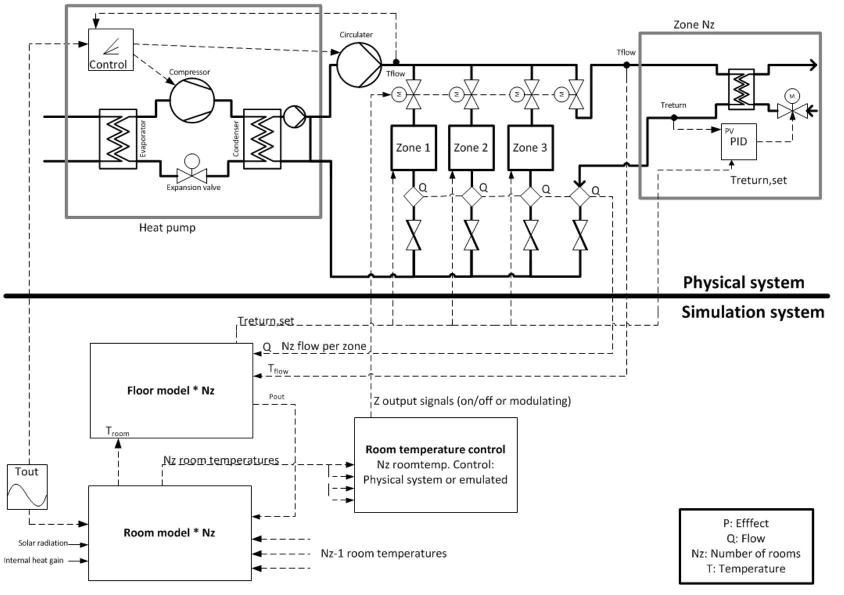


Figure 4. The layout of the OPSYS test rig.

National Projects

Flexible Energy Denmark (FED)

By Henrik Madsen, DTU Compute

The transition to a low-carbon society based on intermittent renewable energy sources calls for a change to an energy system where the demand follows the production. This requires a development of new methods to enable FLEXIBILITY at all levels of the energy system of the modern society. At the same time the system is evolving from a centralized system into a complex set of integrated systems at scales that includes customers, cities and regions. Due to the complexity, the realtime matching of energy demand with production has to take place through data analytics and IoT devices in integrated energy systems. The objective of FLEXIBLE ENERGY DENMARK (FED) is to unlock, describe and test ENERGY FLEXIBILITY at all levels, by empowering integrated energy systems using DIGITALIZATION and data intelligence. We establish a new nationwide data platform of connected LIVING LABS (Uni-Lab.dk) facilitating the coupling of existing domain specific labs and enabling new synergies. FED will provide data intelligent TOOLS and SOLUTIONS for Center Denmark (CD) which will host Uni-Lab.dk. The FED digitalization addresses all steps of the value chain from sensors to analysis to decision support. FED creates innovative SOLUTIONS based on Uni-Lab.dk data, state-of-the-art TOOLS and existing and new PRODUCTS from leading industry partners. FED provides data, AI and IT methodologies enabling the industry to be highly competitive in the digitalization of the energy systems. Hence, FED provides the foundation for a national leadership on green innovation.

FED supports the industrial partners to advance their PRODUCTS to the next generation of data-intelligent SOLUTIONS and test them in a representative environment of LIVING LABS (Uni-Lab.dk). Thereby, drastically reducing the time-to-market for the new SOLUTIONS. FED creates new knowledge about energy FLEXIBILITY to be used for both green innovations (product level) and the green transition (policy level).

Our TOOLS are data-driven exploiting data from several energy systems. Heterogeneous data from 7 Danish LIVING LABS and industrial partners are collected into an integrated open DATA LAKE. The lab-activities in FED provide the foundation for a Danish chapter of the international, smart energy UNILAB (named Uni-Lab.dk) combining proof-of-concept and demonstration with a unique possibility to scale up the algorithms and develop them to fit the needs of the Danish and the International society. Furthermore, this Digitalisation of heterogeneous data into the DATA LAKE allows the implementation of fast and standardised evaluation procedures. The process continues as an iterative cycles: Based on measurement in Uni-Lab.dk and on the impact of our SOLUTIONS, we feed the DATA LAKE with new data and further develop improve TOOLS, PRODUCTS (indirectly) and SOLUTIONS which again are tested under real life conditions in Uni-Lab.dk.

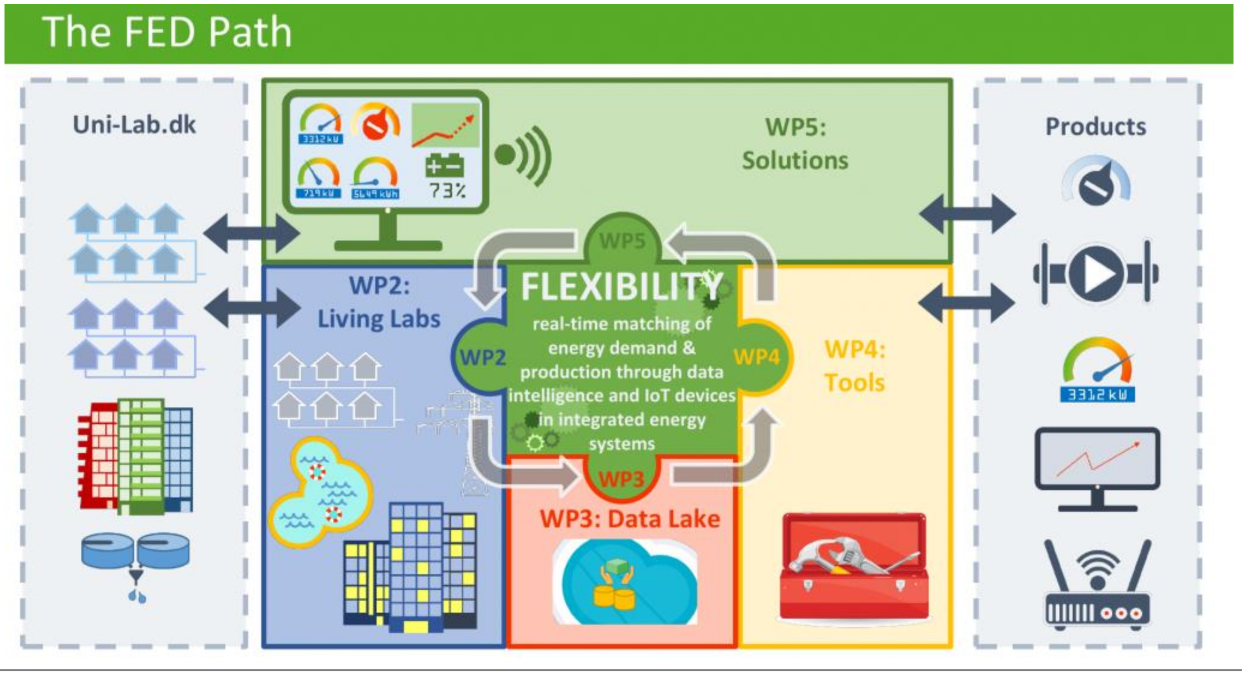
Project leader: Henrik Madsen, DTU Compute

Project partners: In total 20 partners including 4 Danish universities, DSOs, and private companies. The project is managed by EWII

Project timeframe: 2019-2023

Project sponsor: Innovation Fund Denmark

Project webpage: https://smart-cities-centre.org/2019/05/06/flexible-energy-denmark/



OPSYS 2.0

By Søren Østergaard Jensen, DTI

Heat pumps are intended to play a major role in the transition of the Danish energy system from mainly fossil fuels to renewable energy sources. The role of heat pumps is twofold:

- due to the high COP of heat pumps, heat pumps are able to decrease the demand of primary energy for heating in buildings. Heat pumps will further increase the use of electricity for heating and thus facilitate the electrification of the Danish energy system and will, thus, make room for a high utilization of wind power
- heat pumps can be controlled towards using more electricity during periods with high production from renewable energy resources (RES) and less electricity during periods with a low amount of RES in the energy system. This will help stabilize the electric grid and thereby allow for the integration of more renewable energy in the Danish energy system

The here proposed OPSYS concept, where the flow rates through the heat emitters and the forward temperature from the heat pump are continuously optimized, will not only lead to more efficient future heat pump installations but also facilitate upgrade of poor heat pump installations to good installations. The OPSYS concept will be materialized as a control box/retrofit kit for both new and existing heat pump installations.

Both EU and IEA sees the energy flexibility of buildings as an important resource for facilitating the coming transition of energy grids from fossil fuels to RES. Today, heat pumps may be switched off during periods with a low amount of RES in the grid, but it is not possible to store excess heat and thereby prolong the duration of the possible switch off period. This, however, may be done using the OPSYS concept, where the heat emitting system is controlled in such a way that the set point of the thermostats in the rooms may be increased within the comfort range of the room air temperature allowing for the storage of heat in the thermal mass of the house. Another possibility is to increase the set point of a water tank, e.g. the domes-tic hot water tank of the house, in order to store heat when there is a surplus of production from RES in the grid or a surplus of local production from an individual PV system installed on the house.

Surplus of electricity from a PV system on the house may by the OPSYS controller be utilized for an in-creased self-consumption in the house, and, thus, increase the economic benefit of individual PV systems as less electricity needs to be sold to the grid at a very low tariff. Furthermore, the controller may be uti-lized by the grid operator (DSO) to avoid curtailment of PV electricity during high production period to pro-tect the grid against over voltage problems as it is seen especially in southern Germany. The predictive controller may forecast peak production and save storage capacity for such periods, so that no or little PV electricity is wasted.

OPSYS 2.0 is a continuation of the OPSYS project described on page 5.

Project leader: Søren Østergaard Jensen, DTI

Project partners: Danish Technological Institute, Aalborg University, NeoGrid, Wavin and Bosch

Project timeframe: 2019-2022

Project sponsor: Danish Energy Agency

Energy flexibility related events

- **IBPSA BS 2019**

September 2-4, 2019

Rome, Italy

- **Preparation workshop for a new Annex "Demand Response of Buildings in District Heating and Cooling Networks"**

September 9, 2019

AAU in Copenhagen, Denmark

- **Preparation workshop for a follow-up annex to IEA EBC Annex 67**

September 19-20, 2019

DTU in Copenhagen, Denmark

- **Indoor Air 2020**

July 20-24, 2020

Seoul, South Korea

- **8th International Building Physics Conference (IBPC)2021**

June/August 2021

Copenhagen, Denmark

Operative Agent: Søren Østergaard Jensen

sdj@teknologisk.dk

Website: Annex67.org