Intelligent Energy Systems in Buildings

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Green Tech Center, Vejle - June 2018

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Quote by B. Obama at the Climate Summit
in New York in 2014:

We are the ***first generation*** *affected by climate changes,*

and we are the ***last generation*** *able to do something about it!*

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Potentials and Challenges for renewable energy

- **Scenario**: We want to cover the worlds entire need for power using wind power.
- How large an area should be covered by wind turbines?

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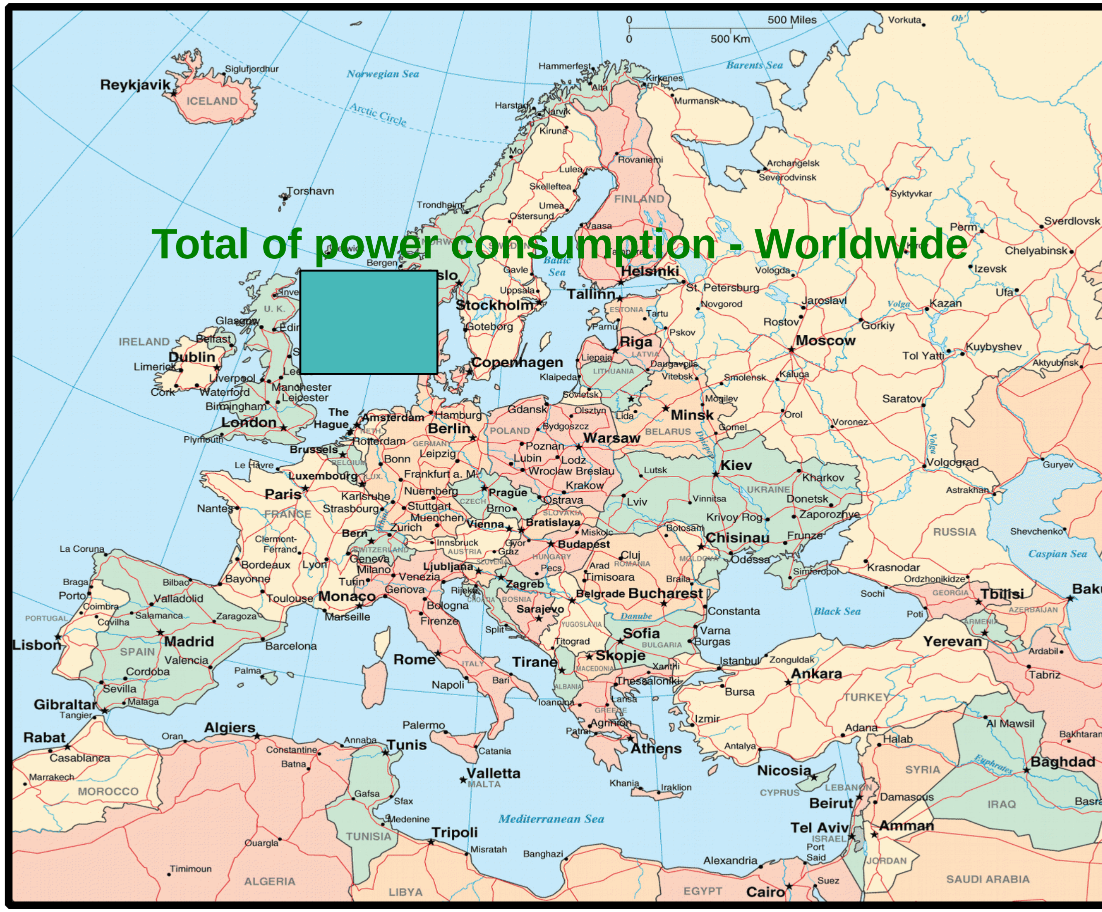
Potentials and Challenges for renewable energy

- **Scenario:** We want to cover the worlds entire need for power using wind power
- How large an area should be covered by wind turbines?
- **Conclusion**: Use intelligence ....
- Calls for **IT / Big Data / Smart Energy/Cities Solutions/** **Data Intelligent and Integrated Energy Systems**



Case Study No. 1

Thermal Performance Characterization of Buildings using (Smart) Meter Data

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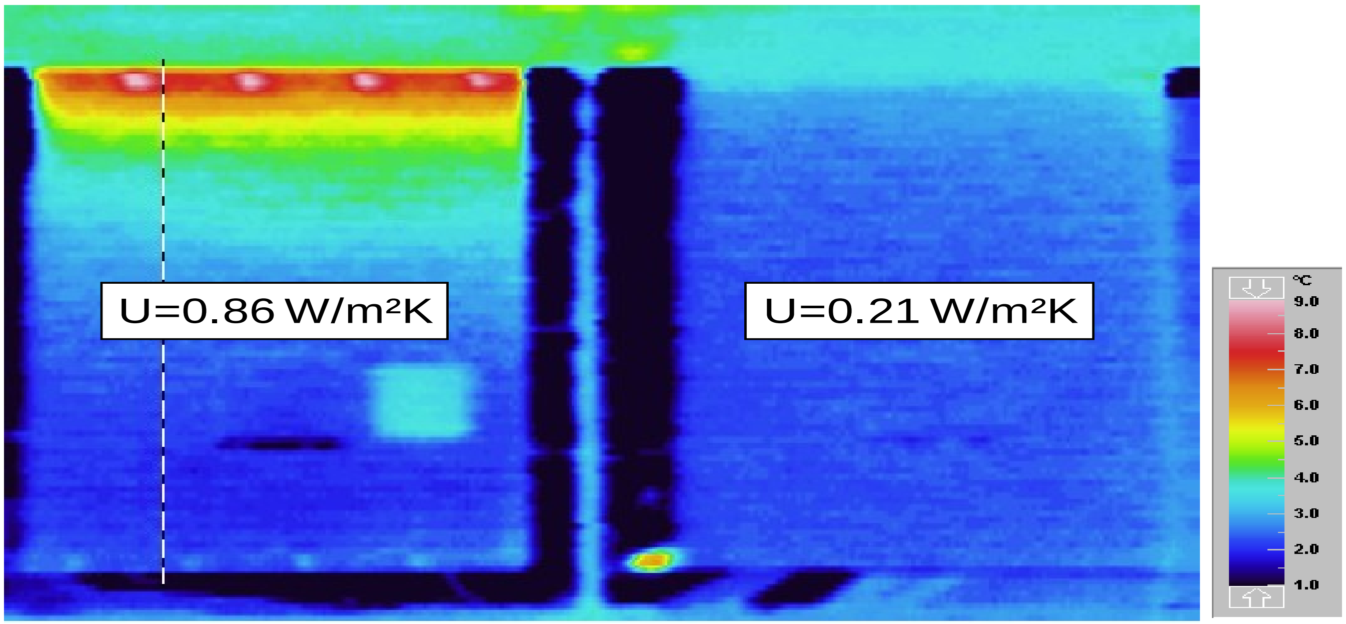
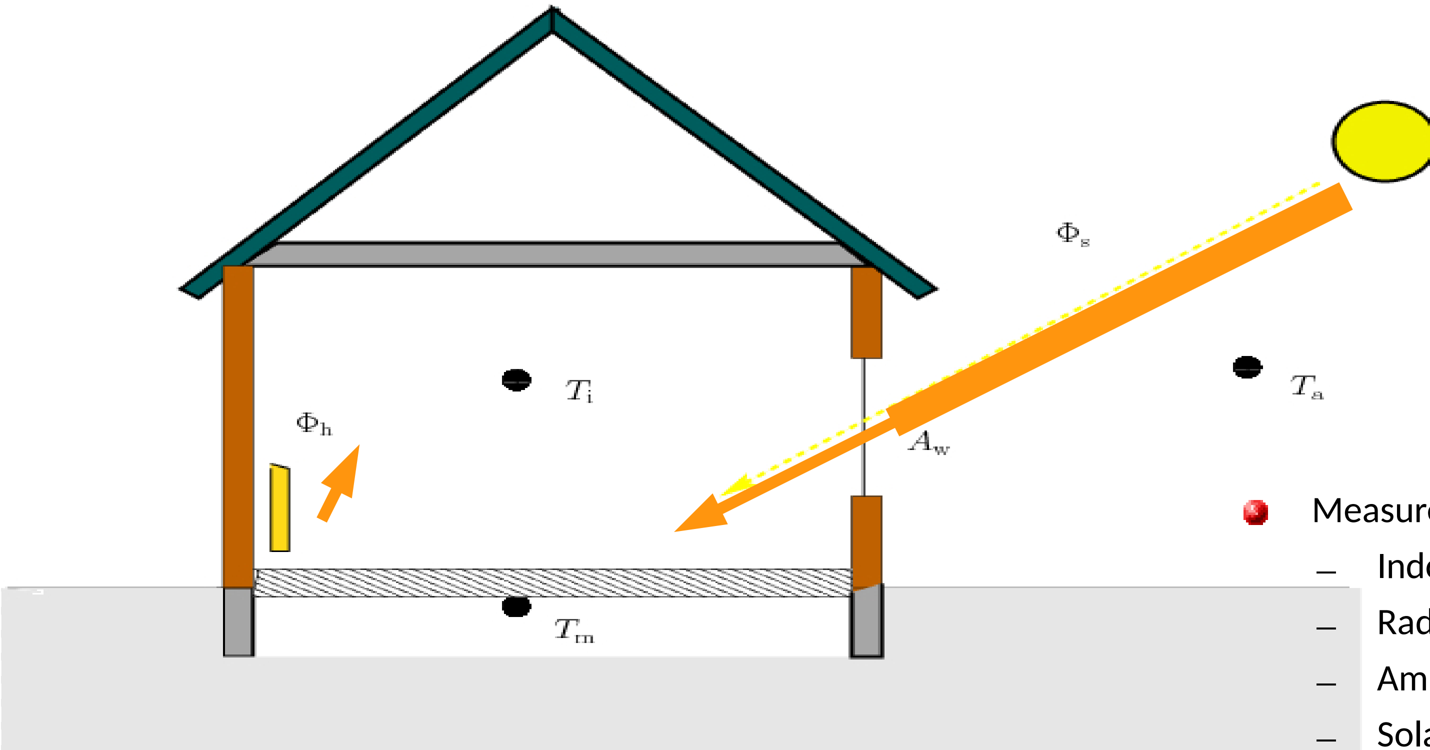
Example

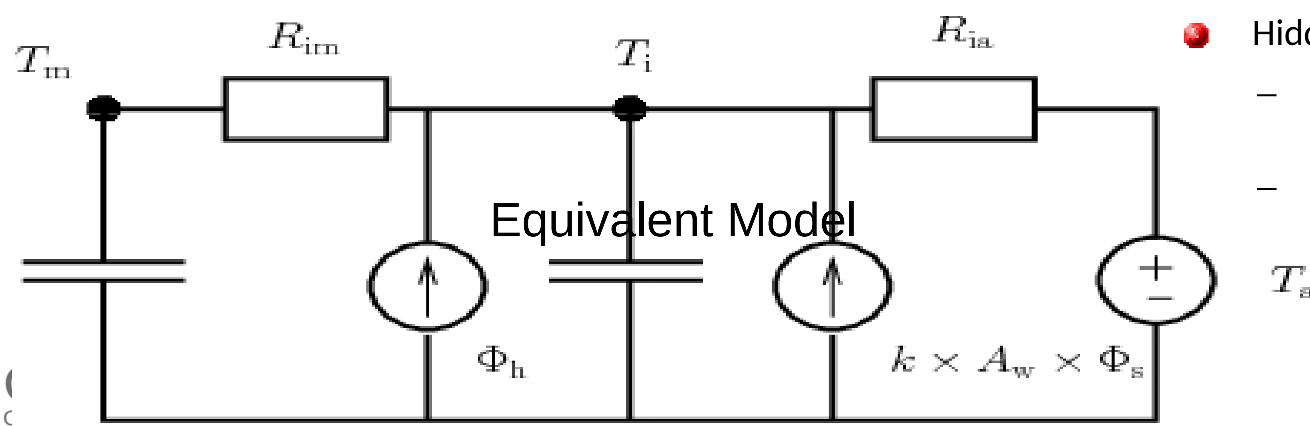


Consequence of good or bad workmanship (theoretical value is U=0.16W/m2K)

Model for the heat dynamics



- Measurements:
  - Indoor air temp
  - Radiator heat sup.
  - Ambient air temp
  - Solar radiations
- Hidden states are:
  - Heat accumulated in the building
  - *k*: Fraction of solar radiation entering the interior



Equivalent Model

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
.	.	.	.	.	.	.	.	.

Perspectives

- Identification of most problematic buildings
- Automatic energy labelling
- Recommendations:
  - Should they replace the windows?
  - Or put more insulation on the roof?
  - Or tigthen the building?
  - Should the wall against north be further insulated?
  - ......
- Better control of the heat supply (.. see later on ..)

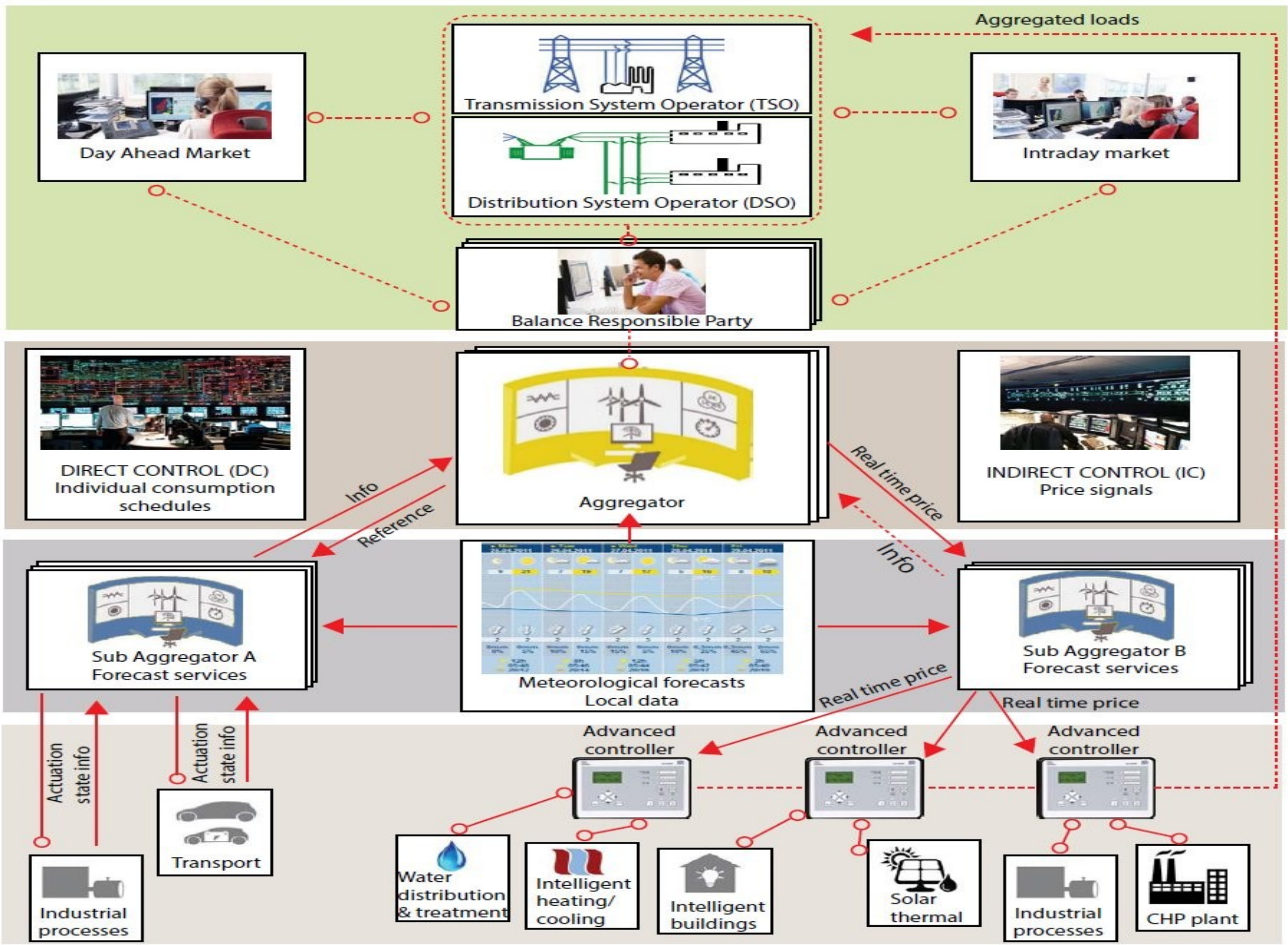
Perspectives (2)

"Skat, jeg kan se på k-værdierne, at vinduerne skal pudses"

Case study No. 2

Control of Power Consumption using the Thermal Mass of Buildings (Peak shaving)

Smart-Energy OS



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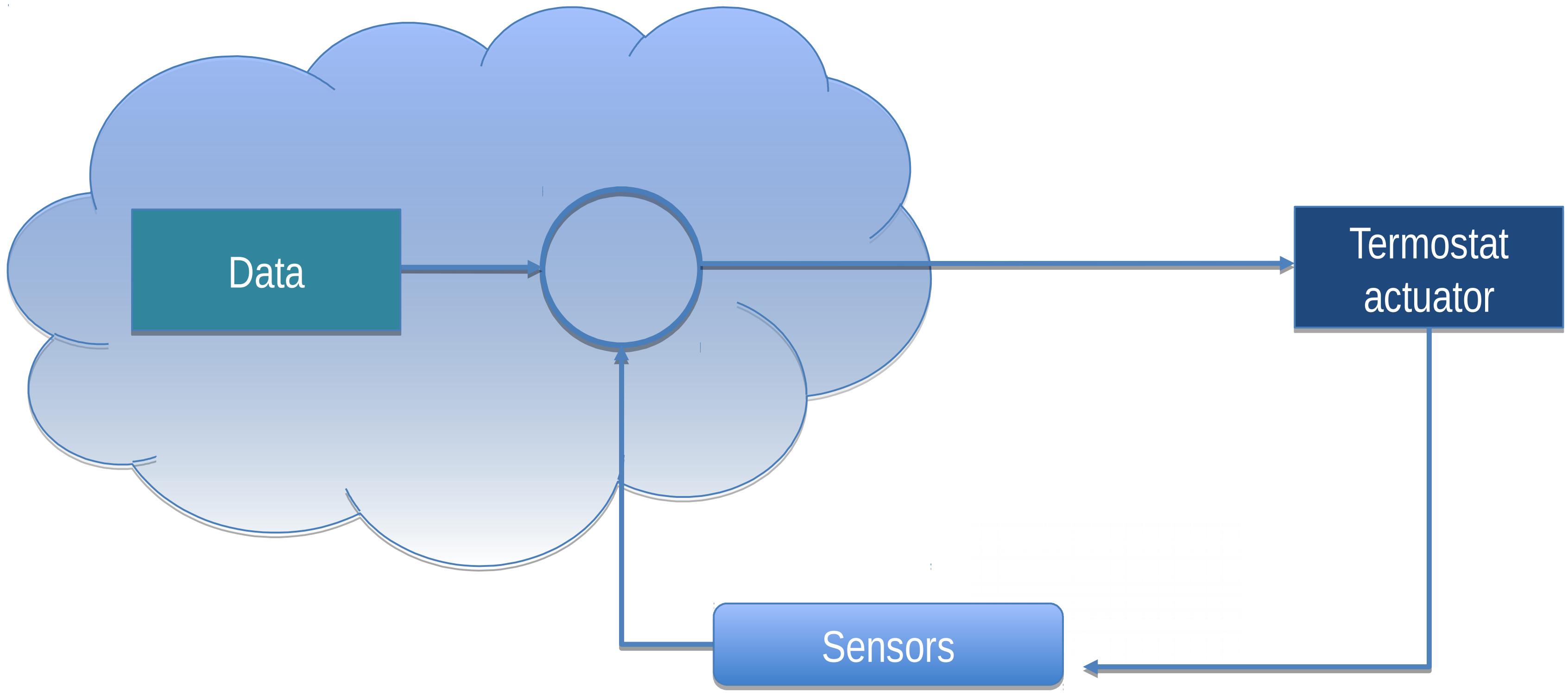
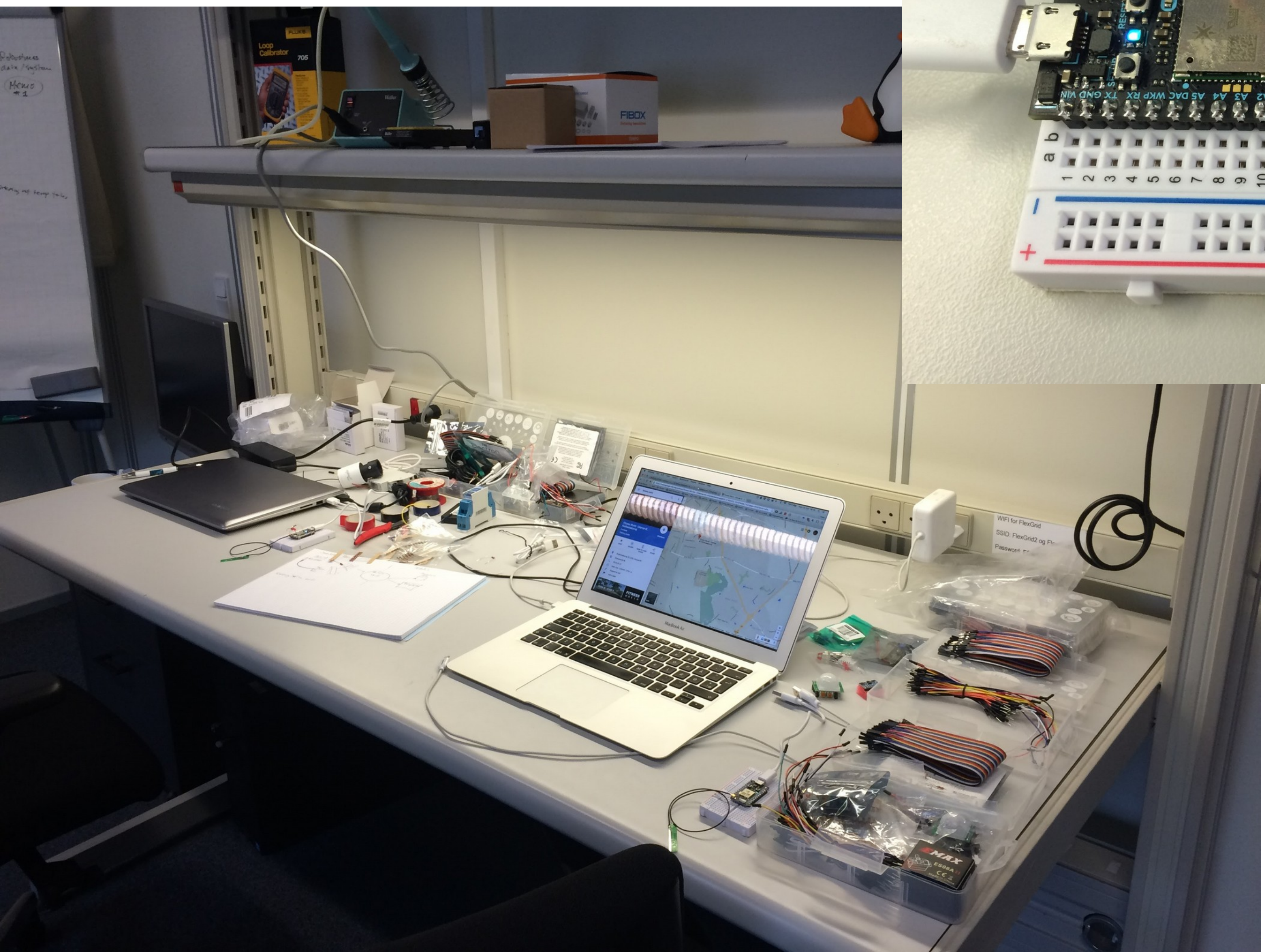
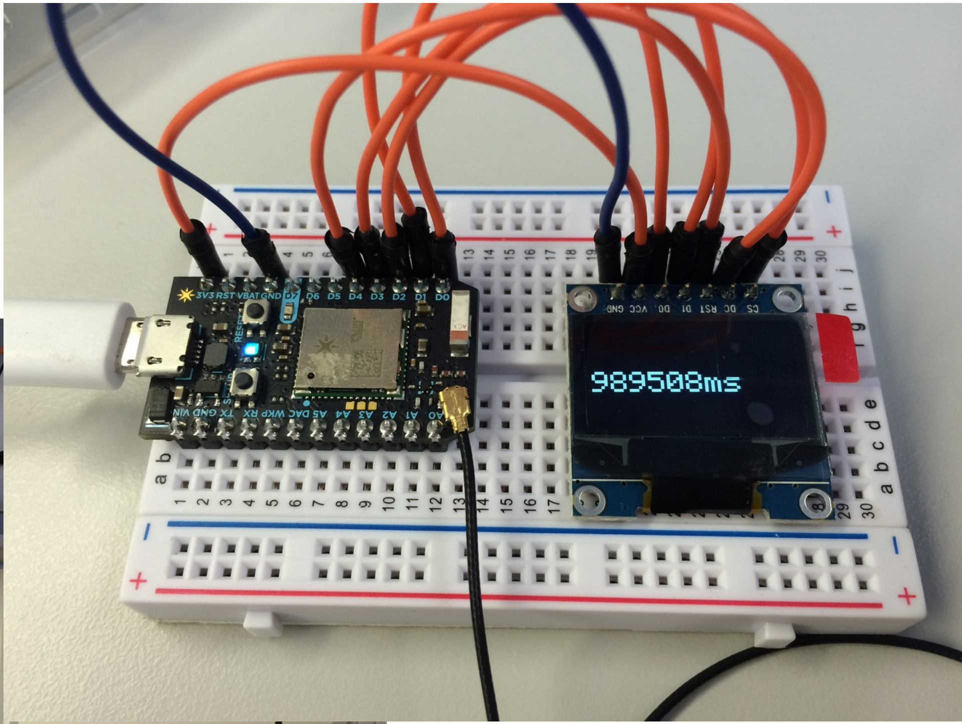
SE-OS
Control loop design – **logical drawing**

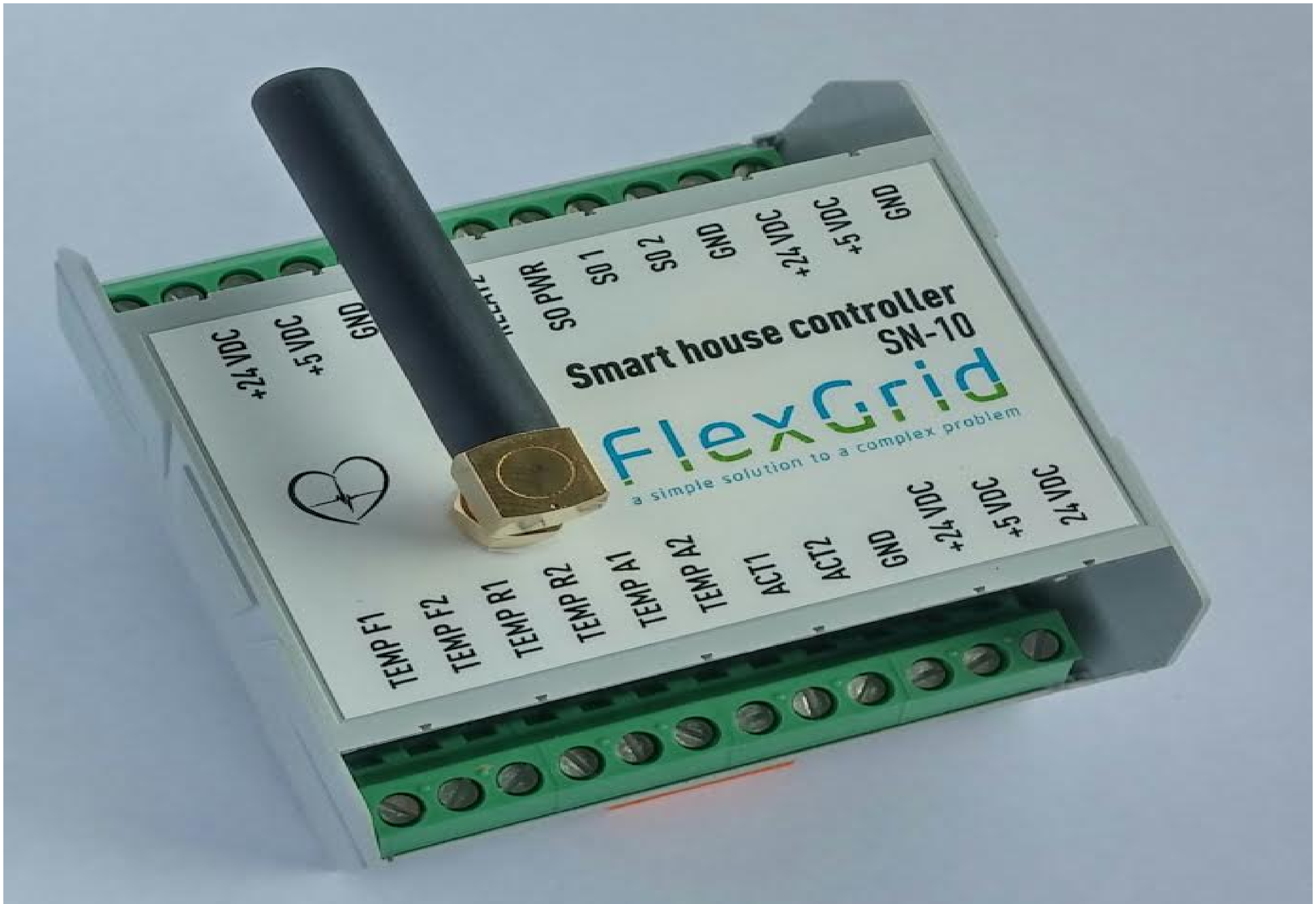


Lab testing ....

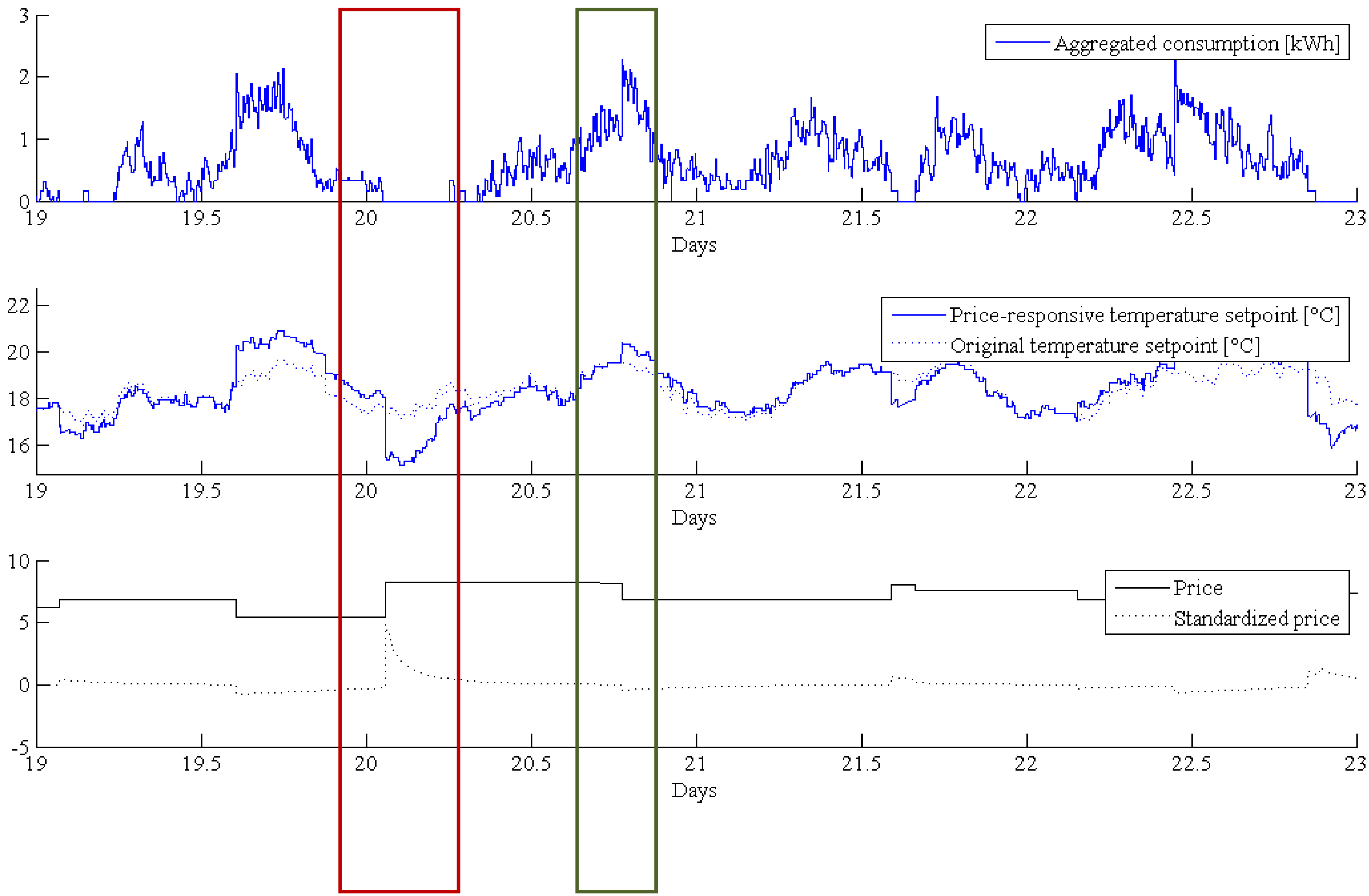




SN-10 Smart House Gateway

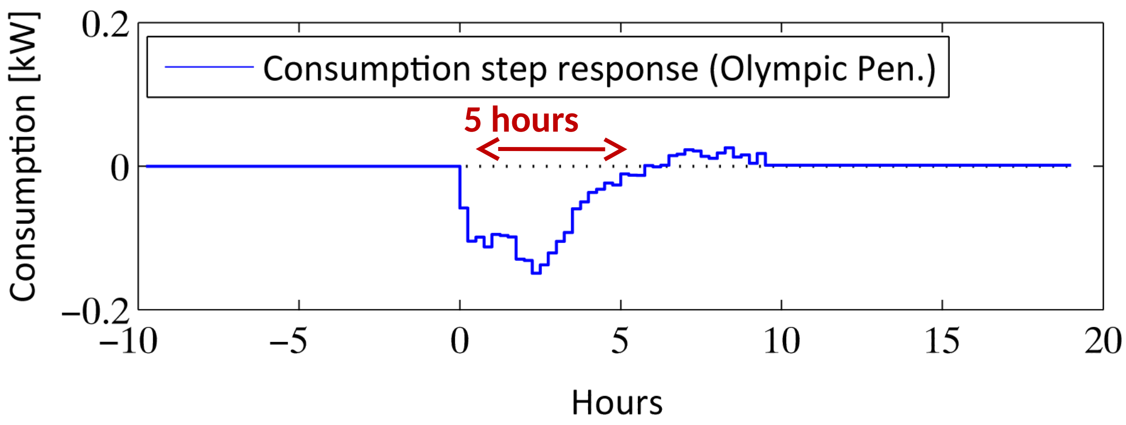


Aggregation (over 20 houses)

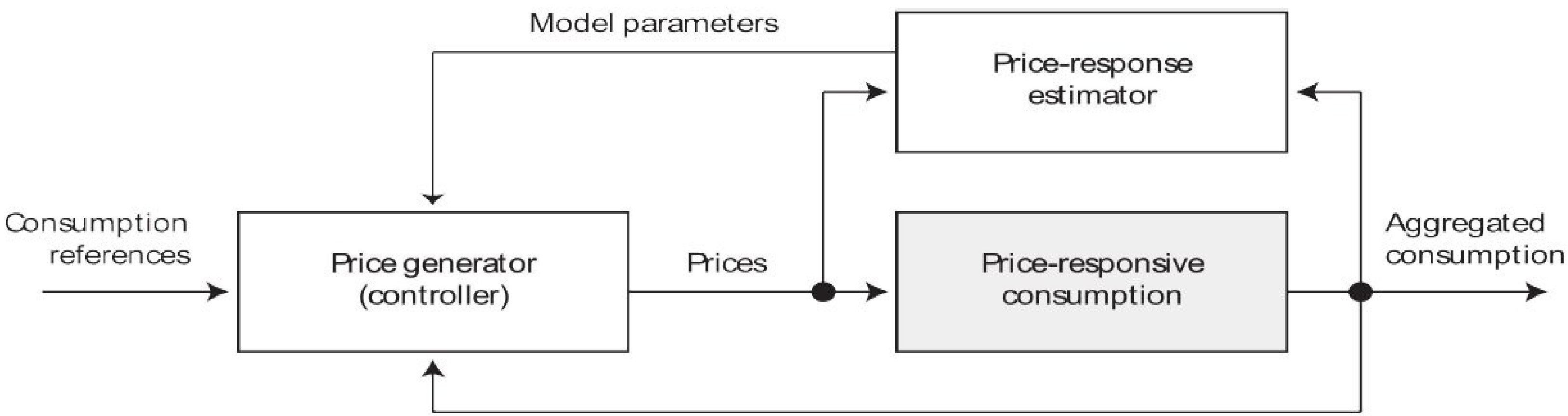


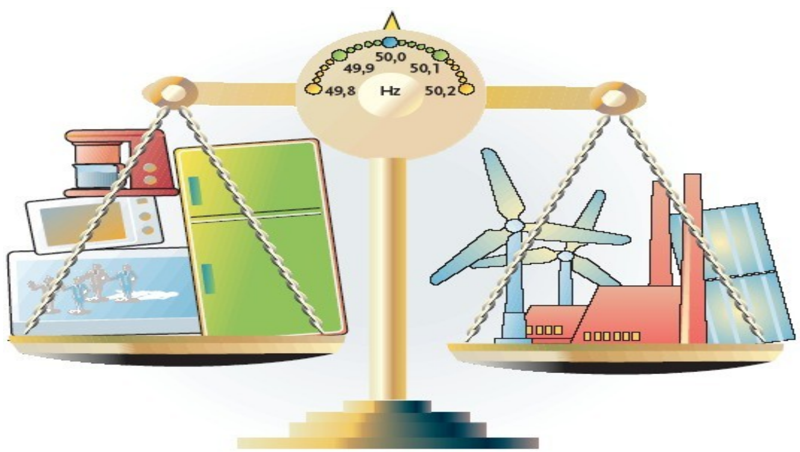
Response on Price Step Change

Olympic Peninsula



Control of Energy Consumption

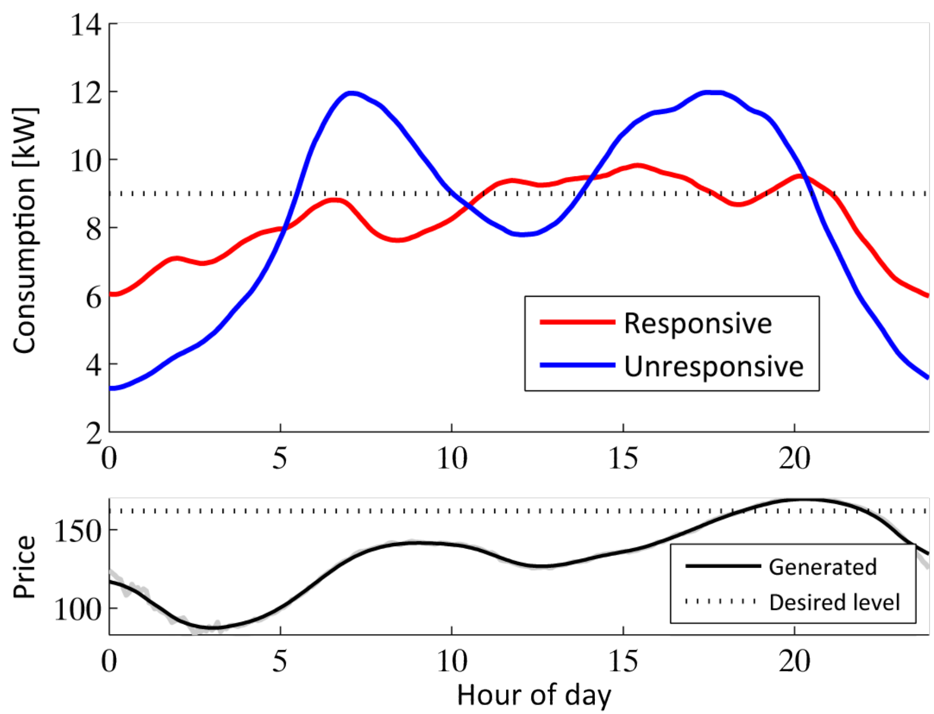




Control performance

Considerable **reduction in peak consumption**

Mean daily consumption shift



Case study No. 3

Control of Heat Pumps
Summer Houses with a Swimming Pool
(CO2 minimization)

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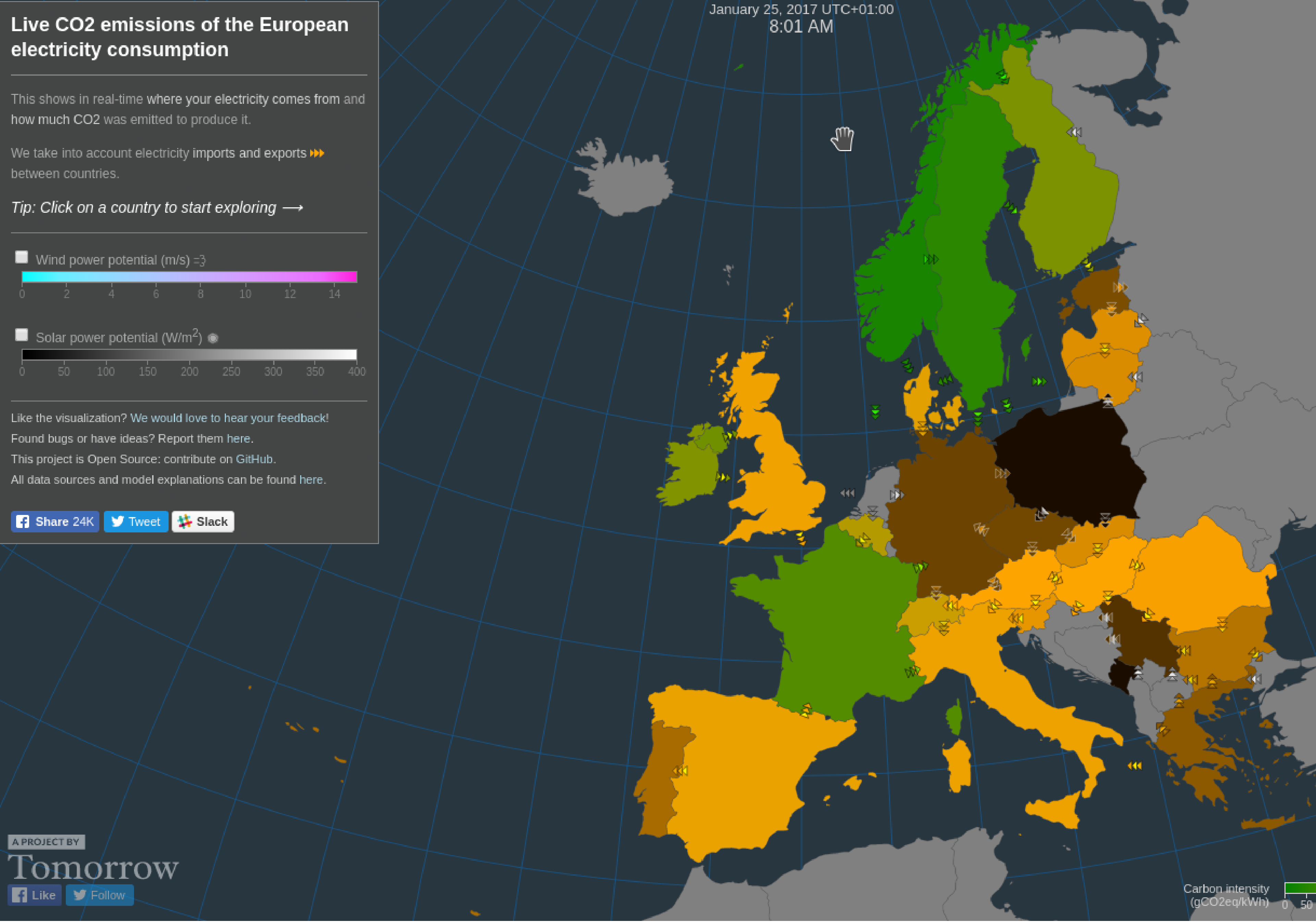

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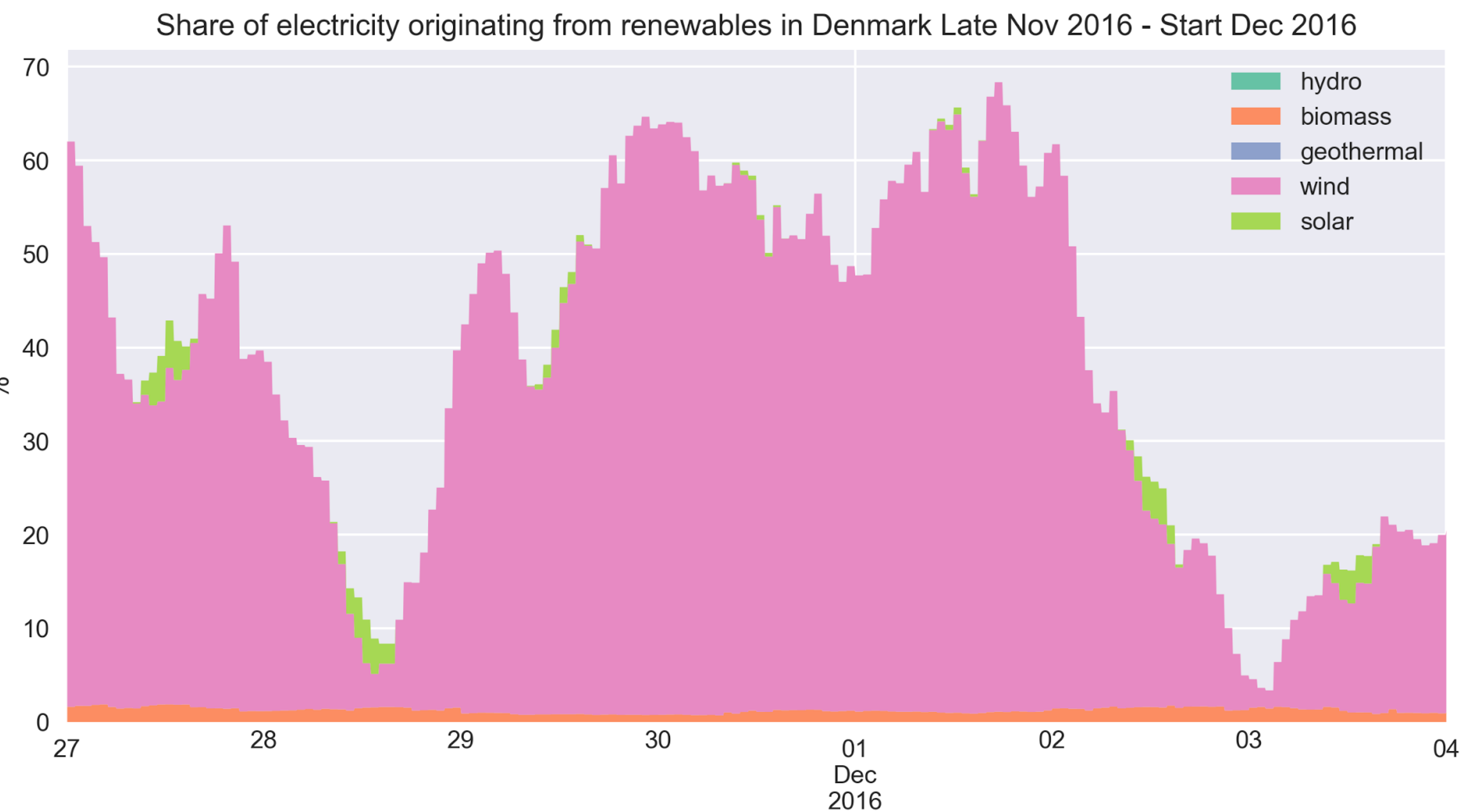

Source: pro.electicitymap.

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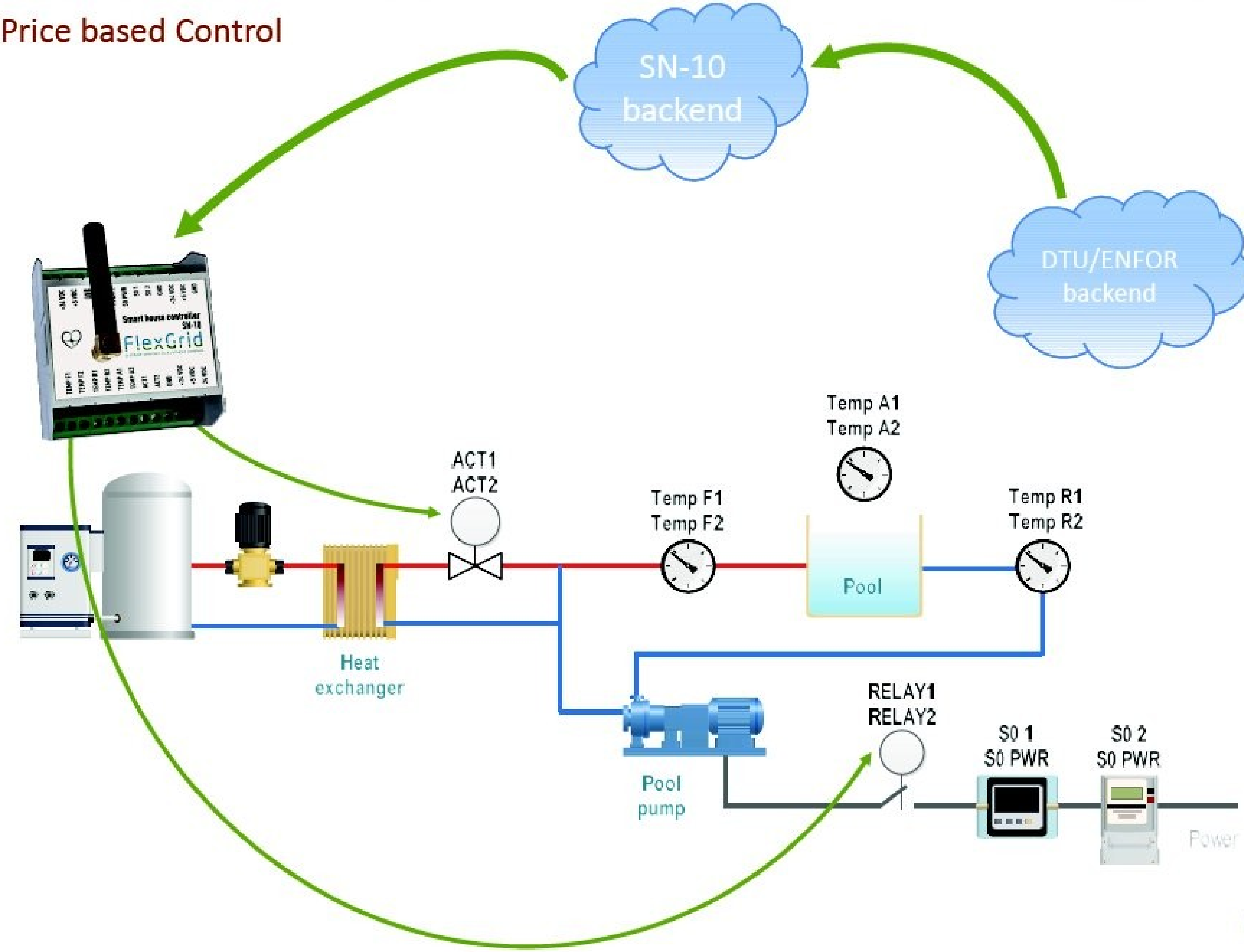
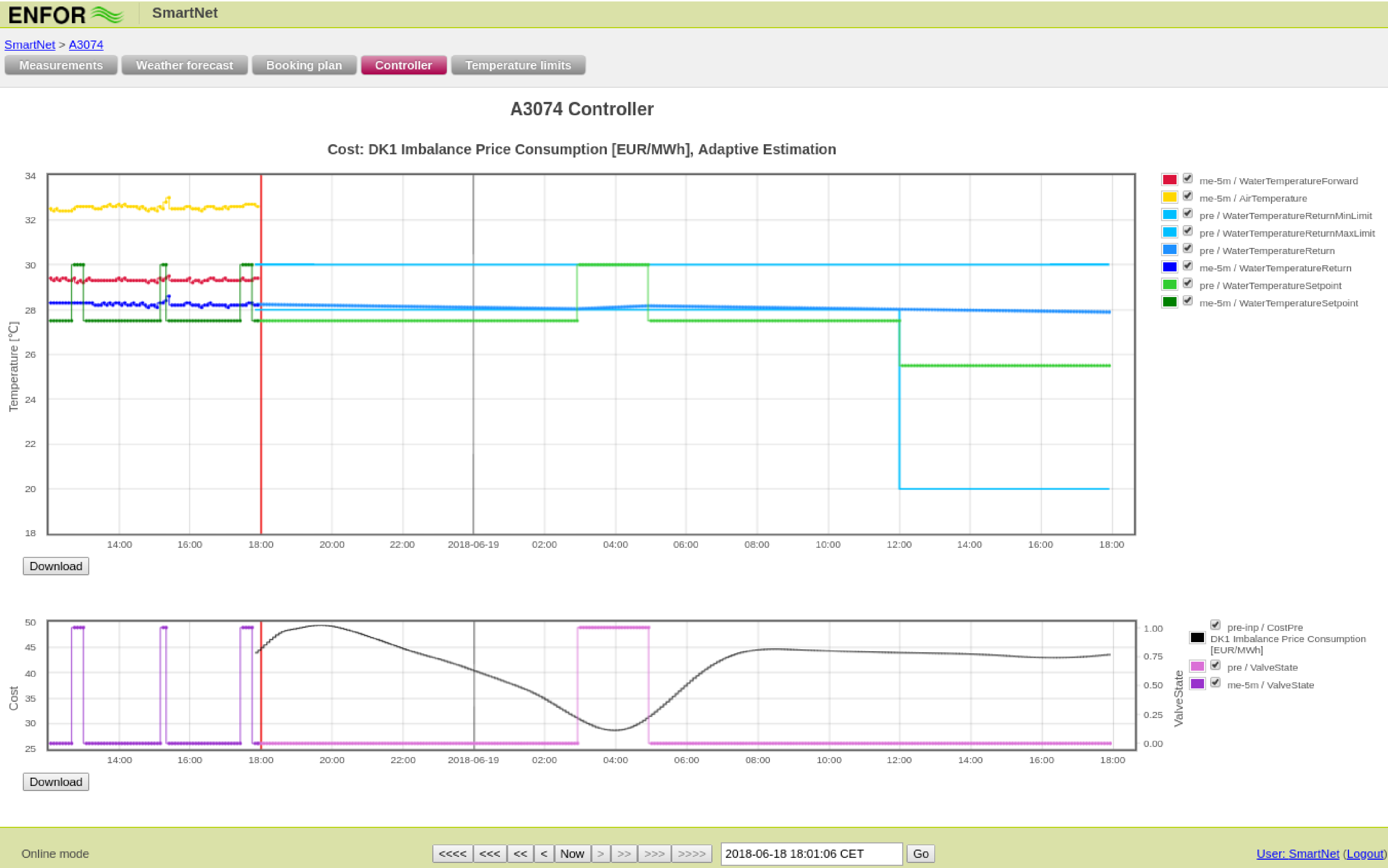
How does it work?

Price based Control



Example: Price-based control



Example: CO2-based control

(40 pct less CO2 emission – 5 pct higher energy consumption)

Flexibility Function and Flexibility Index

Applied for Buildings and Districts

Green Tech Center, Vejle - June 2018

Flexibility Function (FF)

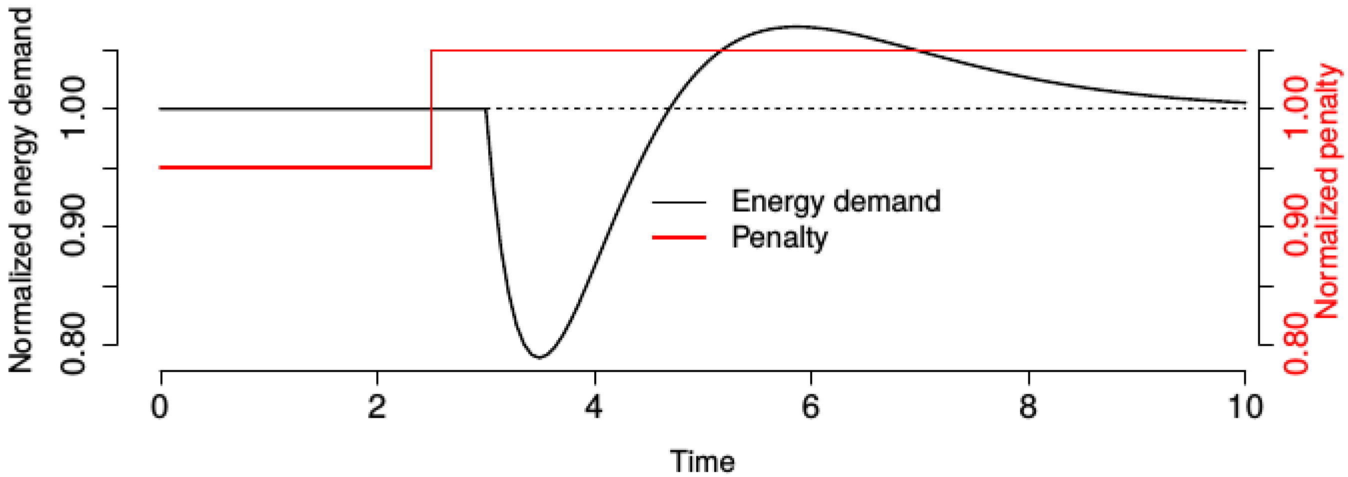


Figure 2: The energy consumption before and after an increase in penalty. The red line shows the normalized penalty while the black line shows the normalized energy consumption. The time scale could be very short with the units being seconds or longer with units of hours. At time 2.5 the penalty is increased,

Equivalent to: Impulse response, transfer function, and frequency resp

Penalty Function (examples)

- **Real time CO_2.** If the real time (marginal) CO_2 emission related to the actual electricity production is used as penalty, then, a smart building will minimize the total carbon emission related to the power consumption. Hence, the building will be *emission efficient*.
- **Real time price.** If a real time price is used as penalty, the objective is obviously to minimize the total cost. Hence, the building is *cost efficient*.
- **Constant.** If a constant penalty is used, then, the controllers would simply minimize the total energy consumption. The smart building is, then, *energy efficient*.

FF for three buildings

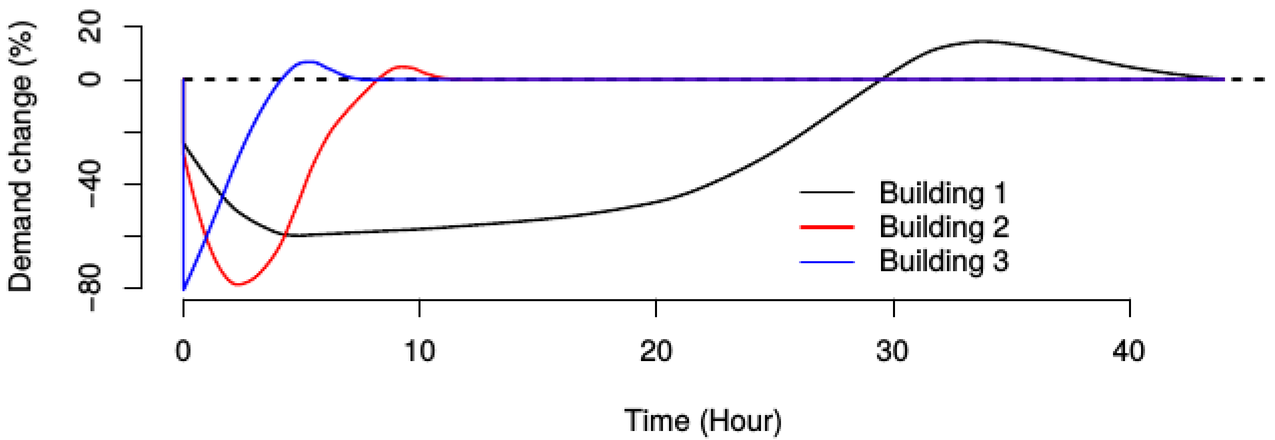


Figure 5: The Flexibility Function for three different buildings.

Flexibility Index

Table 2: Flexibility Index for each of the buildings based reference penalty signals representing wind, solar and ramp problems.

	Wind (%)	Solar (%)	Ramp (%)
Building 1	36.9	10.9	5.2
Building 2	7.2	24.0	11.1
Building 3	17.9	35.6	67.5

Summary

- A Smart-Energy OS for data intelligent control of energy systems in buildings is suggested.
- The controller can provide
  - Energy Efficiency
  - Cost Minimization
  - Emission Efficiency
  - Peak Shaving
  - Smart Grid demand (like ancillary services needs, ...)
- We have demonstrated a large potential in Demand Response. Automatic solutions, and end-user focus are important
- CO2-based control can be used to accelerate the green transition
- The concepts of a Flexibility Funcition and Flexibility Index for Smart Buildings and Districts are defined