Towards IT Solutions to Enable and Control Future Electric Energy Systems

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Center of IT-Intelligent Energy Systems (CITIES)

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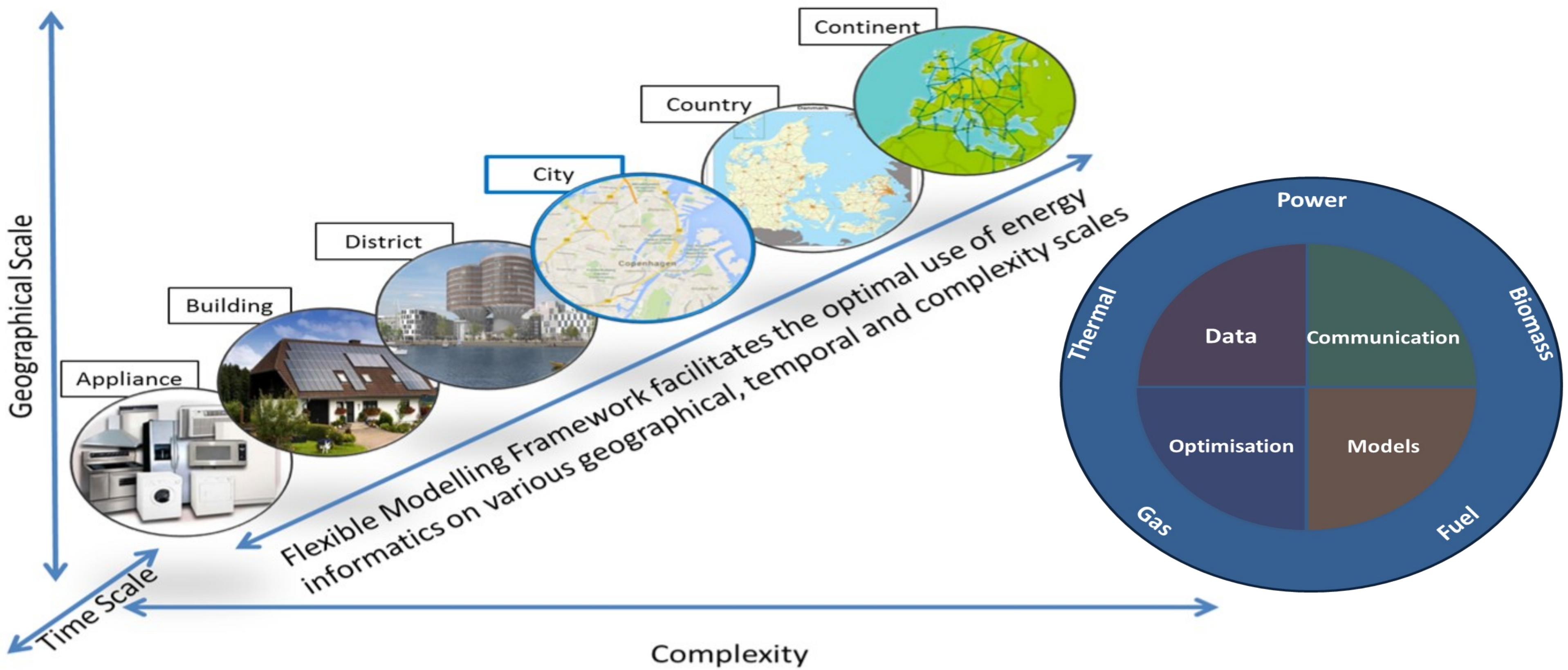
Scientific Objectives of CITIES

To establish methodologies and IT solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales for the future electric energy system



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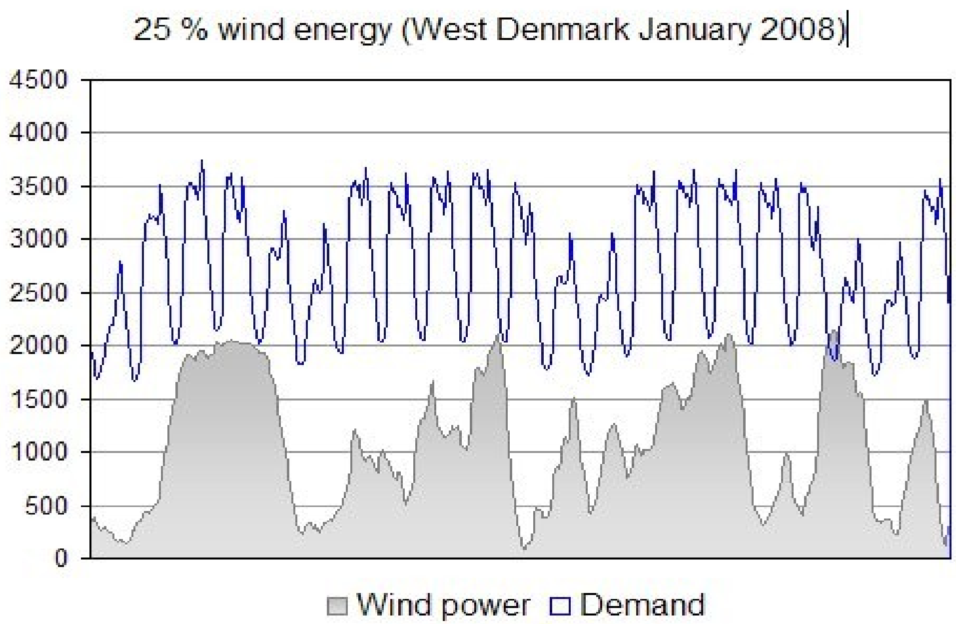
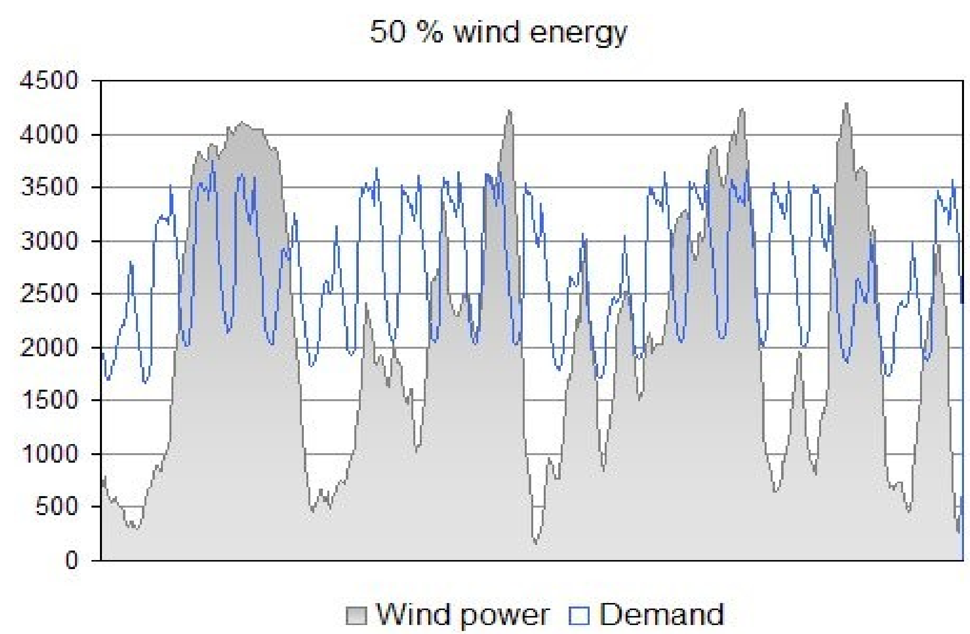
The Danish Wind Power Case

.... balancing of the power system

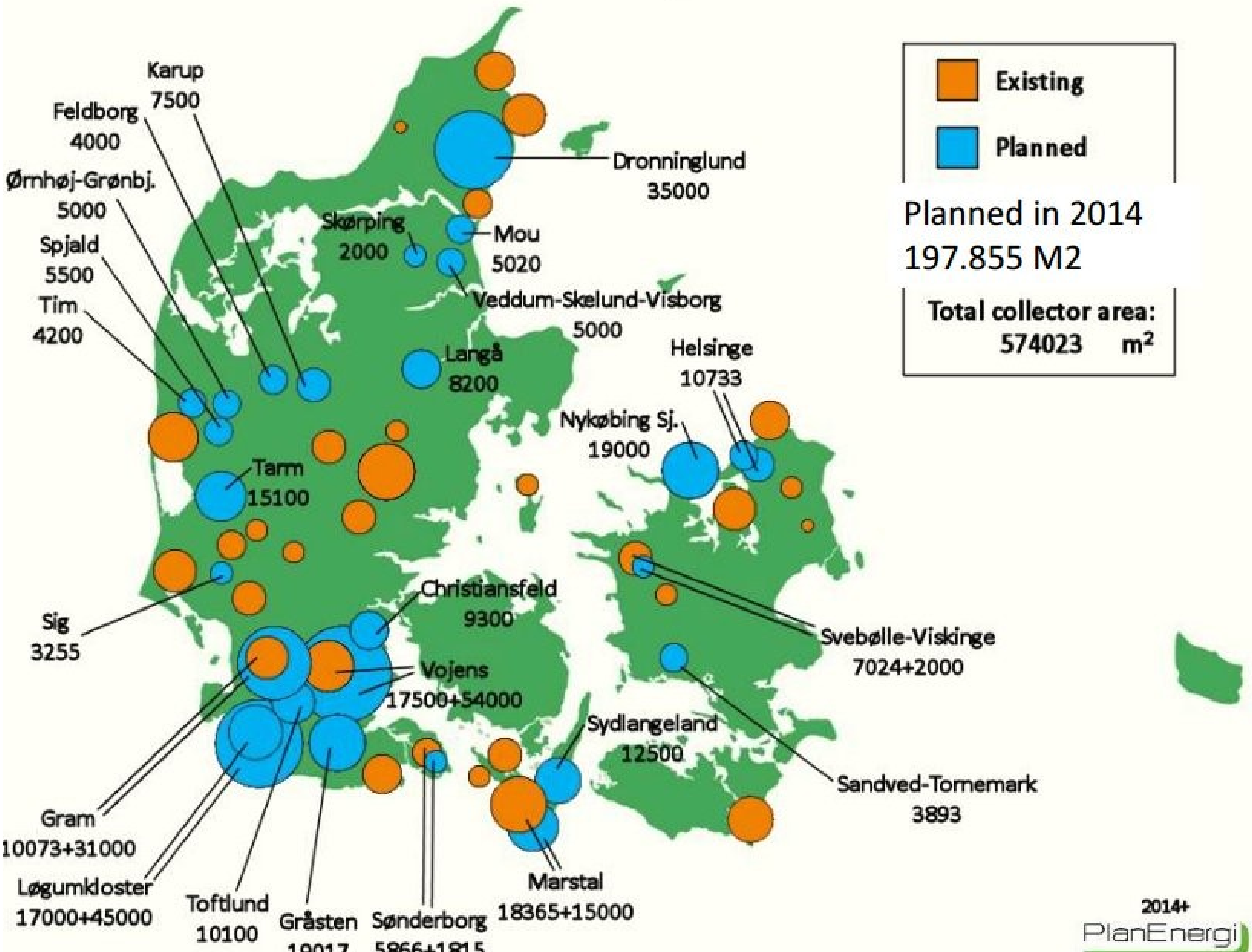


In 2008 wind power did cover the entire demand of electricity in 200 hours (West DK)

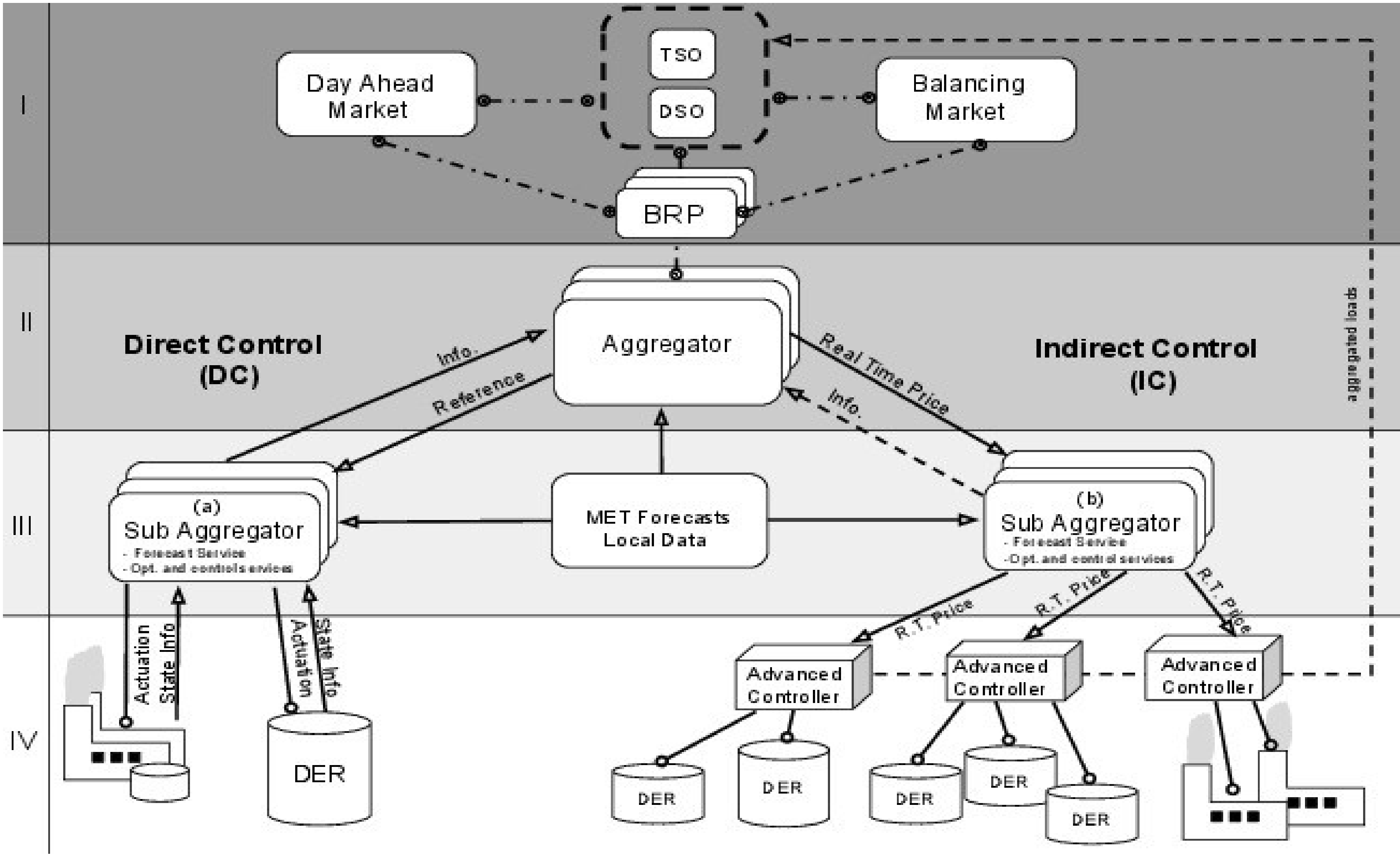


In December 2013 and January 2014 more than 55 pct of electricity load was covered by wind power. And for several days the wind power production was more than 120 pct of the power load

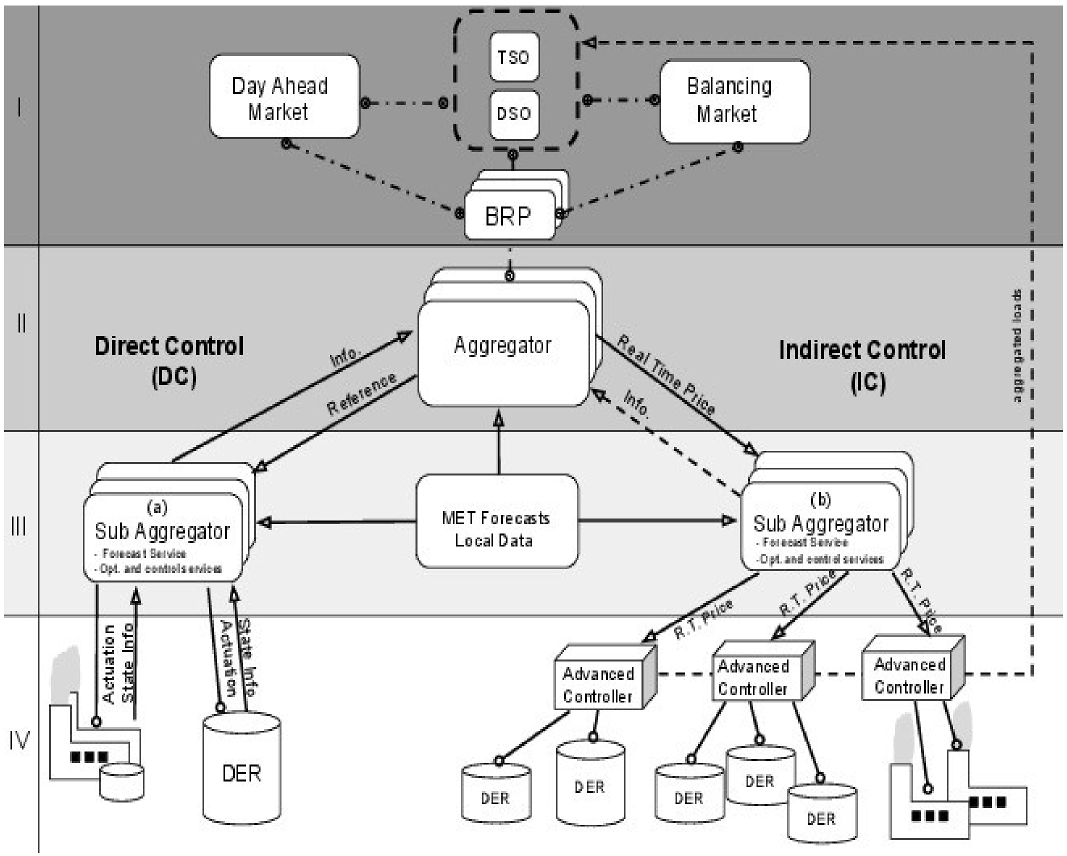
Solar district heating in Denmark



Principles for DSM and Control



Principles for DSM and Control



From a new Wiley Book: Control of Electric Loads in Future Electric Energy Systems, 2014

- ## Day Ahead:

  Stoch. Programming based on eg. Scenarios

  Cost: Related to the market (one or two levels)

- ## Direct Control:

  Actuator: **Power**

  Two-way communication

  Models for DERs are needed

  Constraints for the DERs (calls for state est.)

  Contracts are complicated

- ## Indirect Control:

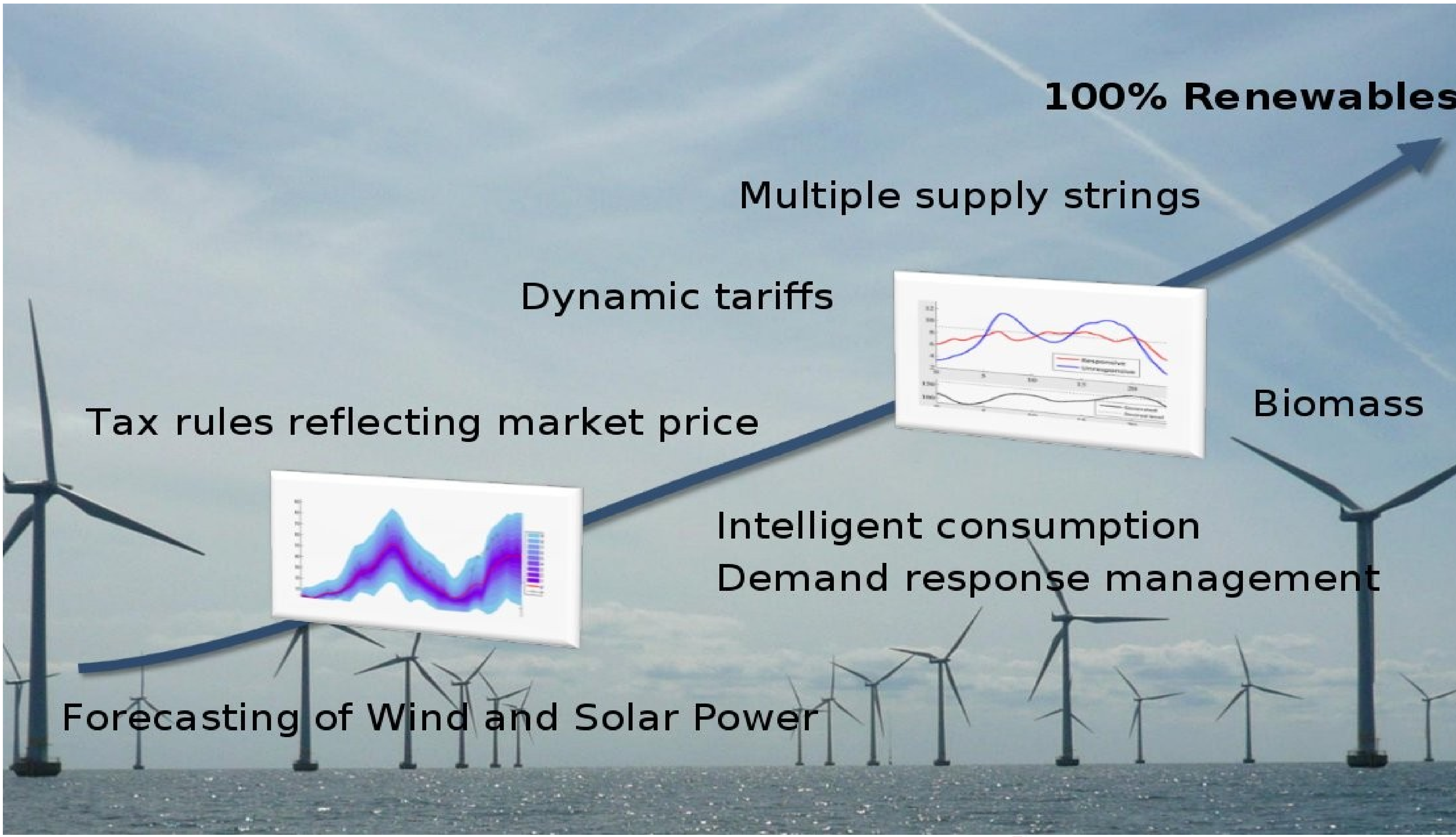
  Actuator: **Price**

  Cost: E-MPC at **low (DER) level**, One-way communication

  Models for DERs are not needed

  Simple 'contracts'

Measures to activate flexibility



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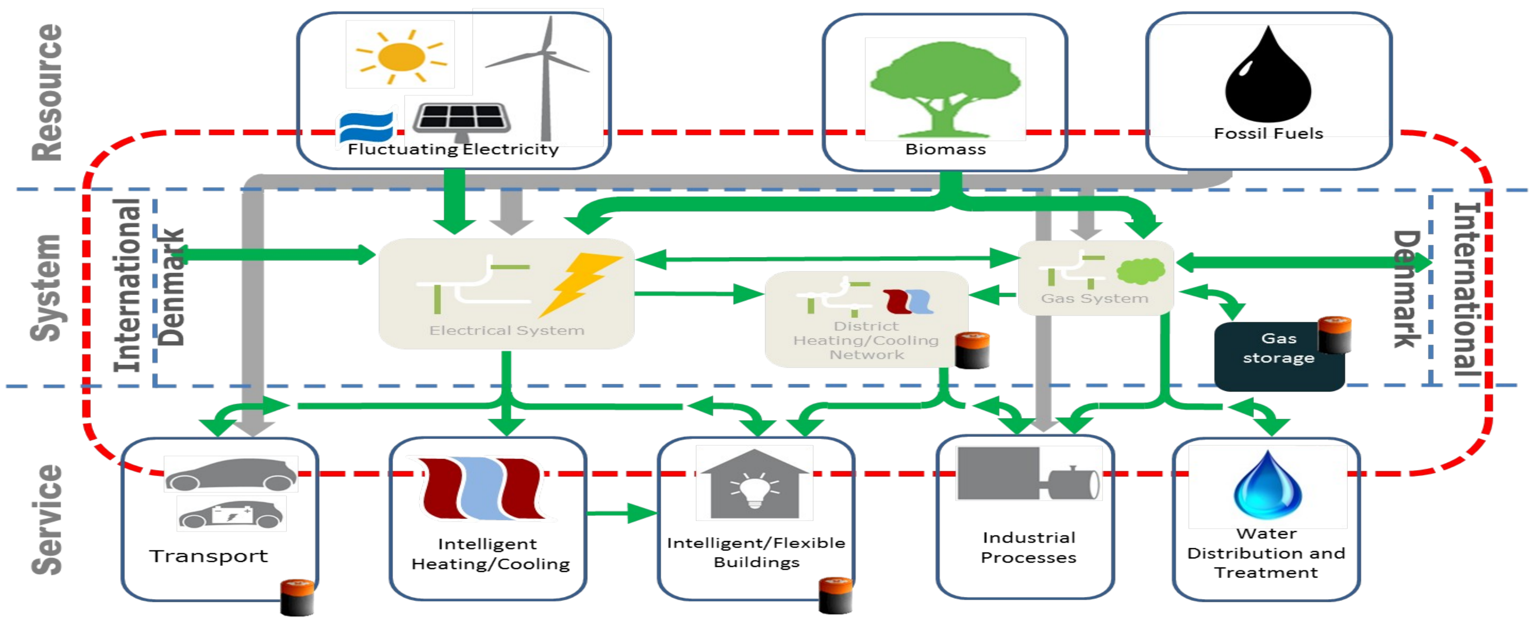
Control and Storage by Energy Systems Integration



- **Operational (grey-box) models, optimization and control**
- **(Virtual) storage principles:**
  - **Buildings provide storage up to, say, 10 hours ahead**
  - **District heating systems lead provide storage up to 2-3 days ahead**
  - **Gas systems provide seasonal storage**

Case Study

Use of
Smart Meter Data

Results

	UA W/°C	σ_{UA}	gA^{max} W	wA_E^{max} W/°C	wA_S^{max} W/°C	wA_W^{max} W/°C	T_i °C	σ_{T_i}
4218598	211.8	10.4	597.0	11.0	3.3	8.9	23.6	1.1
4381449	228.2	12.6	1012.3	29.8	42.8	39.7	19.4	1.0
4711160	155.4	6.3	518.8	14.5	4.4	9.1	22.5	0.9
4836681	155.3	8.1	591.0	39.5	28.0	21.4	23.5	1.1
4836722	236.0	17.7	1578.3	4.3	3.3	18.9	23.5	1.6
4986050	159.6	10.7	715.7	10.2	7.5	7.2	20.8	1.4
5069878	144.8	10.4	87.6	3.7	1.6	17.3	21.8	1.5
5069913	207.8	9.0	962.5	3.7	8.6	10.6	22.6	0.9
5107720	189.4	15.4	657.7	41.4	29.4	16.5	21.0	1.6
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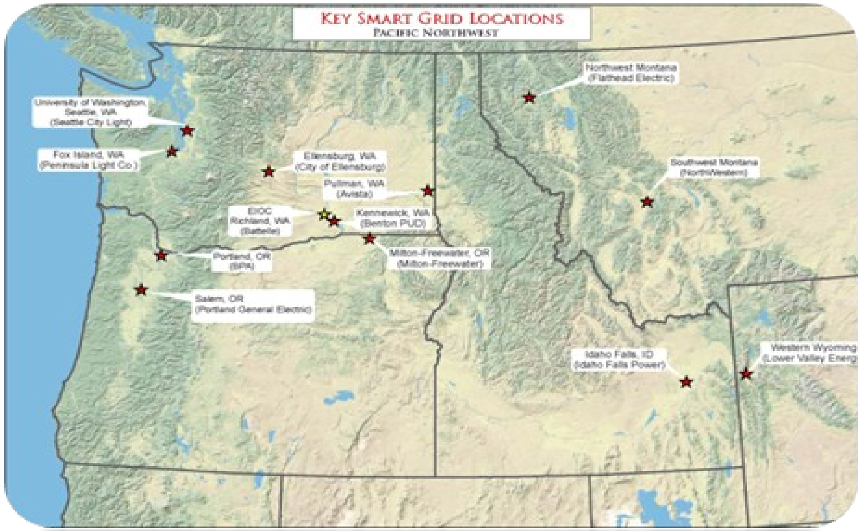
Perspectives for using data from Smart Meters

- Reliable Energy Signature.
- Energy Labelling
- Time Constants (eg for night set-back)
- Proposals for Energy Savings:
  - Replace the windows?
  - Put more insulation on the roof?
  - Is the house too untight?
  - ......
- Optimized Control
- Integration of Solar and Wind Power using DSM

Case study

Control of Power Consumption (DSM)

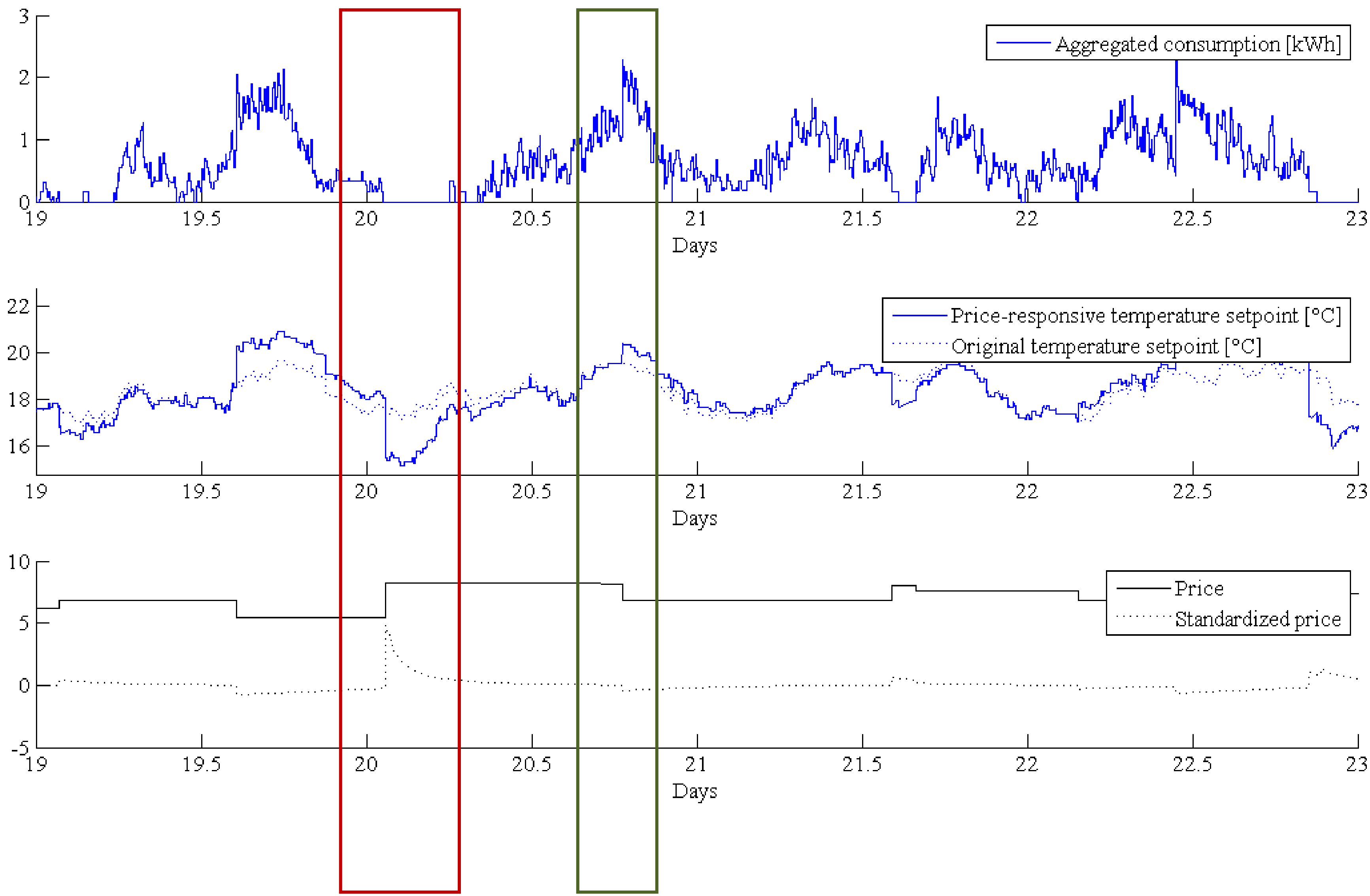
Data from BPA



Olympic Pensinsula project

- 27 houses during one year
- Flexible appliances: HVAC, cloth dryers and water boilers
- 5-min prices, 15-min consumption
- Objective: limit max consumption

Aggregation (over 20 houses)



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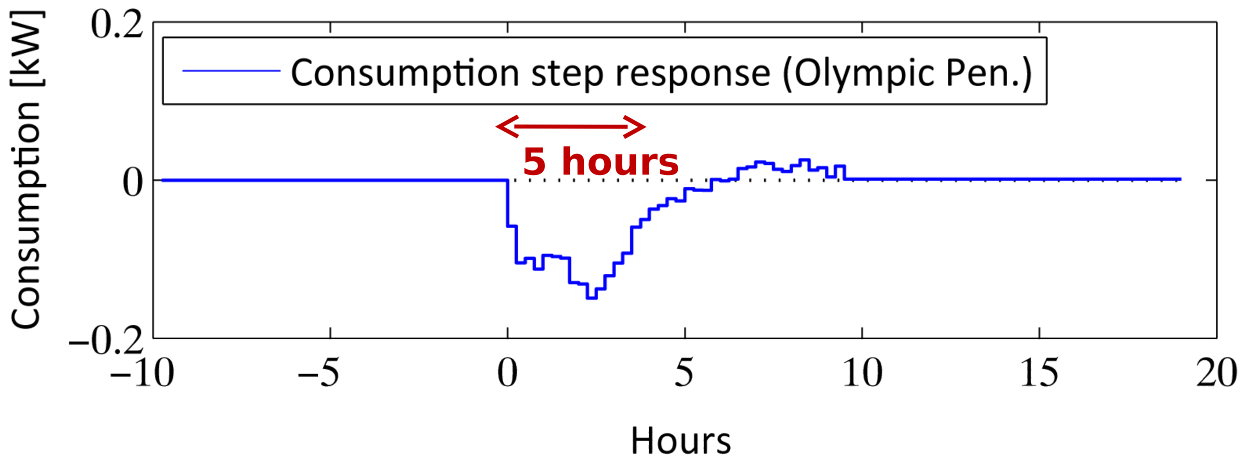
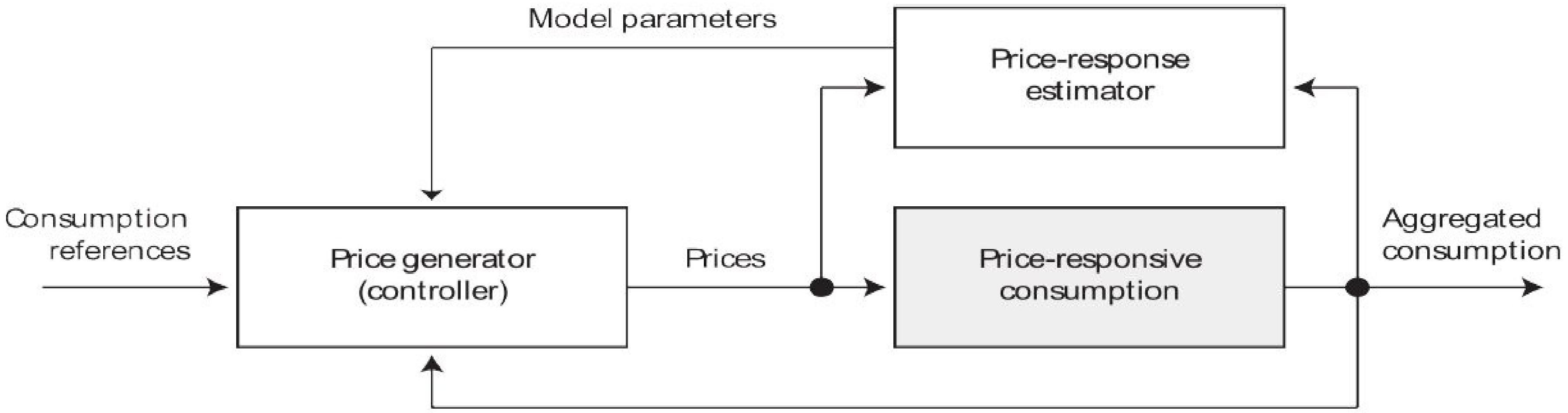
Non-parametric Response on Price Step Change

Model inputs: price, minute of day, outside temperature/dewpoint, sun irrandiance

Olympic Peninsula



Control of Energy Consumption



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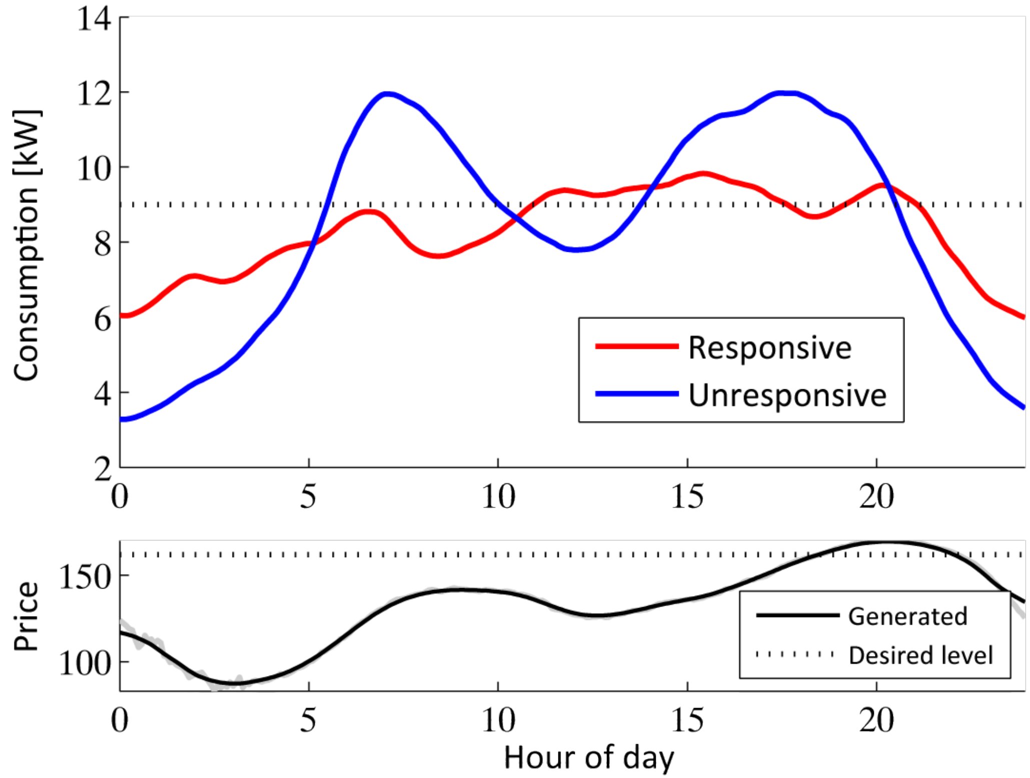
Control performance

- Considerable **reduction in peak consumption**
- Mean daily consumption shift

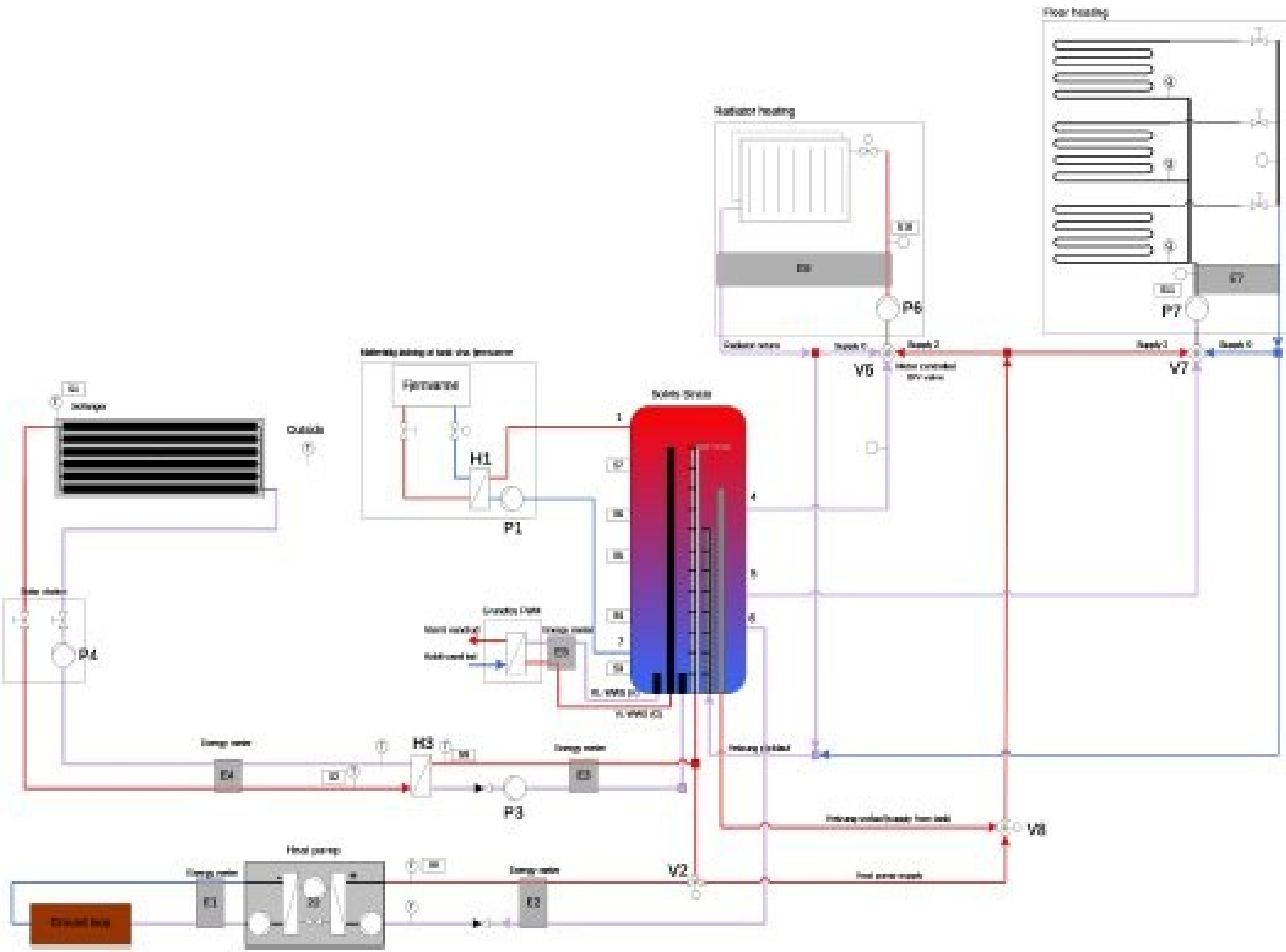


Case study

Control of Heat Pumps

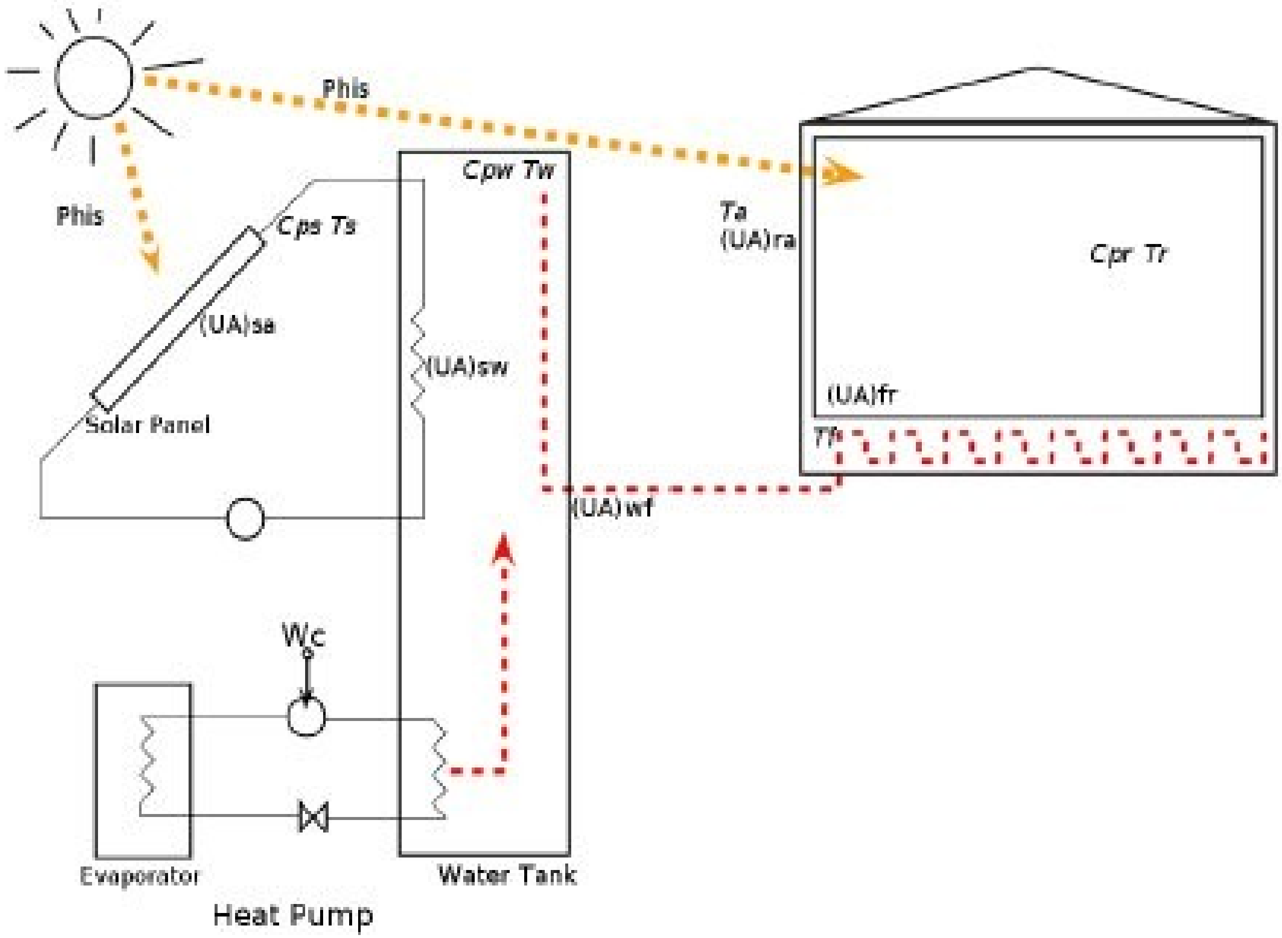
Grundfos Case Study

Schematic of the heating system

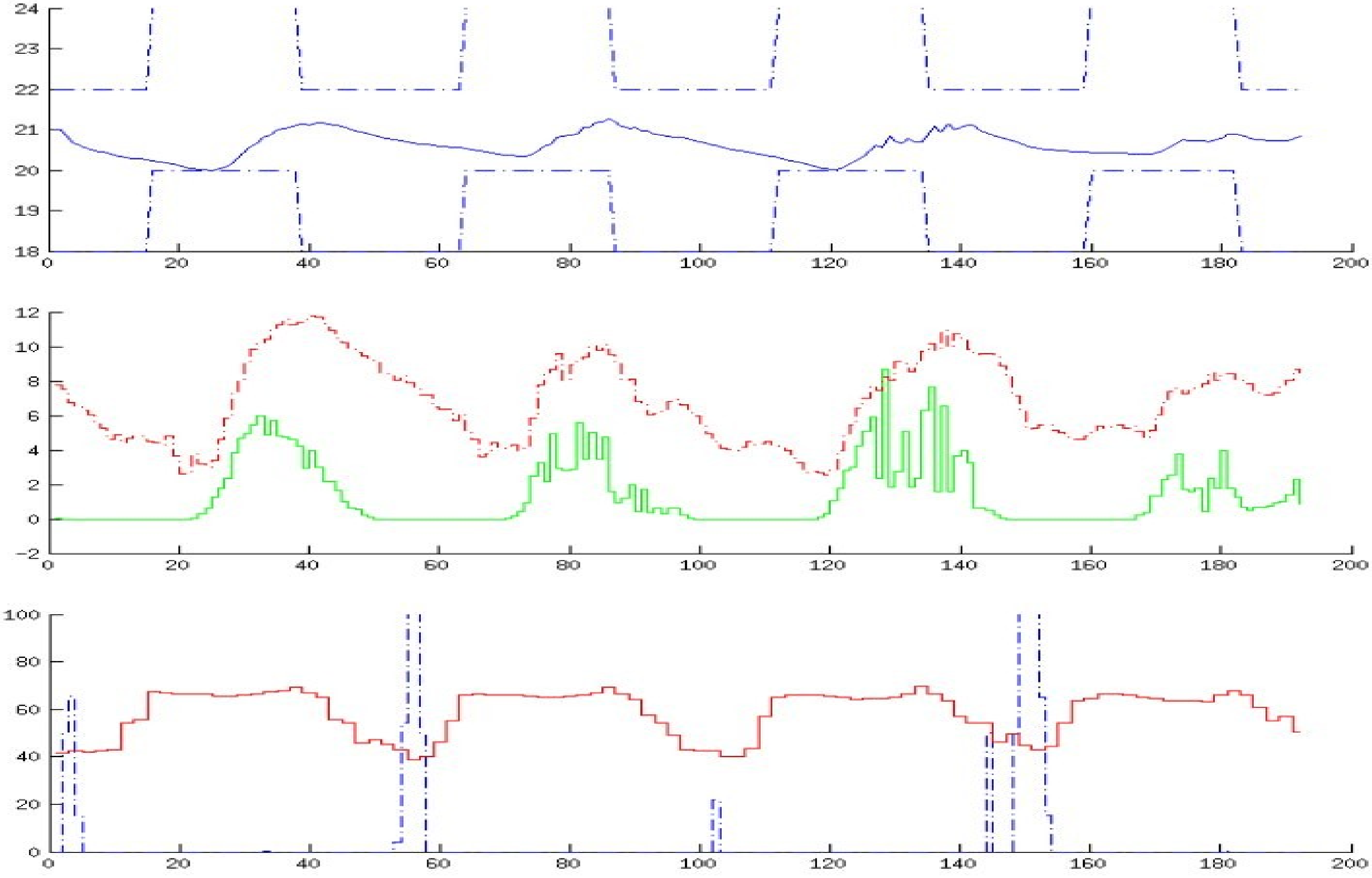


Modeling Heat Pump and Solar Collector

Simplified System



EMPC for heat pump with solar collector – savings: 35 pct



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Our IT solutions for Smart Energy Systems

- Temperature control in houses (Samsung, ENFOR)
- HVAC systems (Grundfos, Samsung, ...)
- Supermarket cooling (Danfoss, ...)
- Electricity consumption in family houses (Saseco, ...)
- District heating/cooling networks (EMD International)
- Combined Heat and Power plants (Dong Energy, Cowi, ENFOR)
- Intellingent use of biomass (HOFOR, Dong Energy)
- Wastewater treatment plants (Kruger, Veolia)
- ....

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For more information ...

- See for instance

  www.henrikmadsen.org

  www.smart-cities-centre.org

- ...or contact
  - Henrik Madsen (DTU Compute)

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