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Opsys 2.0 - Measured and predicted energy flexibility in a single family house

EUDP project

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Opsys 2.0 Project

- Financial support by EUDP
- Running 2019-2023
- Total budget DKK 10 mill.
- Industrial partners: Bosch, Neogrid, Wavin
- R&D partners: Aalborg University, DTI
- Follow-up on the former Opsys project

Combined optimization of heat pumps and heat emitting systems

Energy and Climate

Søren Østergaard Jensen, Danish Technological Institute

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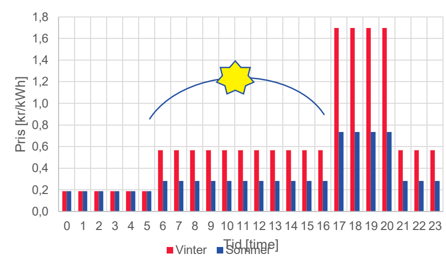
Heat pump issues

SG Ready Smart Heat Pumps

Nettarif C (Radius)



- Forward temperature set too high
- No central control of valve opening
- Only simple means are available for HP override control
- Self consumption with PV power requires advanced control

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Opsys 2.0 Project goals:

1. Develop a controller for heating, which combines both the heat source system and the emittent heat system. In this way we are able to utilize the thermal mass of the building as a free storage and also improve the efficiency of the heat pump.
2. Develop an algorithm with forecasting, taking into account the weather (Heat demand and PV production) and further the electricity prices. Hereby it should be possible to lower the demand for buying expensive electricity in peak load hours.
3. Demonstrate this in practice in an inhabited house, as well as in the laboratory, so that we can gather operational experience and optimise the control.

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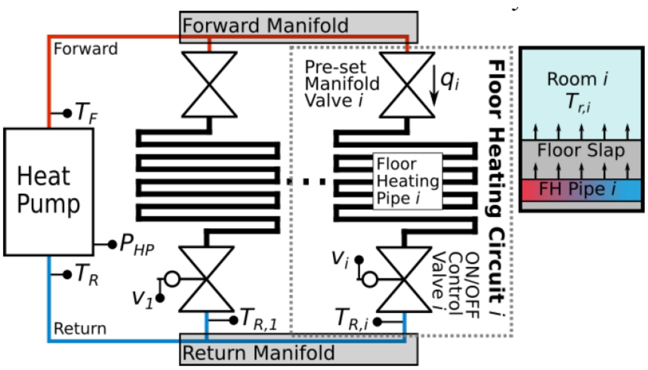
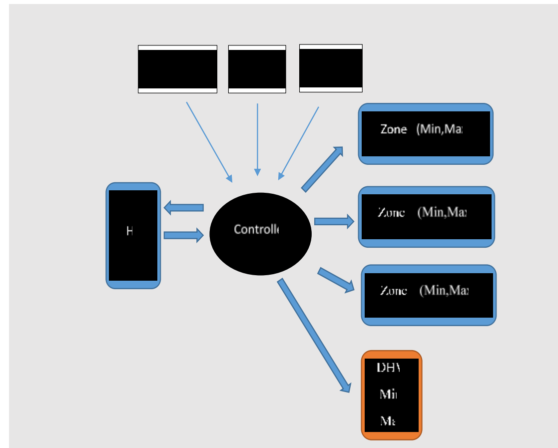
The Opsys 2.0 concept





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Main activities

- Newly developed controller installed in a house in Kalundborg
- Batterydata from a house in Roskilde analyzed
- MPC controller developed
- Test rig at DTI refurbished
- Model for battery and PV implemented

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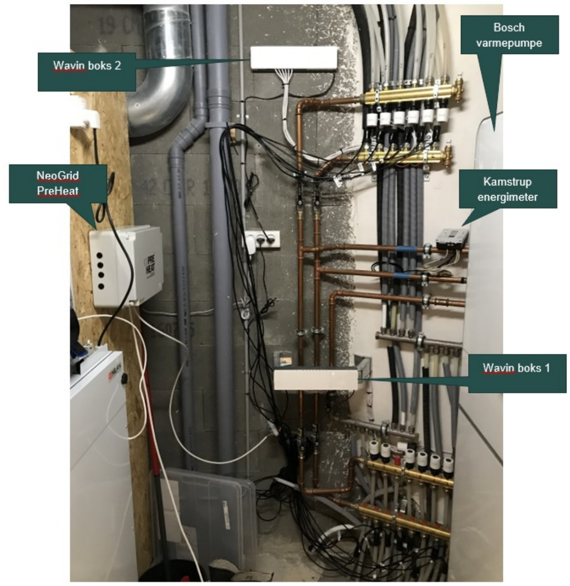
Demo house in Kalundborg



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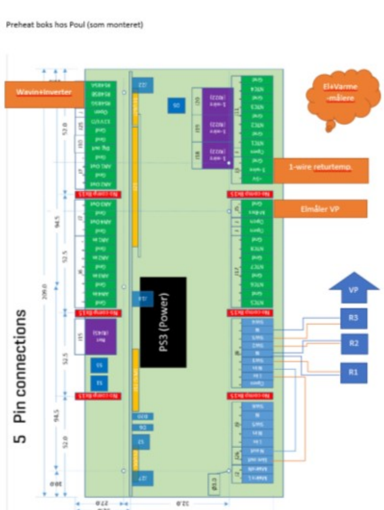
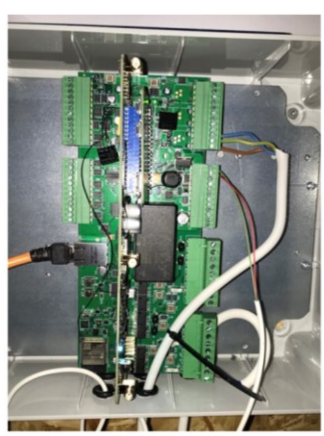
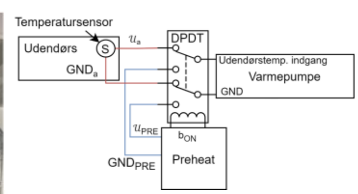
Hardware







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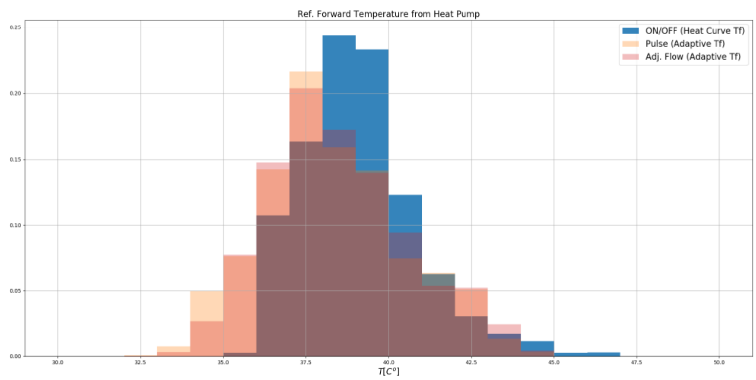
Simulation: Forward temperature self-lowering algorithm

- Decreases forward temperature until the highest demanding room demand the valve to be continuously ON.
- Shuffles the PWM cycles for each valve to maintain constant flow
- Only an estimate of nominal flow is needed.



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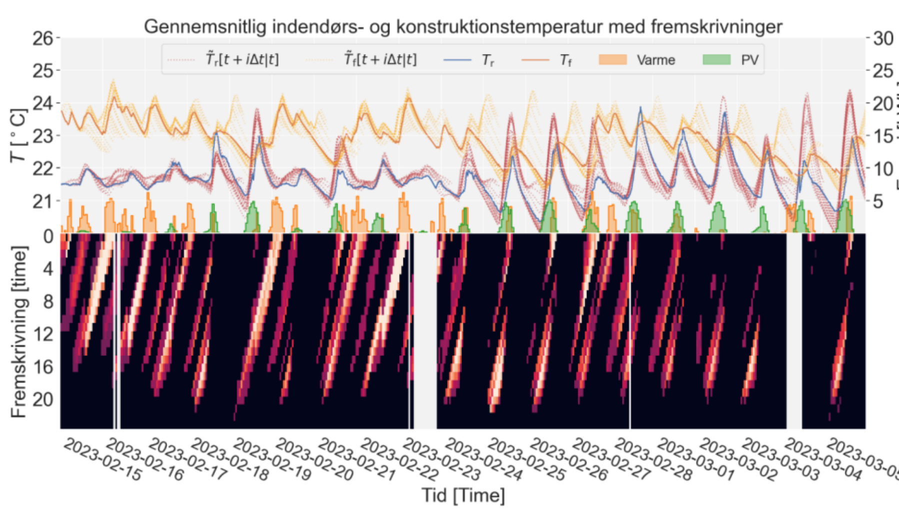
Test of the MPC (Kalundborg house)

- 24 h demand prognosis
- Hourly update
- Comparison with 97 days reference period: 11% savings



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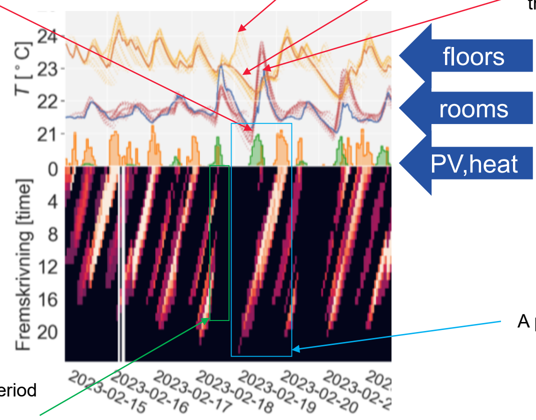
Here the future shows a heated floor

The trajectory ends up being a cooled floor

The house ends up being warm even though no heat was produced

Here the house and floor has been Precooled and is now ready for the heating event



A planned heating period is being carried out

Here is an excessive heating period being cancelled well in time

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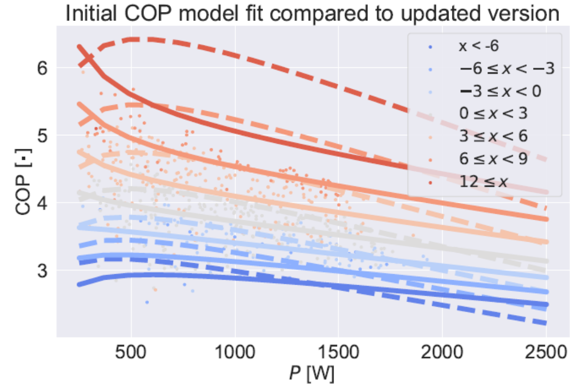
COP of the heat pump as a function of power uptake and temperature

$$\mathrm{COP_{HP}} = \frac{k}{P_{\mathrm{HP}}} + \left(\frac{k_0}{P_{\mathrm{HP}}} + k_1 + k_2 P_{\mathrm{HP}}\right)\mathrm{COP_{CARNOT}} \tag{13}$$

with

$$\mathrm{COP_{CARNOT}} \equiv \frac{T_{\mathrm{F}} + 273.15\,^{\circ}\mathrm{C}}{T_{\mathrm{F}} - T_{\mathrm{a}}} \tag{14}$$

Initial COP model fit compared to updated version



It has a cost to push HP output!

Dotted lines = original fit
Full lines = new best fit

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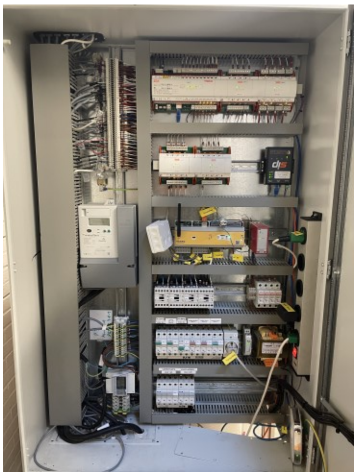
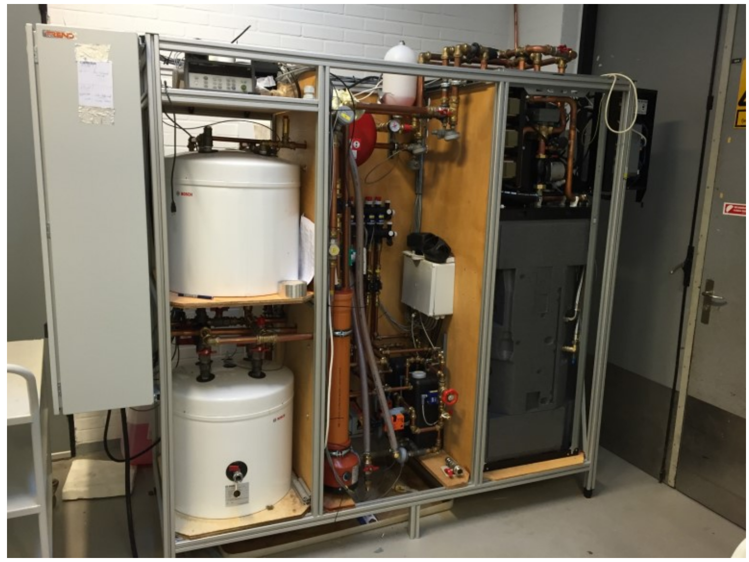
Testrig at DTI





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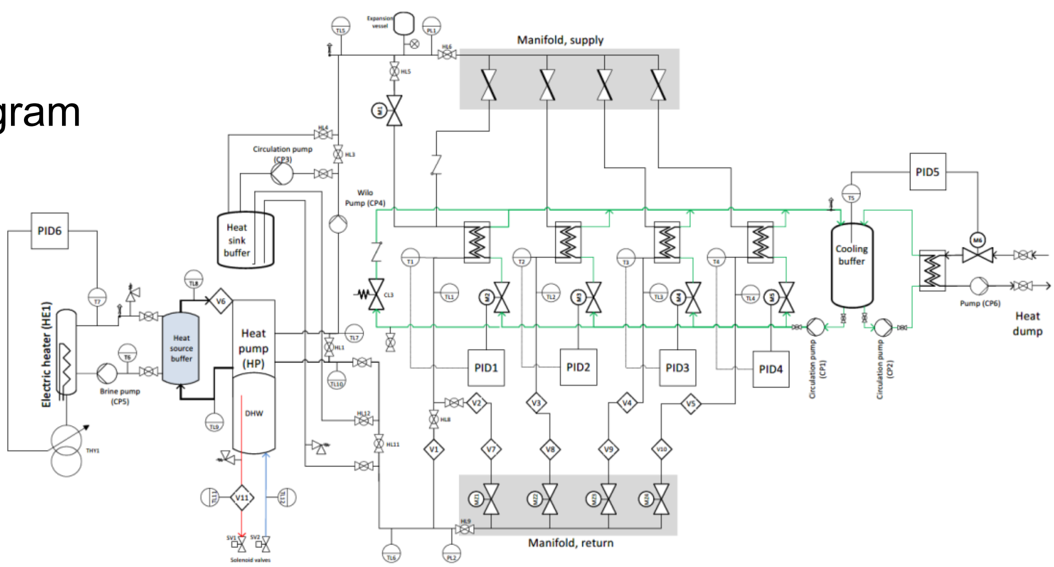
PI-diagram



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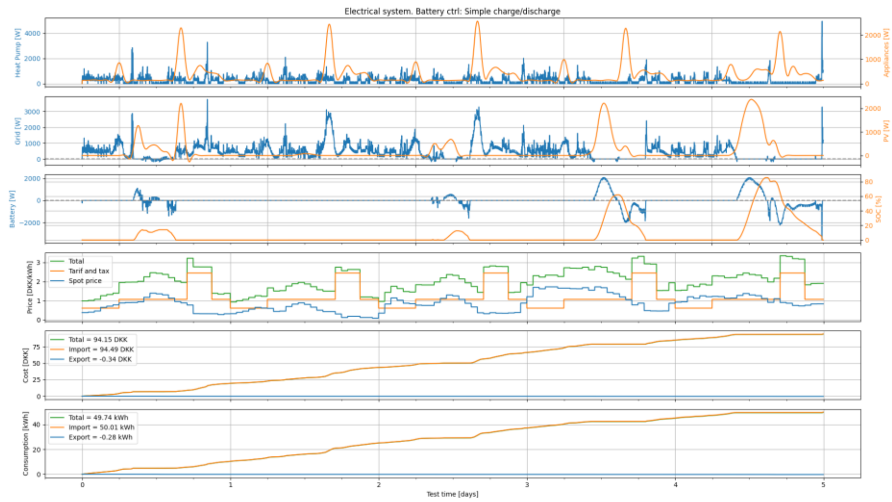
Testrig: Results simple on/off charging on demand



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Testrig: Results MILP battery controller

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Main conclusions:

- Heat pumps can be disconnected during the electricity evening peak without loss of comfort in houses with concrete floor heating.
- In the low-energy test house in Kalundborg, efficiency was already quite good so savings were low. The saving rate was an estimated 11% over the test period of 97 days.
- The highest potential for energy savings is on relatively cold days with a high solar gain.
- Test results from the test rig at DTI show that the advanced control algorithm saves money (not energy) compared to simpler strategies. By implementing this one could save up to 20% on operational cost.
- There is still room for improvement and simplification of the control system. Most important, heat pumps should have an interface to allow external control of certain parameters such as the detected outdoor temperature. It is not a feasible solution to use “homemade” bypass control like in the current project.
- The system is most suitable for colder and sunny climates where there is a high heating demand during winter but also significant PV production to power a heat pump.