

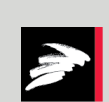


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Combined Thermal and Electrical PV Storage in Households

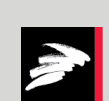
– experience and measurement results

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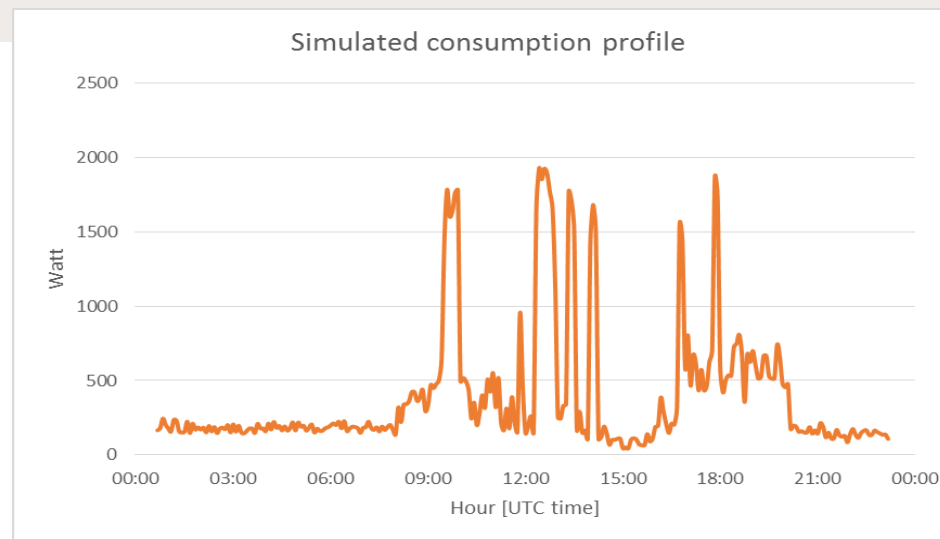
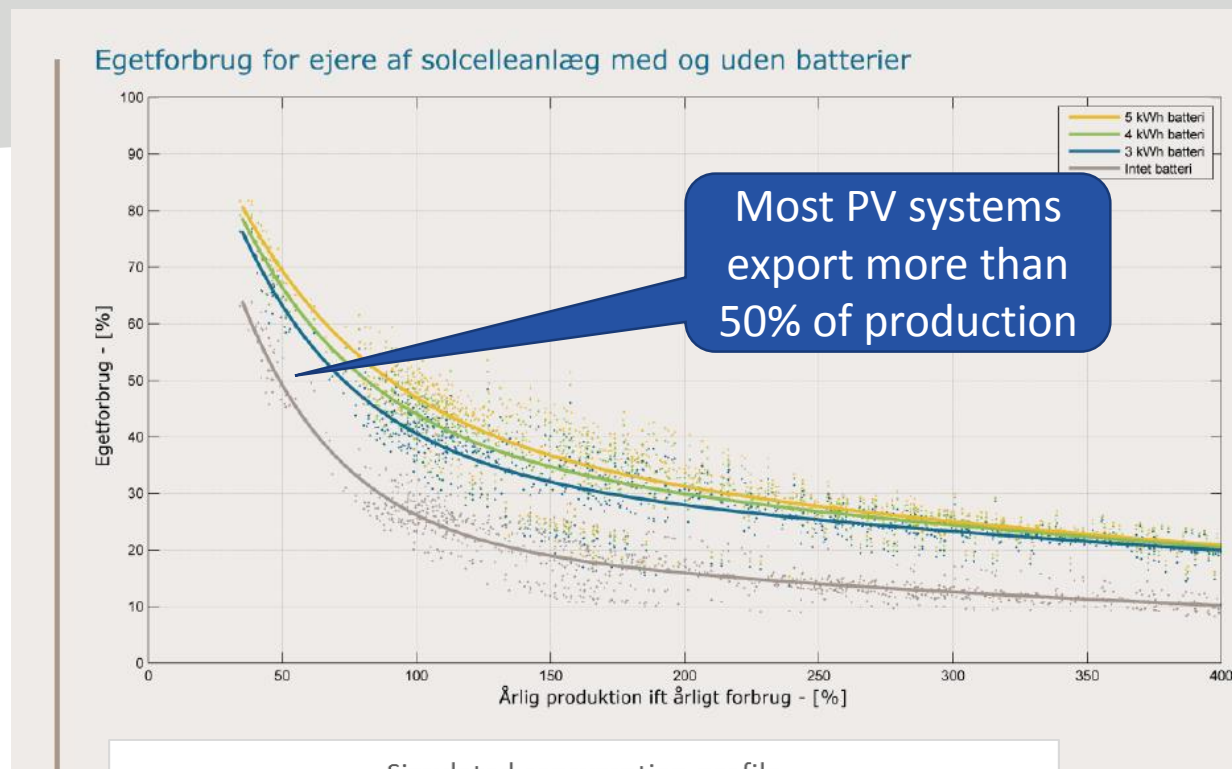
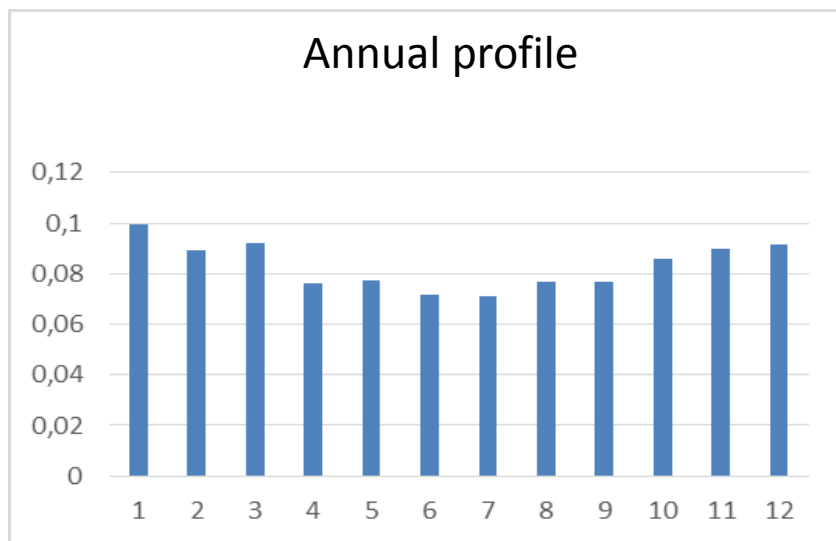
Project scope

- Increase self-consumption of PV electricity in households
- Evaluate total efficiency of battery energy storage with a new BMS
- Demonstrate cost-effective solutions for thermal storage
- Test a new heat pump controller with smart grid functionality
- Develop a simple tool for system sizing



PV owner's pain

- Consumption profiles
 - Seasonal mismatch
 - Daily mismatch



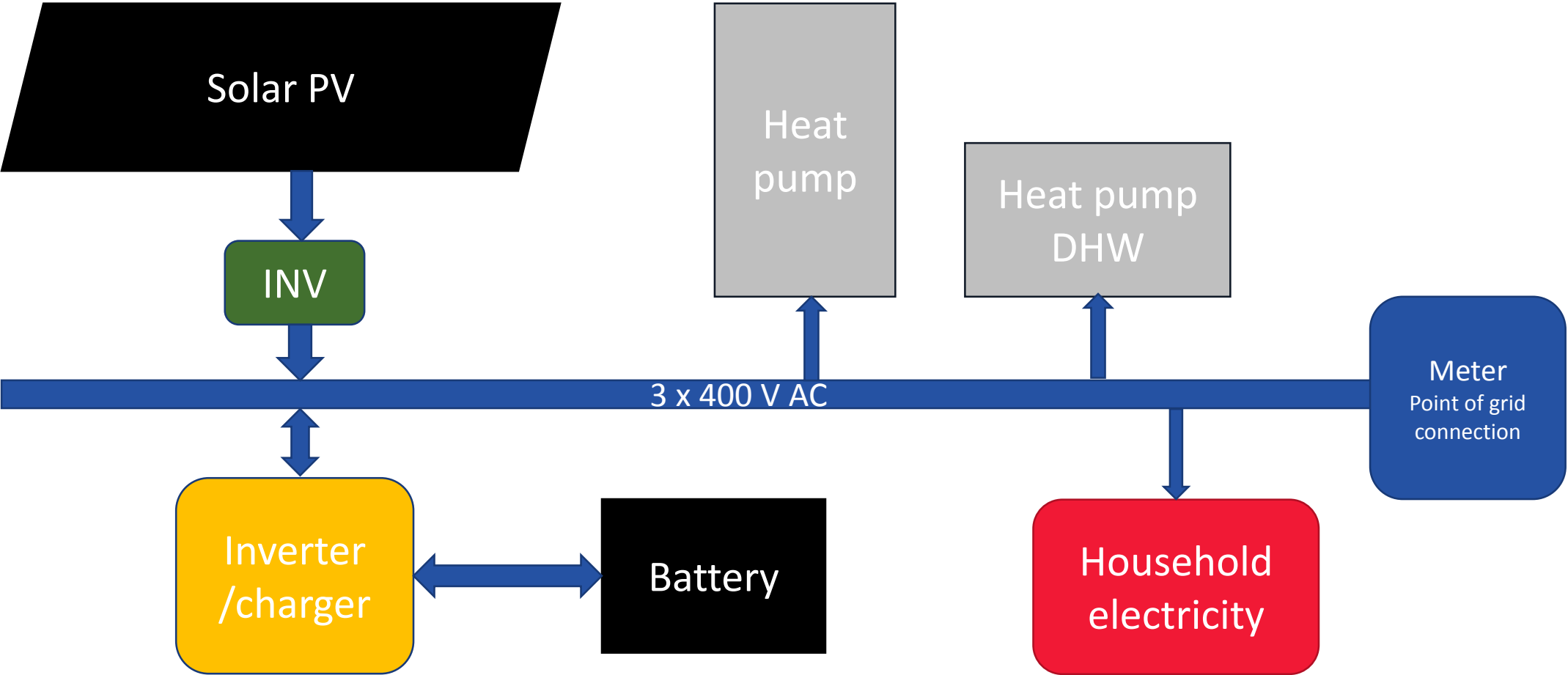


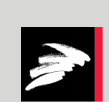
- EnergyFlexHouses
 - NZEB design
 - 500+ data points
 - Side-by side rooms
 - Floor heating
 - Radiator heating





Experimental system configuration

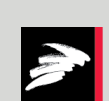




System components

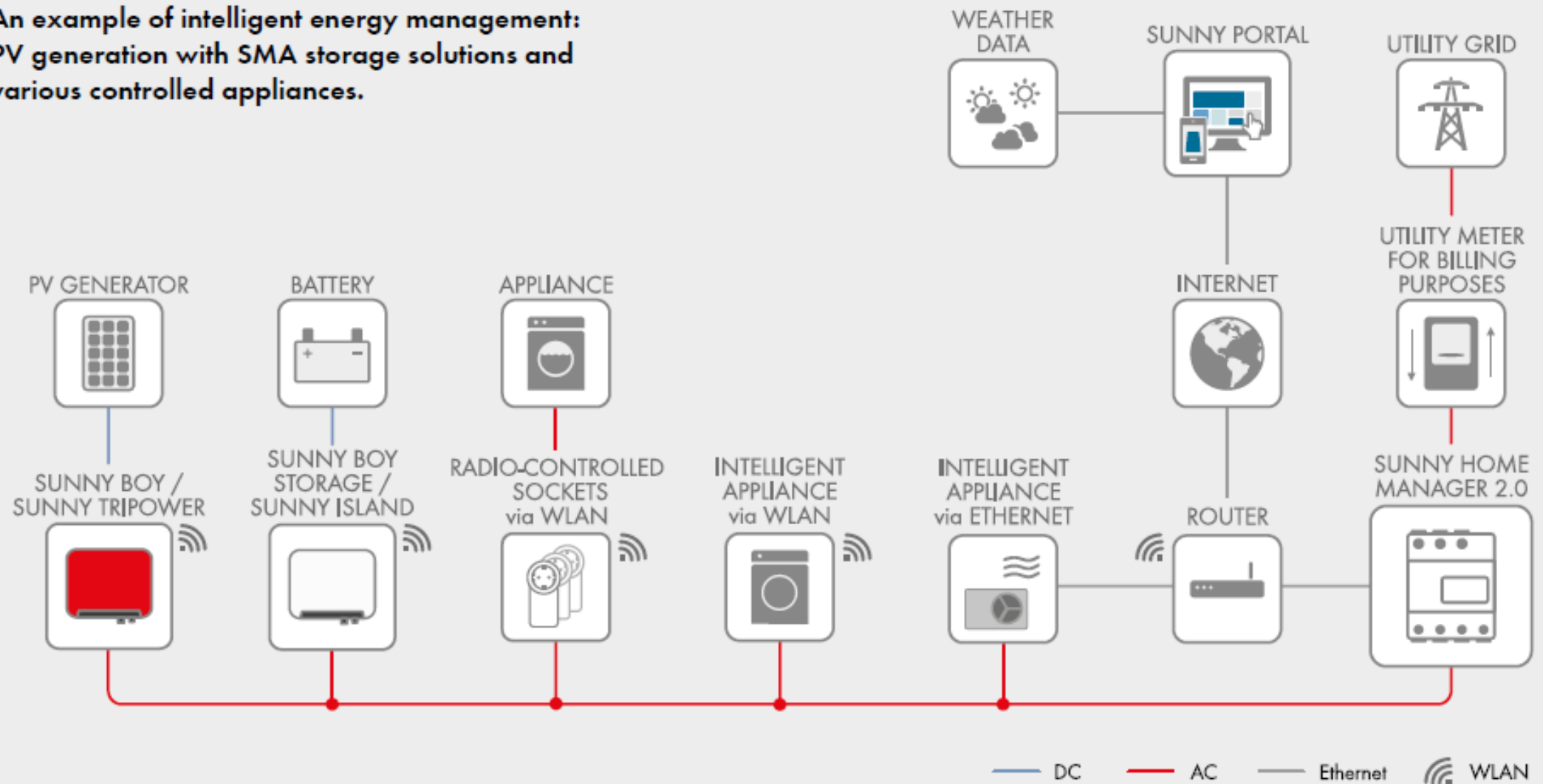
- 2 x 3.5 kWp PV system
- 4.8 kWh LiFePo battery
- 2.3 kVA battery inverter
- 6 kW(T) heat pump
- 250 l buffertank
- 180 l DHW tank
- Smart electricity meter
- 2 x WiFi sockets

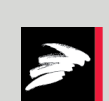




Smart Grid in practice

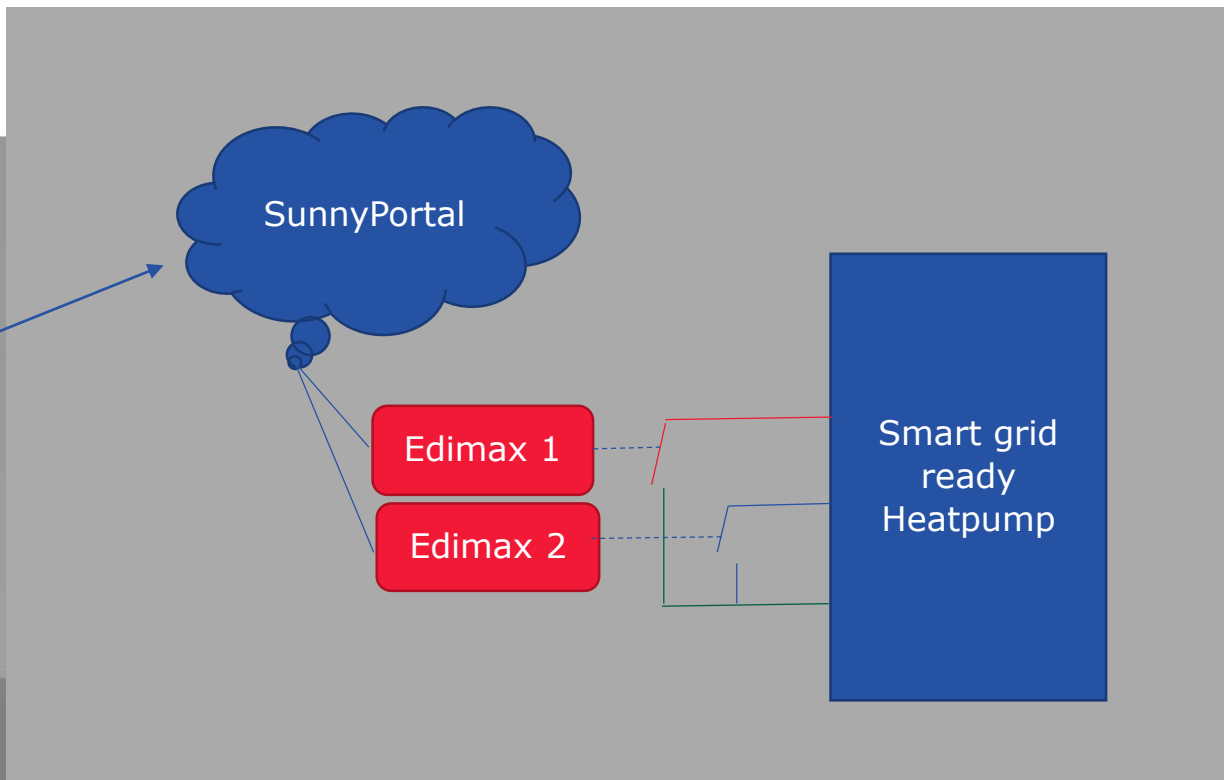
An example of intelligent energy management:
PV generation with SMA storage solutions and
various controlled appliances.





- Overall control based on SMA Home Manager 2.0
- Connection to smart grid ready NILAN heatpump
 - 3 modes: Normal, off or high temperature (+10K)

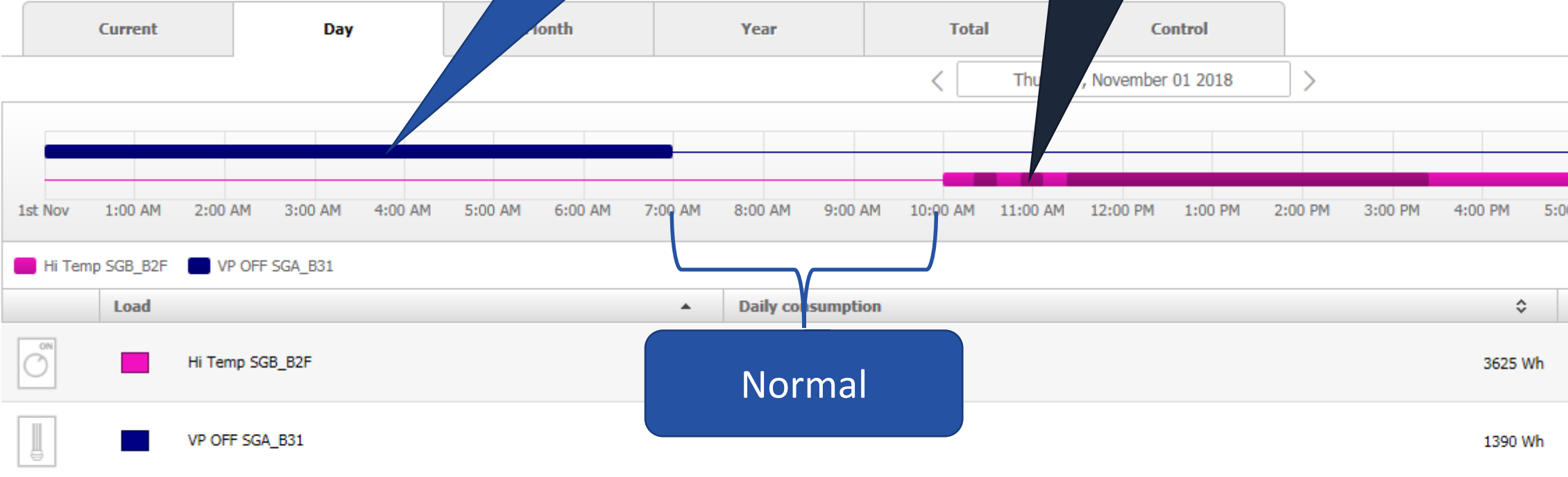
SUNNY HOME MANAGER 2.0

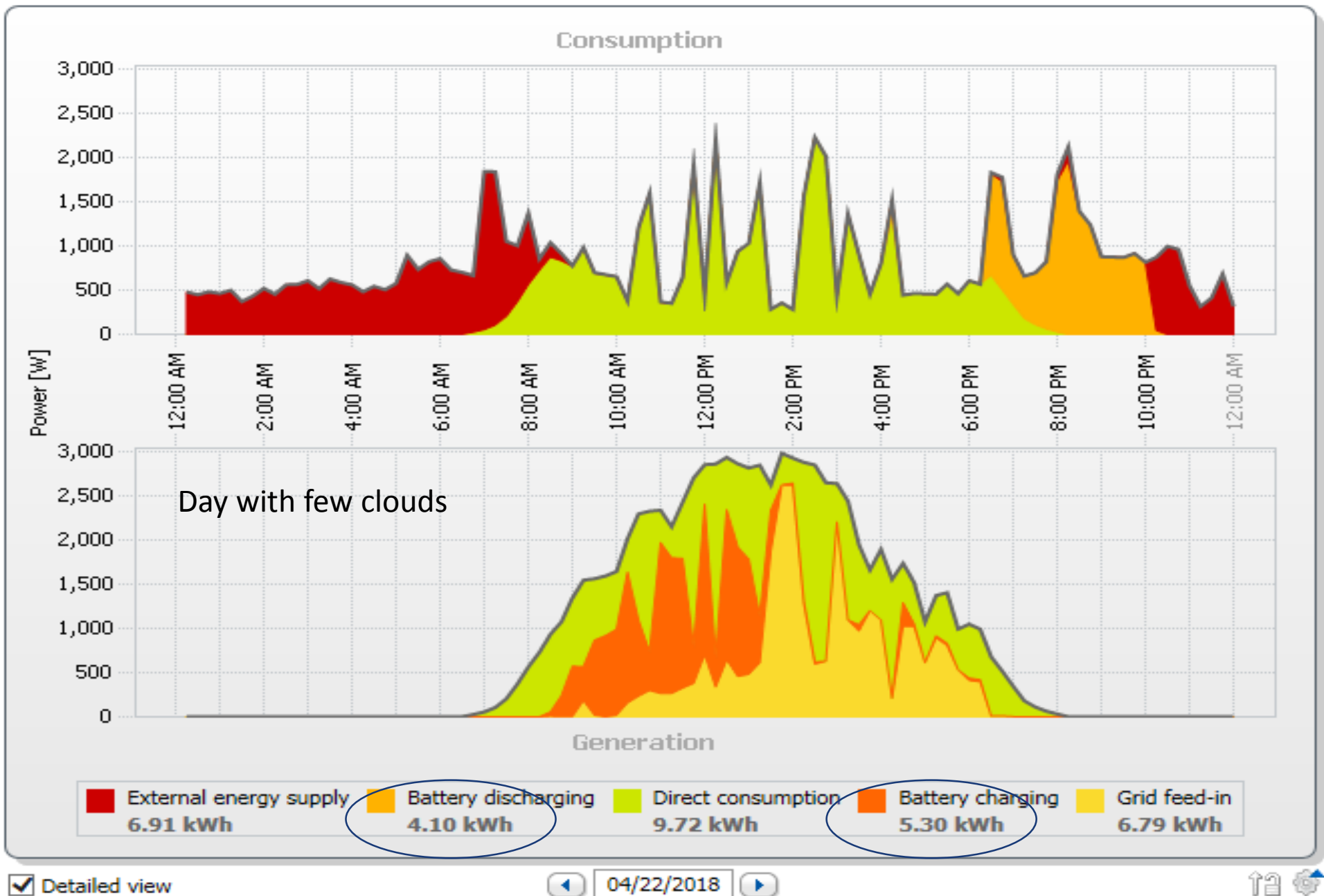


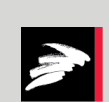


Programming in Sunny Portal

Load Balance and Control







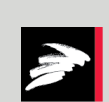
Battery cycling results

- Monthly AC efficiency 66-77%
- Standby losses are significant! It may be better to buy some power instead of starting up the battery inverter.
- Difficult to determine state of charge when not fully charged. This caused the voltage guard to trip the whole system



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Heat storage solutions in family houses with heatpump



Theoretical heat storage capacity

- Total water volume = $250 + 180 = 430$ liter.
- $Q = M \cdot C_p \cdot dT = 430 \text{ kg} \cdot 4,186 \text{ kJ/kgK} \cdot 10 \text{ K} = 18000 \text{ kJ} =$

5,0 kWh thermal (10K)

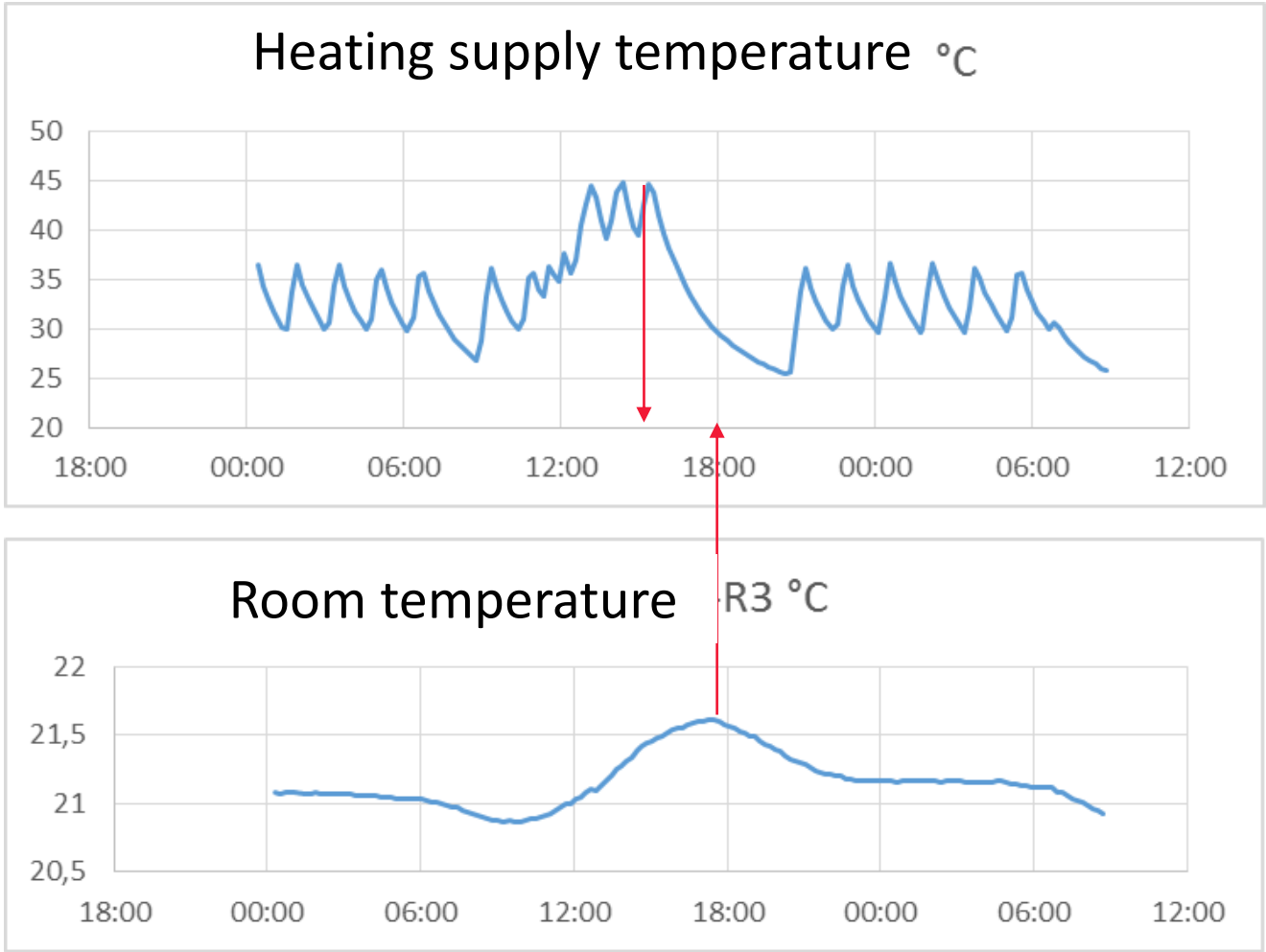
- Concrete floor mass = $2300 \text{ kg/m}^3 \cdot 0,1\text{m} \cdot 100\text{m}^2 = 23000 \text{ kg}$
- $Q = M \cdot C_p \cdot dT = 23000 \cdot 2,38 \text{ kJ/kgK} \cdot 3 \text{ K} = 164220 \text{ kJ} =$

45,6 kWh thermal (3K)

- Total equivalent electricity use in a heat pump = 15-20 kWh/cycle



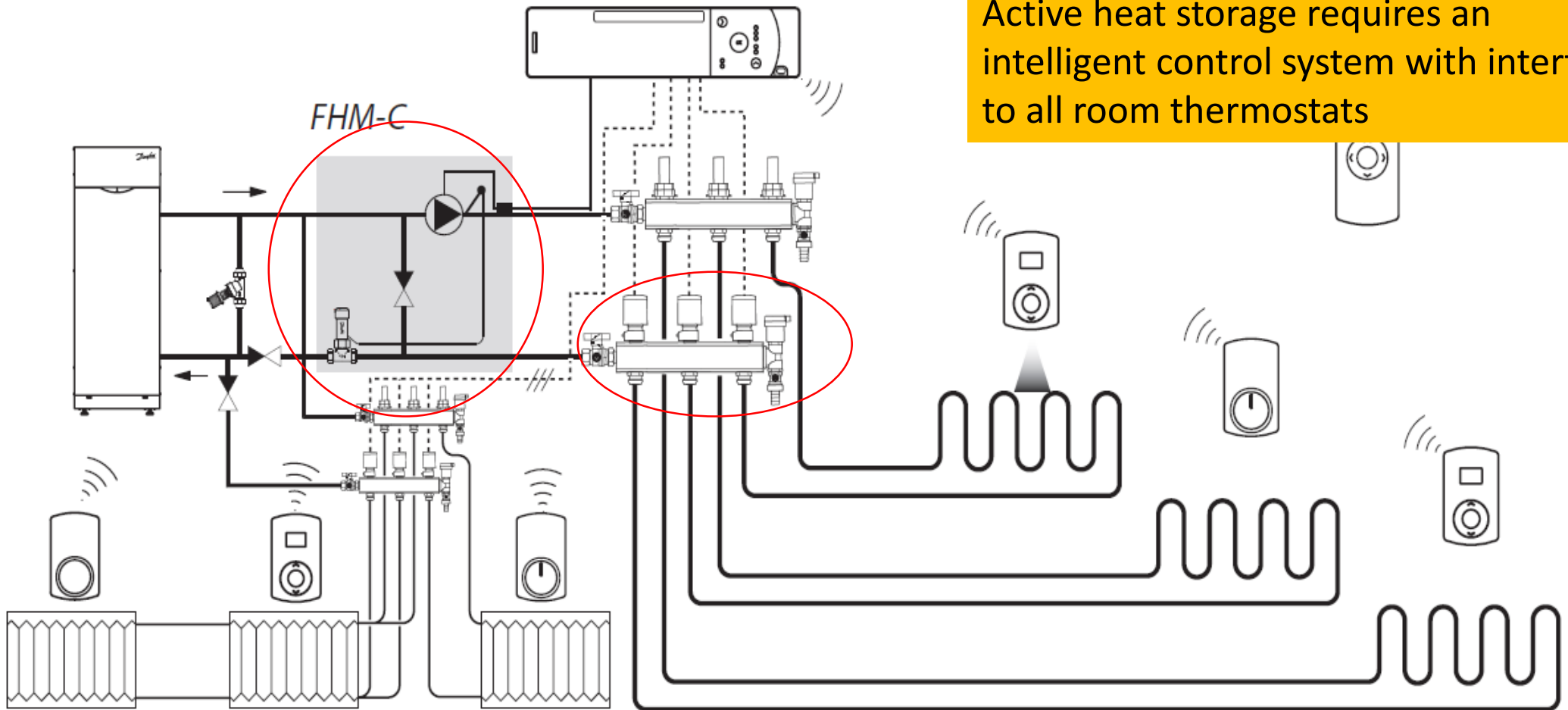
Heat storage in 10 cm thick concrete floor





Getting the lowest possible temperature for the heat pump

A generic problem. Bypass circuits should be avoided!

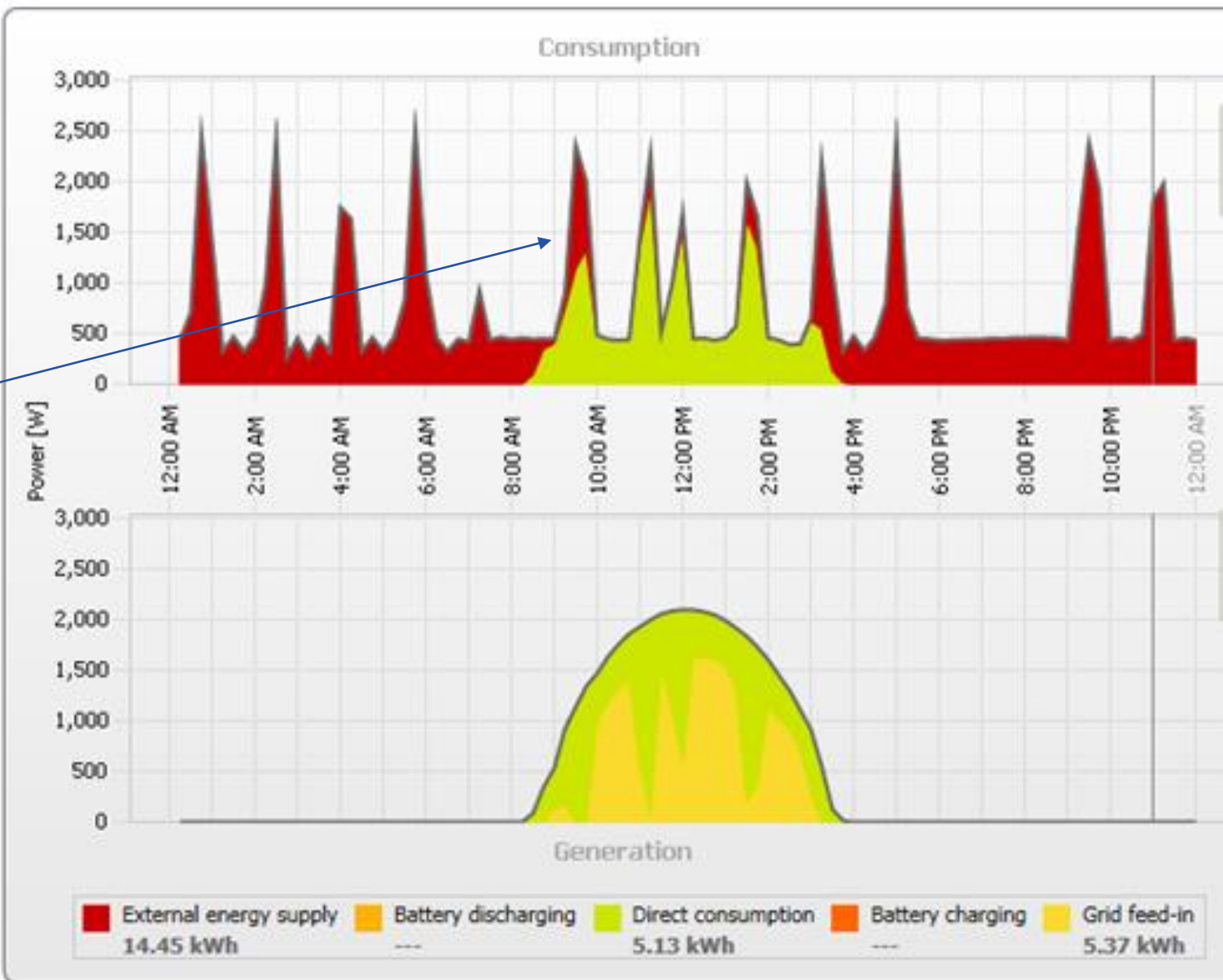


Active heat storage requires an intelligent control system with interface to all room thermostats



Period with heat
storage only

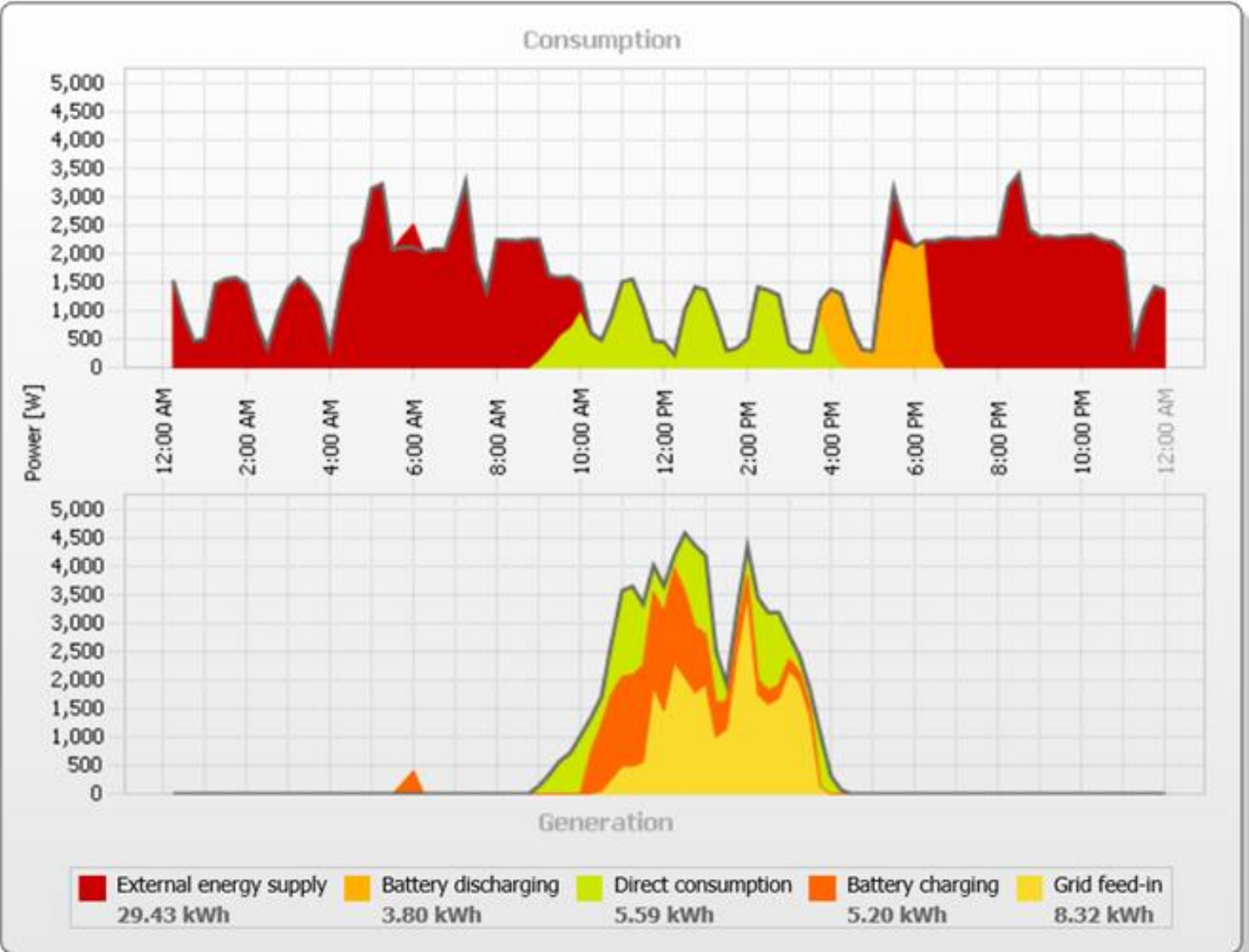
Power modulation
of the heatpump
could help fill the
gaps/cut the peaks





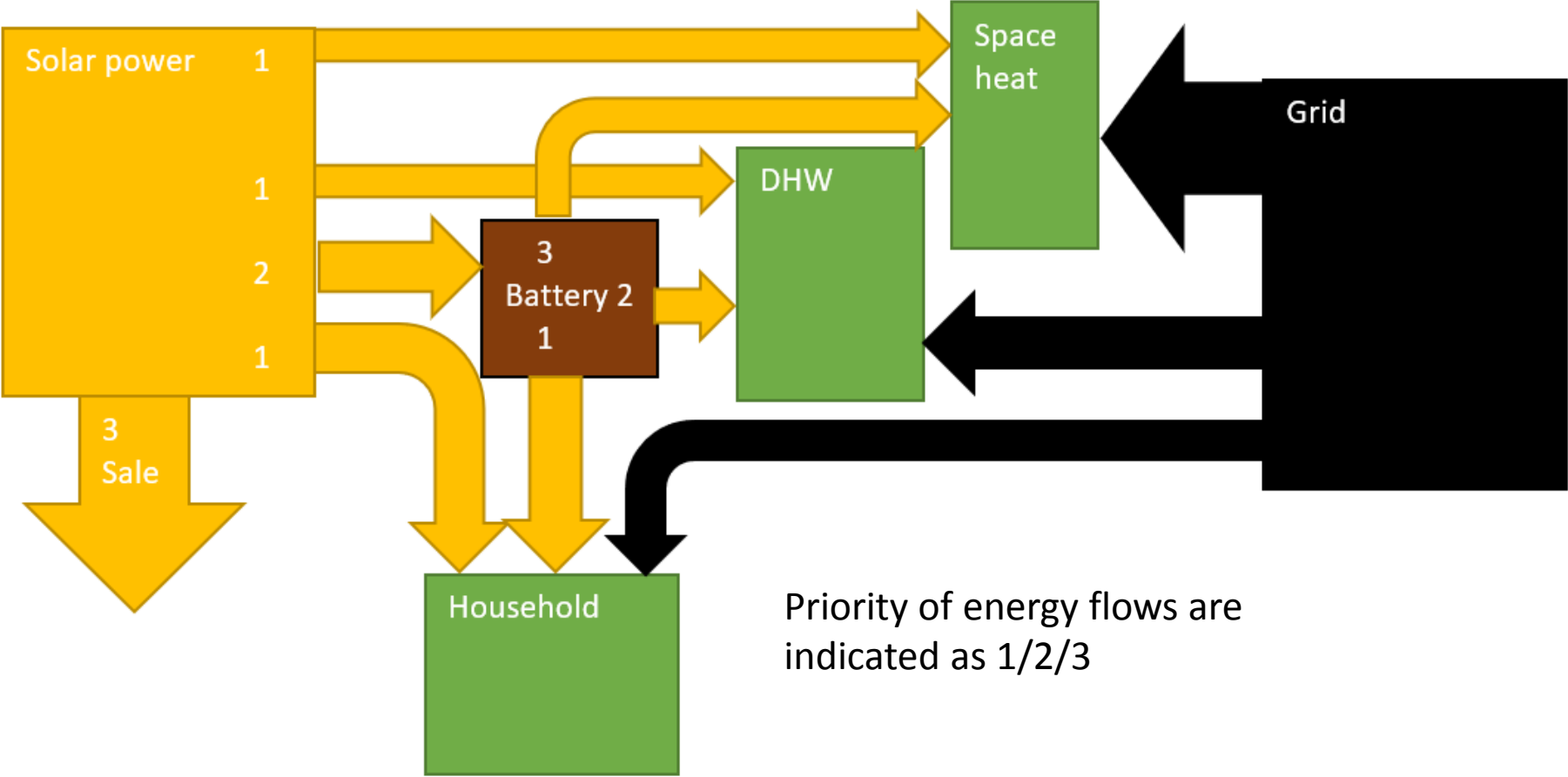
The power was reduced to 60% and the battery connected

Longer runtime and 100% self consumption in daytime



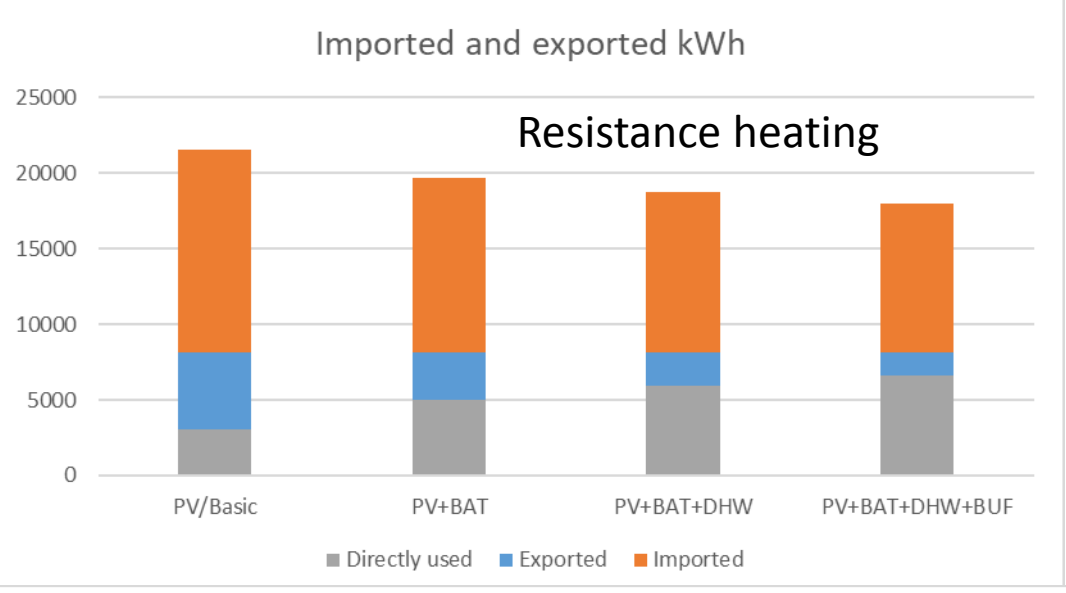
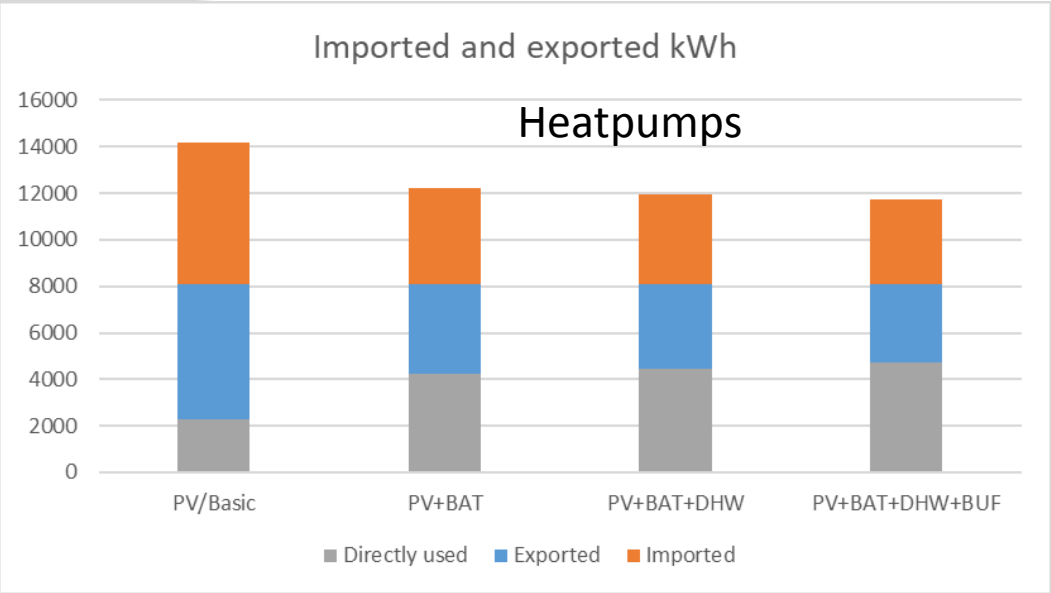


Simulation model

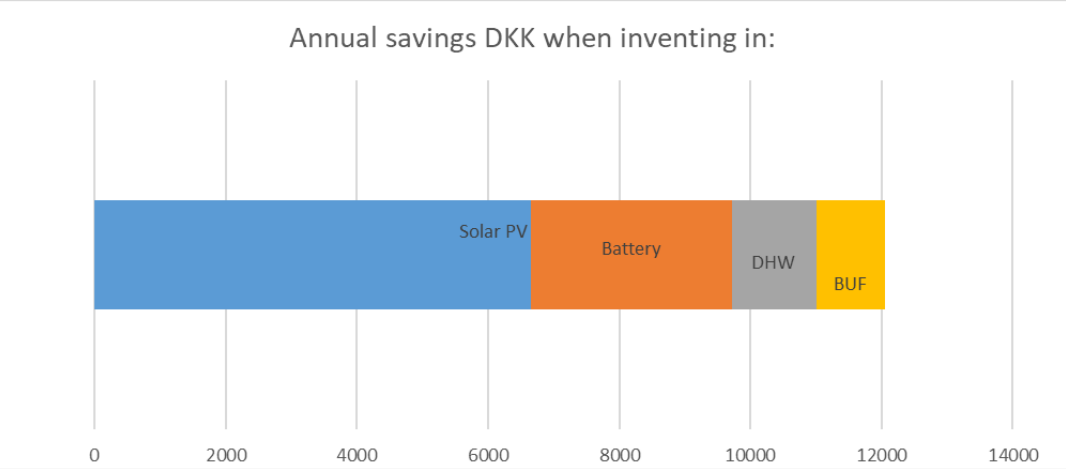




Simulation results



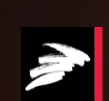
PV system	8	kW
Battery	8	kWh
DHW storage	5	kWh
Buffertank	15	kWh





What have we learned?

- *Smart Grid Ready* does not mean end of all problems!
- Cloud monitoring and -control requires technical skills and a lot of attention
- Limited options for control of heat pumps as "dump load" for excess electricity
- Central heating systems are not built for grid flexibility, smarter control systems are required
- The tested system was time consuming to adjust and was sensitive to many small technical problems
- Differentiated tariffs = game changer



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Thank you!

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