Results from the projekt Solar/Electric heating systems in the future energy system

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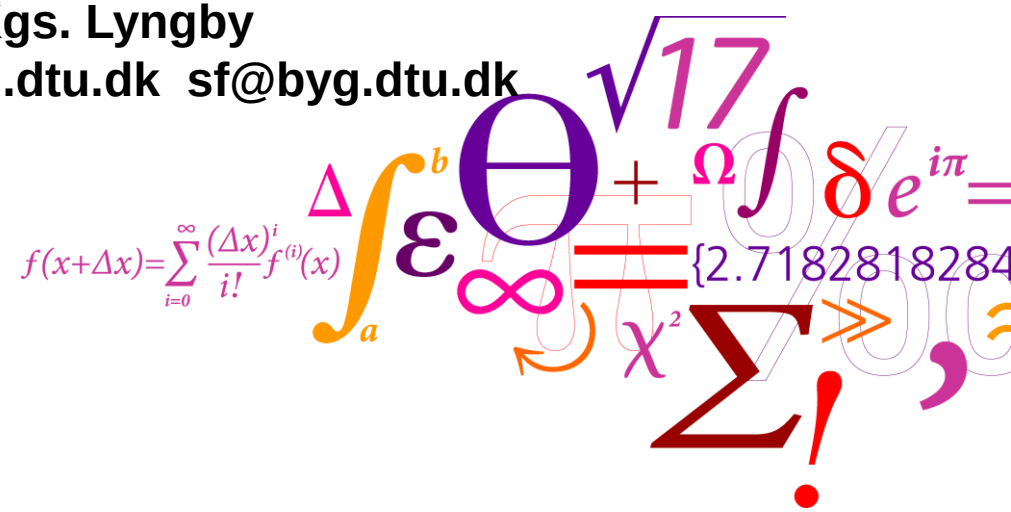


DTU Civil Engineering
Department of Civil Engineering

Partners in the Solar Electric project

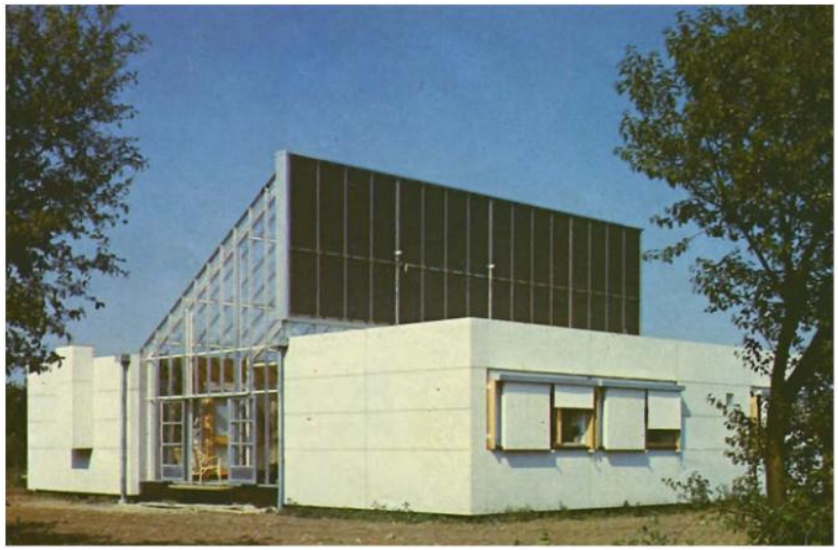
- **DMI** (More accurate weather forecasting inlcuding solar radiation)
- **DTU Byg** (Project leader and system research)
- **DTU Informatics** (detailed dynamic modelling and forecast control)
- **COWI A/S** (System modelling on national level, Socio economic study)
- **ENFOR A/S** (close cooperation with DTU informatics)
- **Ajva Aps** (Prototype storage tanks)
- **Innogie Aps** (Smart forecast control system for the lab test)
- **Ohmatex Aps** (Fabric stratifier prototypes)

ESTTP vision for solar heating 2050

50% of Europe's heating and cooling demand covered by solar thermal

New buildings: Heating and cooling demand fully covered by solar thermal

Zero energy house, DTU 1975

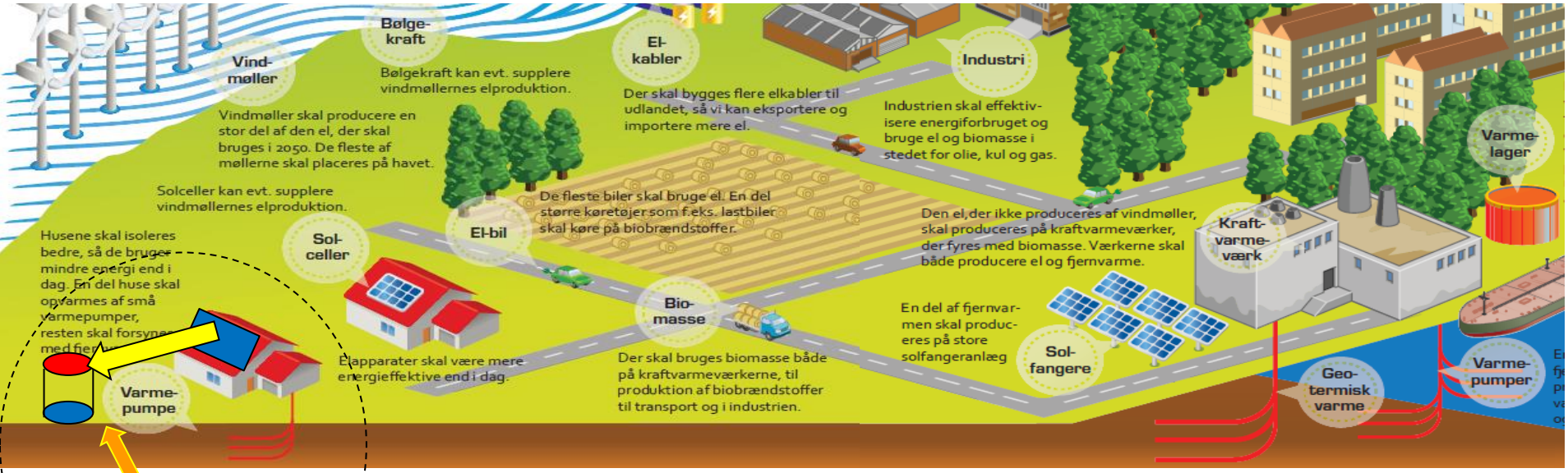


Renovation of buildings: More than 50% of heating and cooling demand covered by solar thermal

http://www.estif.org/fileadmin/estif/content/esttp/downloads/SRA/ESTTP_SRA.pdf

Need for education, research, development and demonstration now!

Denmark: Phase out all fossil fuels before 2050



Wind energy:

2012: 30% of electricity

2020 → 50 % of increased electricity consumption (incl. transport, heat pumps, …)

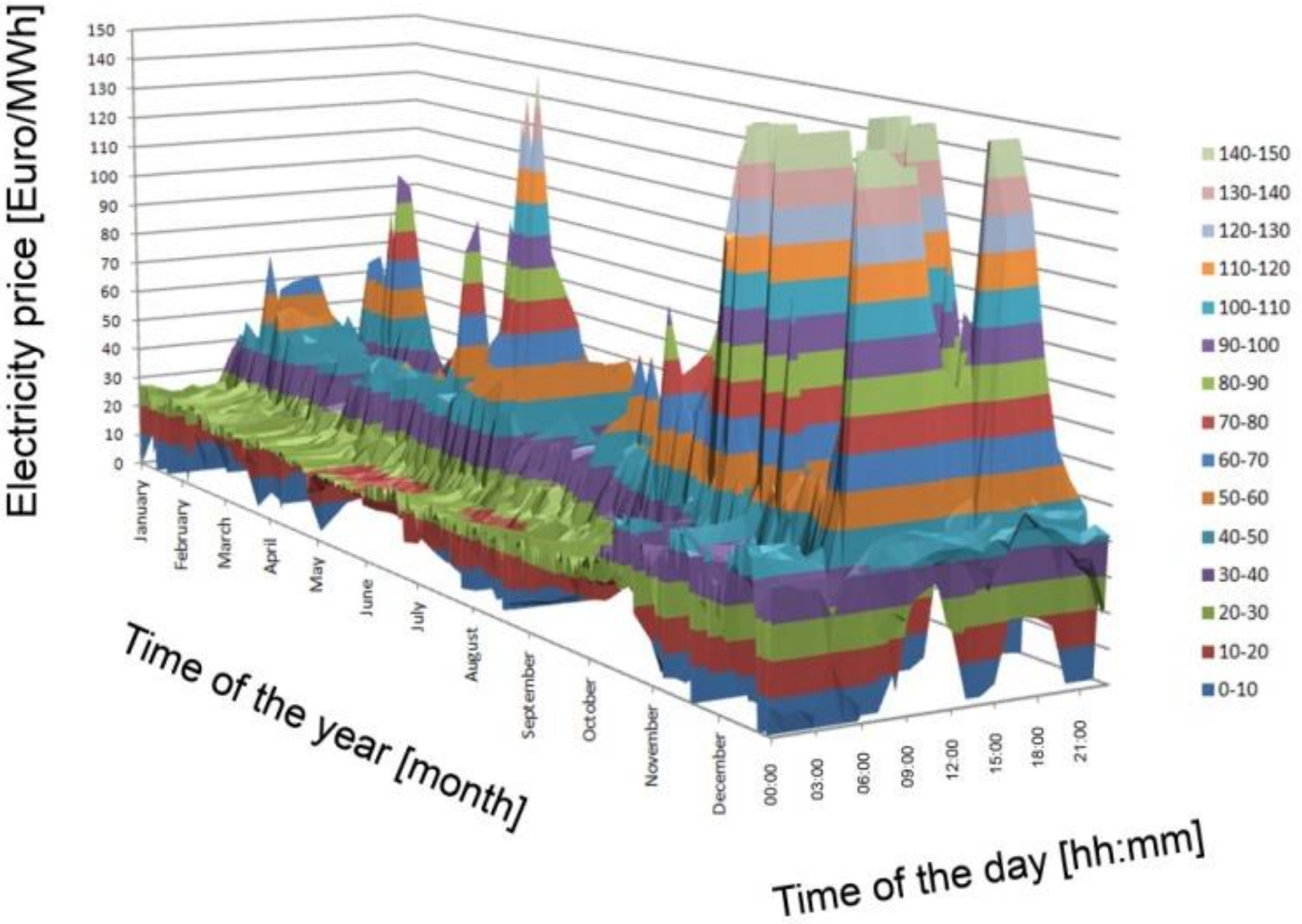
Solar heating:

2030: 15% of decreased heating demand

2050: 40% of decreased heating demand – 80% of this by district heating & 20% individual systems

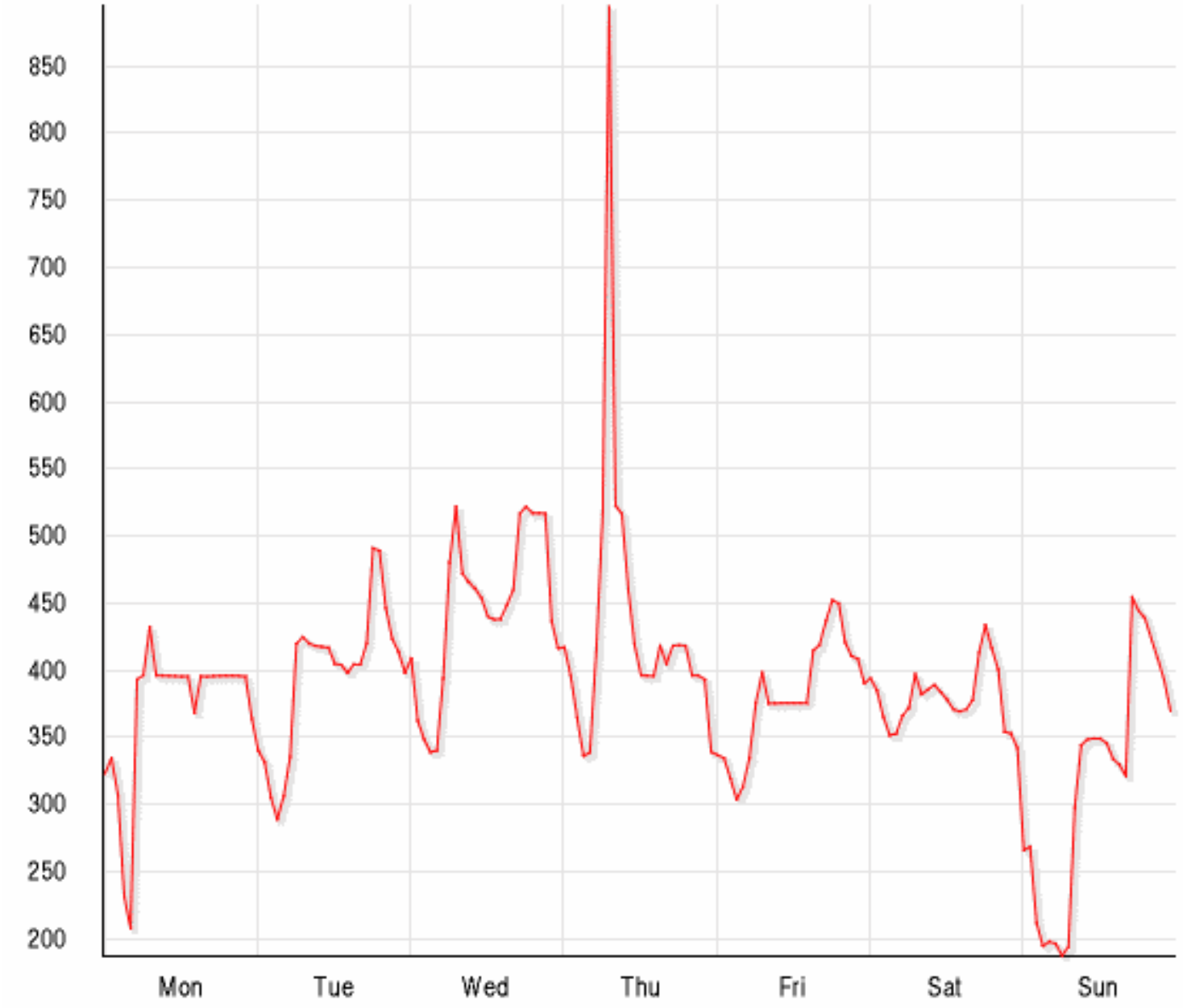
Danmark west, 2007 - from Nordpool

Electricity price variations during one year

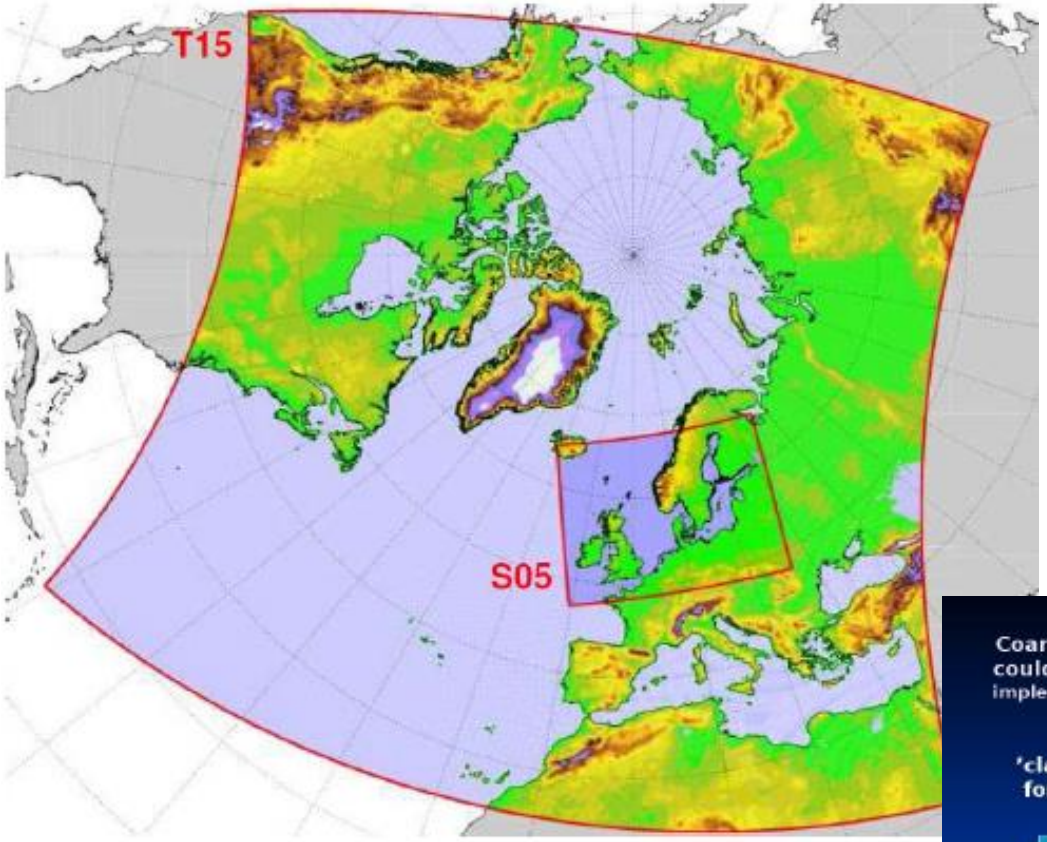


Electricity price, DKK/MWh

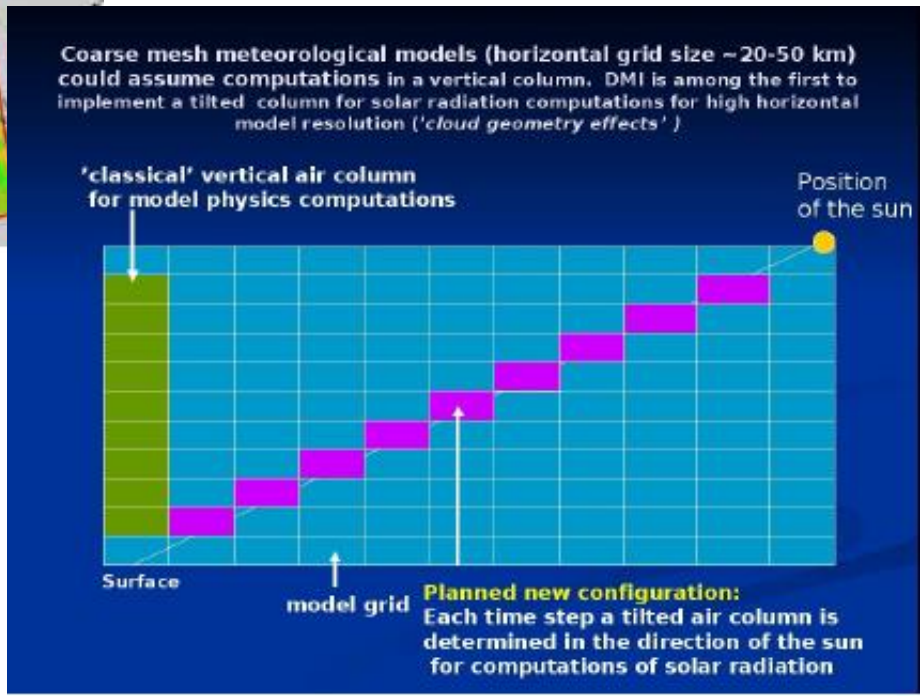
Denmark west, November 3.-9., 2008



DMI weather forecast modelling



”3D” Solar Radiation Forecasting



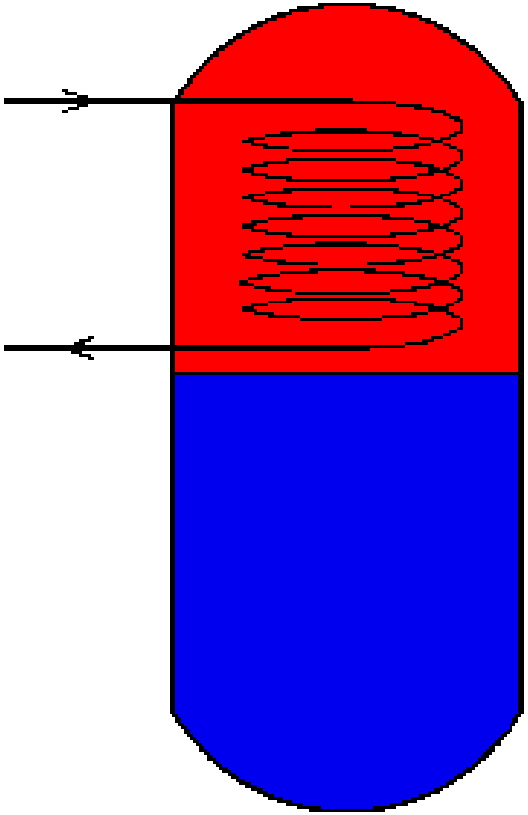
Individual solar/electric heating system for the future smart energy system

Individual solar/electric heating systems with smart heat storages, which can be heated by solar collectors and by electricity in periods with low electricity prices

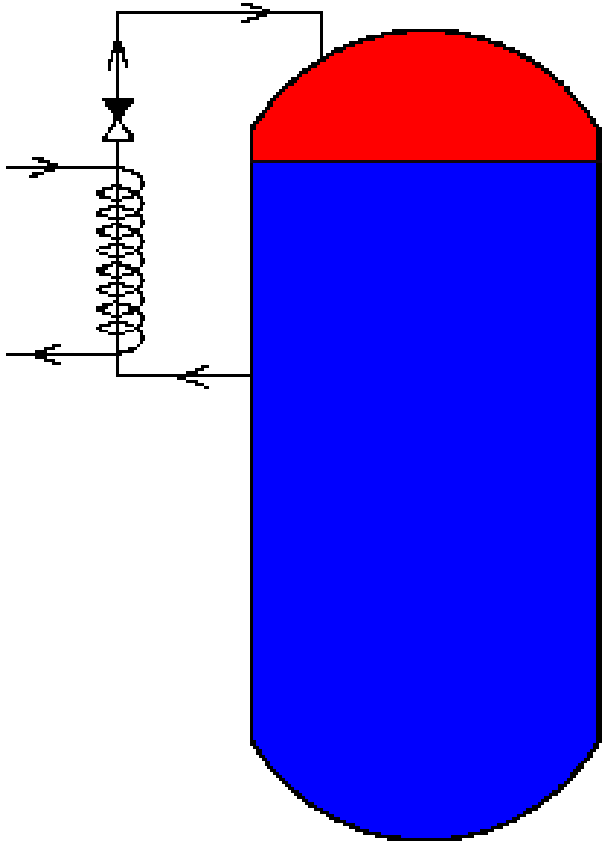
- Heat is produced by solar collectors and by electric heating elements or a heat pump
- Electric heating elements/heat pump if possible only in operation in periods where solar heat can not fully cover heat demand and where the electricity price is low
- System equipped with a smart heat storage (variable auxiliary volume) and a smart control system based on prognoses for:
  - heat demand
  - solar heat production
  - electricity price

Smart solar tanks for solar heating systems

MARKETED SOLAR TANK



SMART SOLAR TANK



TANK HEATED FROM THE TOP

INDIVIDUAL FLEXIBLE ENERGY CONTROL SYSTEM

Solar heating systems with smart solar tanks

Increased thermal performance by up to 35% due to:

☺ Decreased tank heat loss

☺ Increased solar heat production

Further, also additional improved cost efficiency due to:

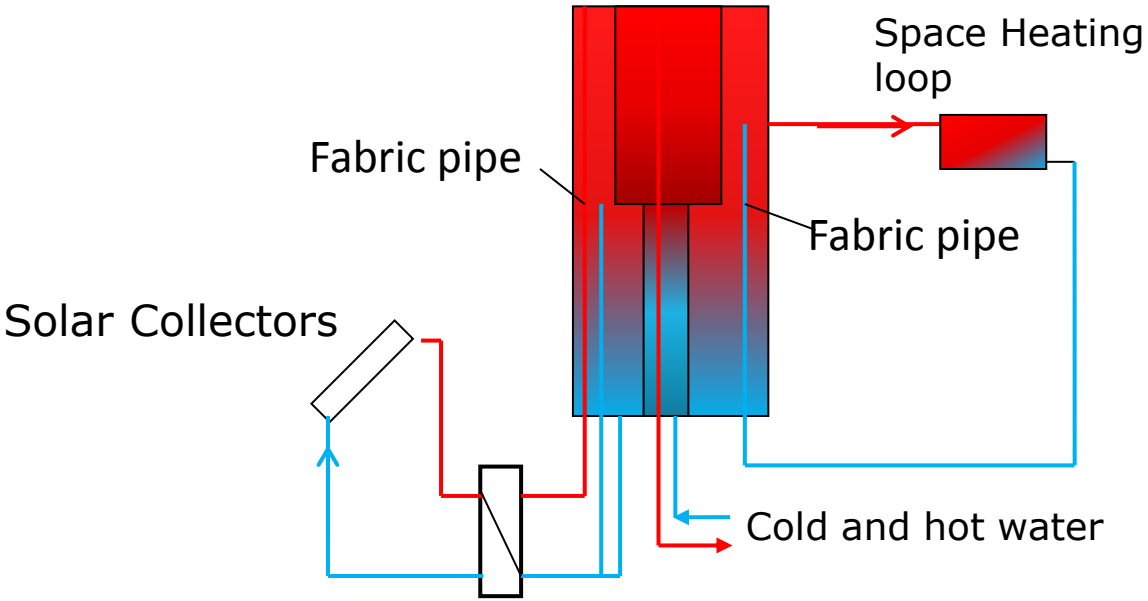
☺ Use of low price electricity

Three Solar Electric Systems tested side by side at DTU Byg

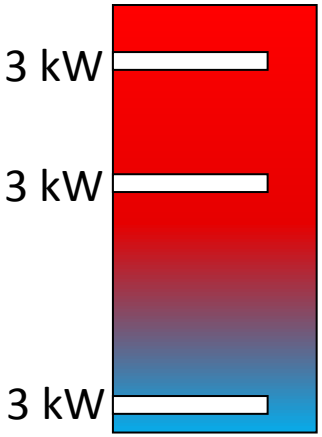
Air source Heat pump (outside)

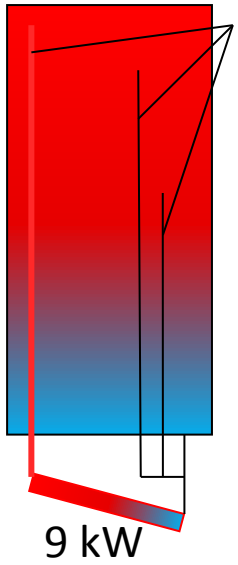
- 9 m² solar collector
- 735 l smart solar tank. Auxiliary: 1.One electric heating element 2.Three electric heating elements 3.Heat pump
- Smart control system - Heat content in tank, Weather forecast, coming Heat demand, coming Solar heat production, coming Electricity prices from NORDPOOLSPOT

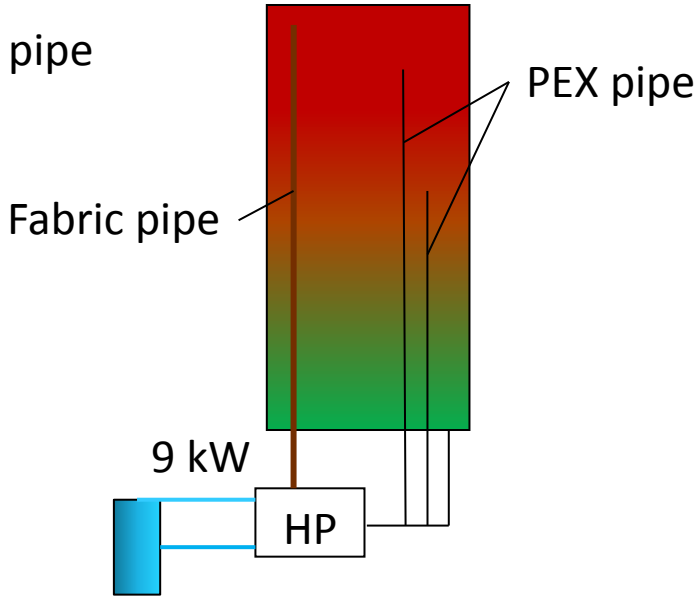
Solar collector loop & discharge loops



3 different Auxiliary heating principles

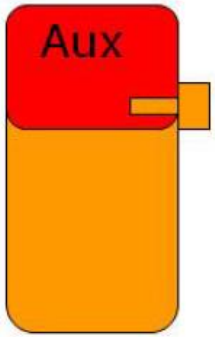




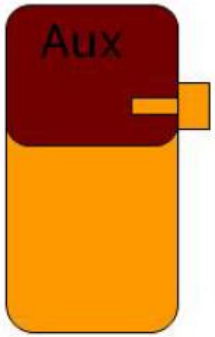


Storage charging options

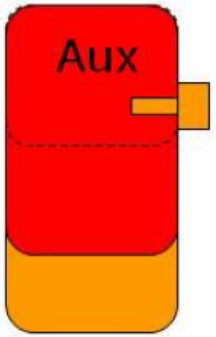
Standard
Auxiliary:
Fixed T-setpoint
Fixed volume.



Adaptive
Auxiliary temperature setpoint.

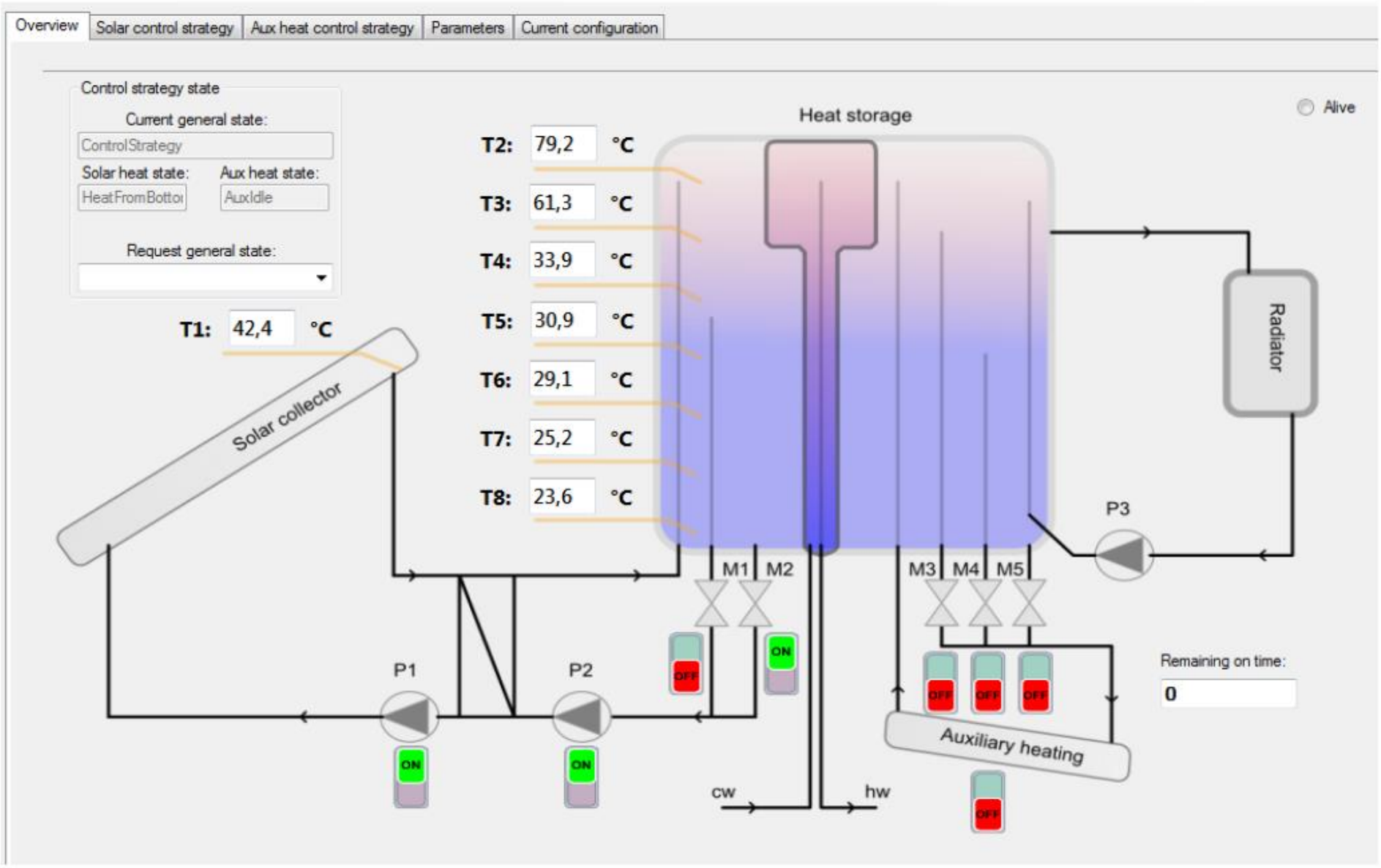


Adaptive
Auxiliary volume.
Fixed T-setpoint.

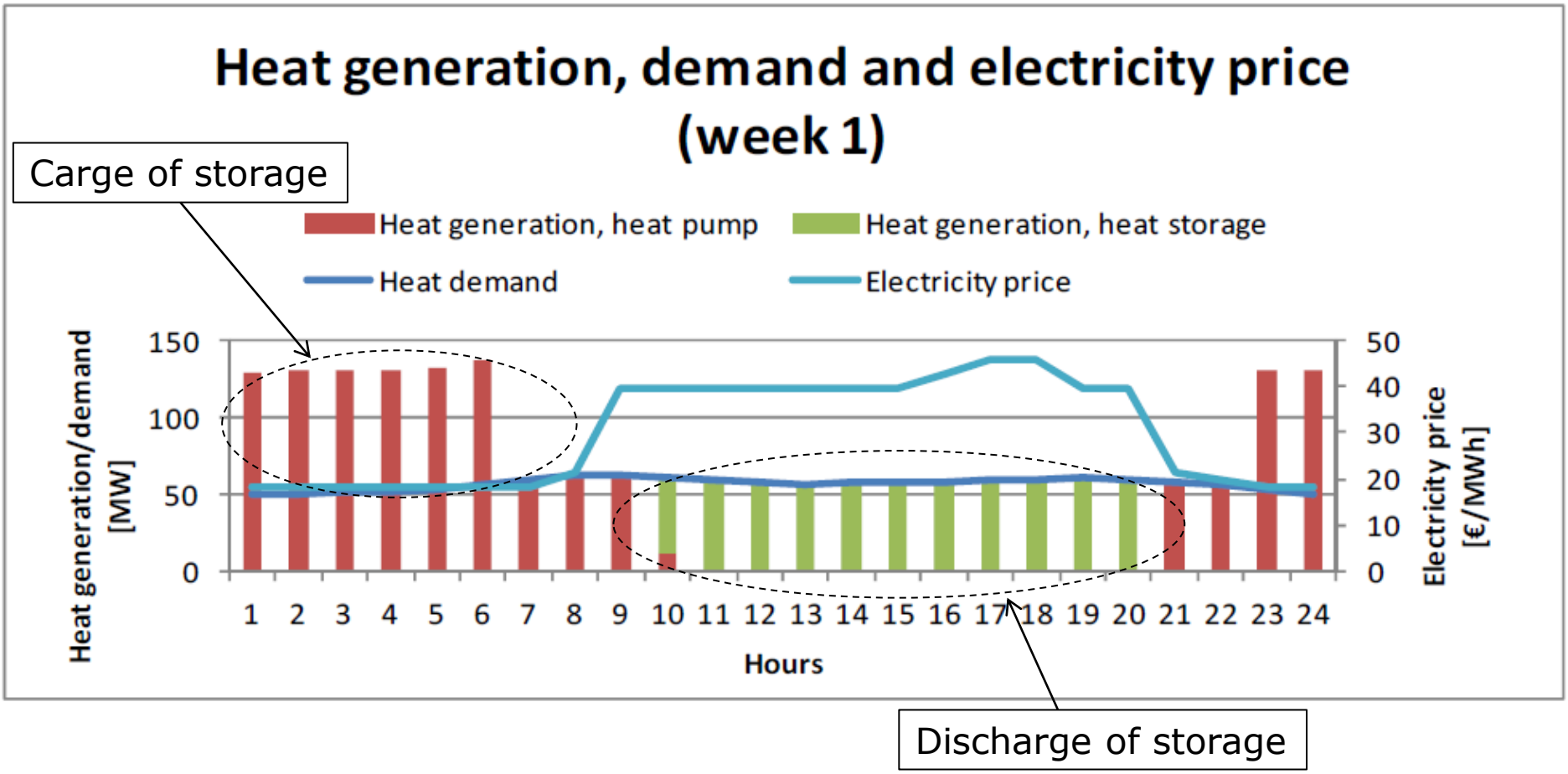


Adaptive
in both ways

Forecast based, smart control system



Smart Control example in a house with Heat Pump.

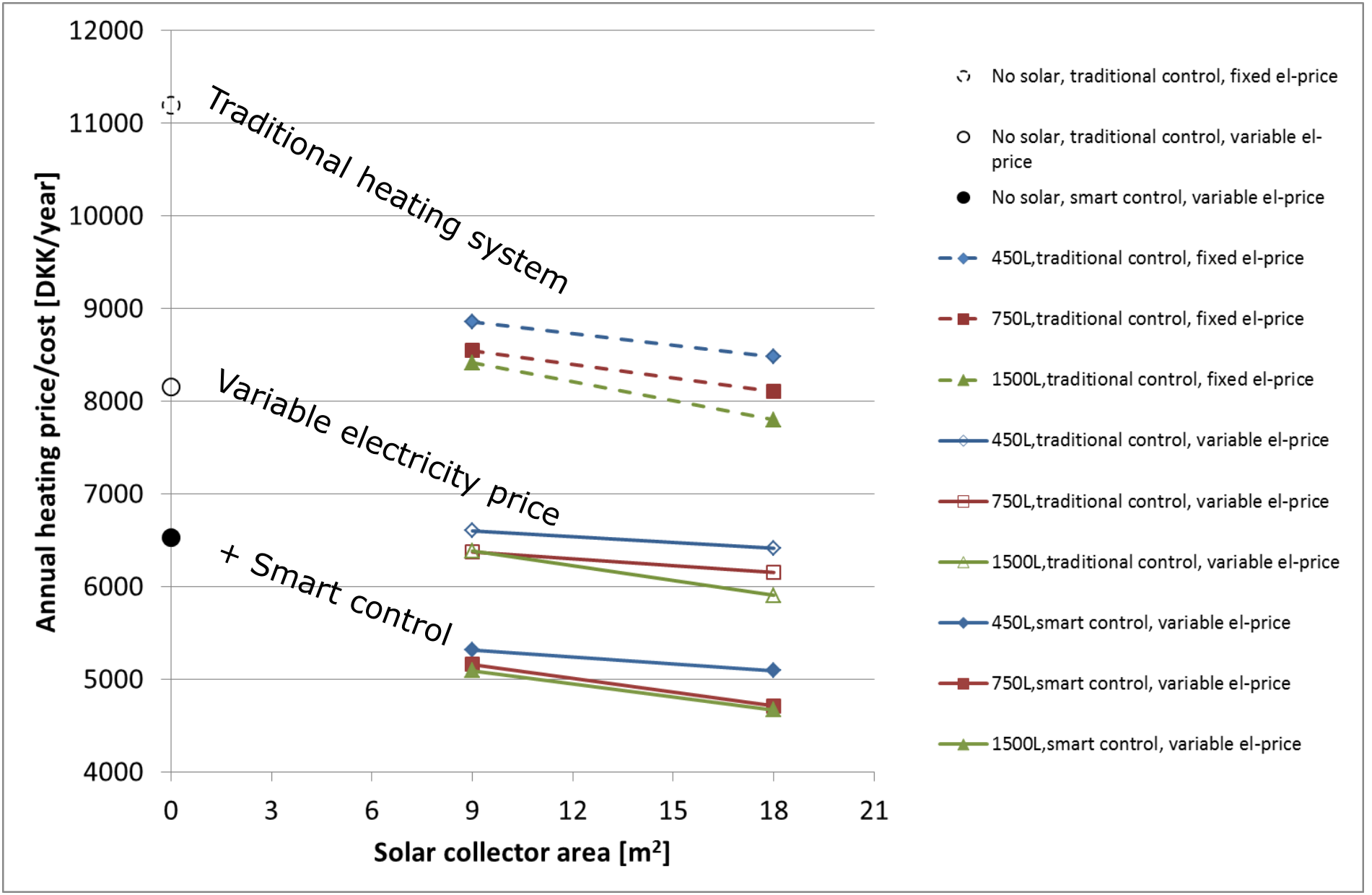


Measured results for spring 2013 at DTU

- Heat price for the two systems based on one electric heating element and three electric heating elements almost the same
- Heat price for system with heat pump = 50% of Heat price for the systems with electric heating element(s)
- (Differences in whole system investment cost, not included here)

Further **Information available in report** "Solar/electric heating systems for the future energy system", Department of Civil Engineering, Technical University of Denmark, report R-288. Can be downloaded from: http://www.byg.dtu.dk/~/media/Institutter/Byg/publikationer/byg_rapporter/byg-r288.ashx

Comparison of Simulated Operating Costs for Hot Water plus Space Heating.



Socio Economic and CO2 results. Balmorel COWI on Danish National level

	Economic benefit (reduction in socio-economic costs)		Reduction in CO2 (which is also included in the economic benefit)		
	Million EUR/year	Euro per installation/year	1,000 ton/year	Ton per installation/year	
S/E heating units (HP) replaces gas and oil boilers	64	814	200	2,5	Solar+ Heatpump
S/E heating units (EH) replaces gas and oil boilers	33	426	-155	-2,0	Solar+ "Elpatron"
S/E heating units (HP) replaces gas and oil boilers - lower heat demand	26	329	53	0,7	Solar+ Heatpump
S/E heating units (EH) replaces gas and oil boilers - lower heat demand	23	292	17	0,2	Solar+ "Elpatron"

Theoretical calculations - results

Home owner

- Heat price for normal house: 100%
- Heat price for house with 10 m² *solar combi system*: 70-80%
- Heat price for house with 10 m² smart solar heating system with *electric heating elements* and variable electricity price: 30-50%
- Heat price for house with 10 m² smart solar heating system with *heat pump* and variable electricity price: 15-25%

Society

- Socio-economic benefit of smart solar heating systems compared with a reference scenario with oil and gas boilers:
- The total benefit: 2200 - 6100 DKK per system per year

Conclusions from the Solar Electric Project

- Individual smart solar heating systems with electric heating elements/heat pump and variable electricity price, are more cost-effective than traditional solar heating systems.

- Individual smart solar heating systems with electric heating elements/heat pump can help integrating wind power in the energy system and contribute to an increased share of renewable energy

- For *houses with low heat demand* a smart solar heating system with electric heating elements is most attractive.

- For *houses with normal or high heat demand* a smart solar heating system with a heat pump is most attractive.

Recommendations

Development of individual solar heating systems for the future

General:

- Low flow systems: Serial connected solar collectors of different types, small all in one solutions for solar collector loops including hot and cold pipes, small low energy circulation pumps with variable flow rates
- Heat stores: Low heat losses from pipe connections and thermal bridges, good thermal stratification (tank design, inlet stratifiers), discharge from different levels, smart tanks with variable auxiliary volumes, new insulation materials
- Good interplay between solar collectors and auxiliary energy supply system, including heat pumps.
- Smart control systems
- Prefabricated easy to install solar tank/energy system units
- Drain back systems using water as solar collector fluid
- Compact seasonal heat storage: PCM heat storage, chemical heat stores

Specific:

- Heating systems based on solar collectors, a smart tank with electric heating element(s) and a smart controller for houses with low heat demand
- Heating systems based on solar collectors, a heat pump, a smart tank and a smart controller for houses with normal or high heat demand

Perspectives for Solar + Heat Pump
Individual small systems

- Individual smart solar/electric heating systems for buildings outside district heating systems can in the future play an important role for home owners and for the energy system.
- Individual smart solar/electric heating systems combines in an excellent way solar and wind energy
- *Traditional solar+heat pump systems* probably most interesting for *existing houses*.
- More advanced *compact solar+heat pump solutions* interesting also for *low energy houses.*
- Solar+ HP Combination with PV to produce the electricity needed, can give net zero house quite easily.
- The solar heating part has to be easy to install, reliable and not too expensive.