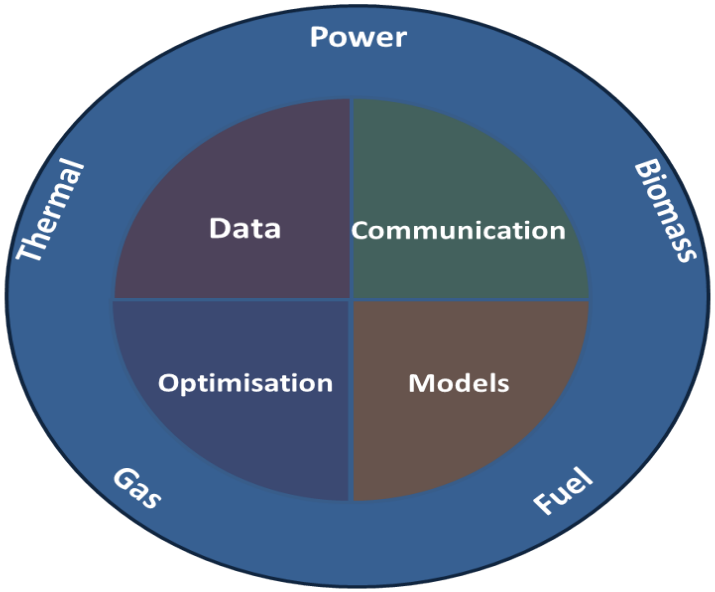
Intelligent and Integrated Energy Systems

Energy Systems in Smart Cities

for the Smart Society

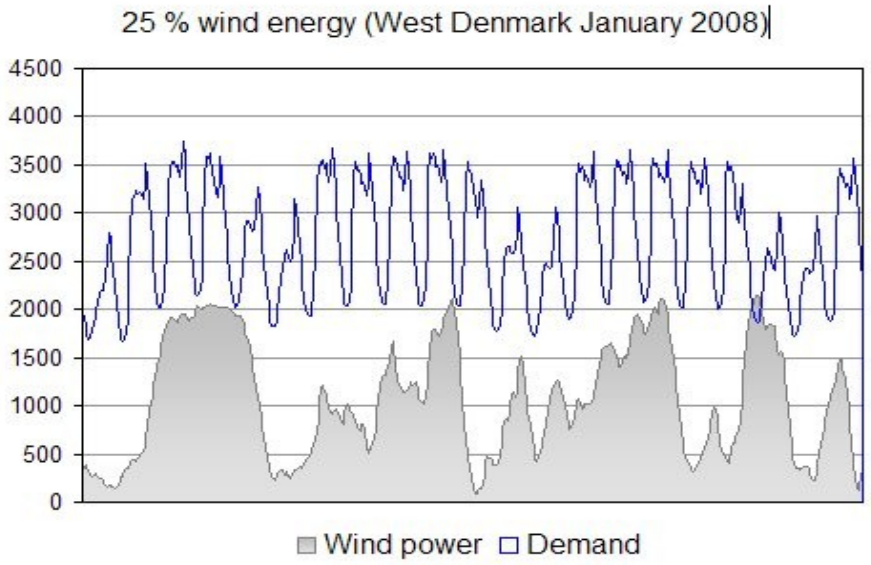


Henrik Madsen

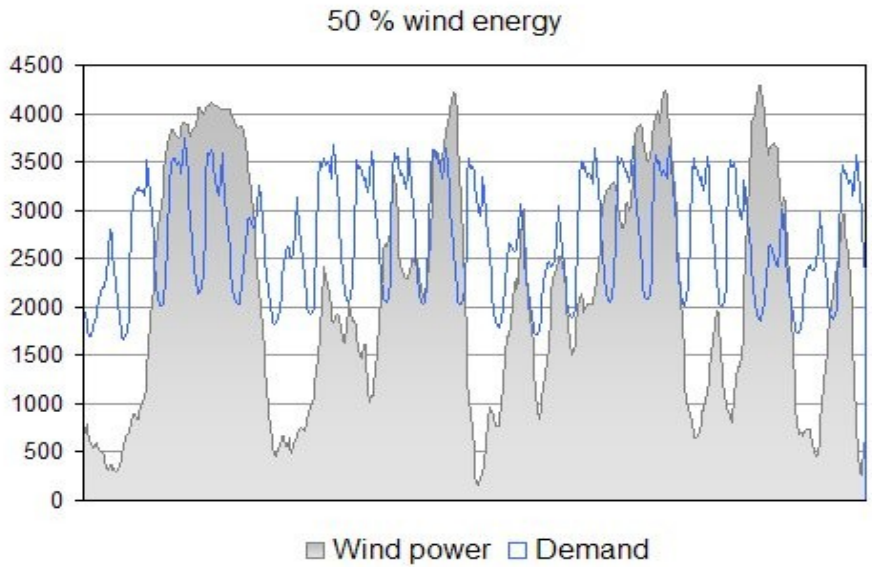
CITIES (smart-cities-centre.org) and Smart City Accelerator (smartcitiesaccelerator.eu)

The Danish Wind Power Case

…. balancing of the power system



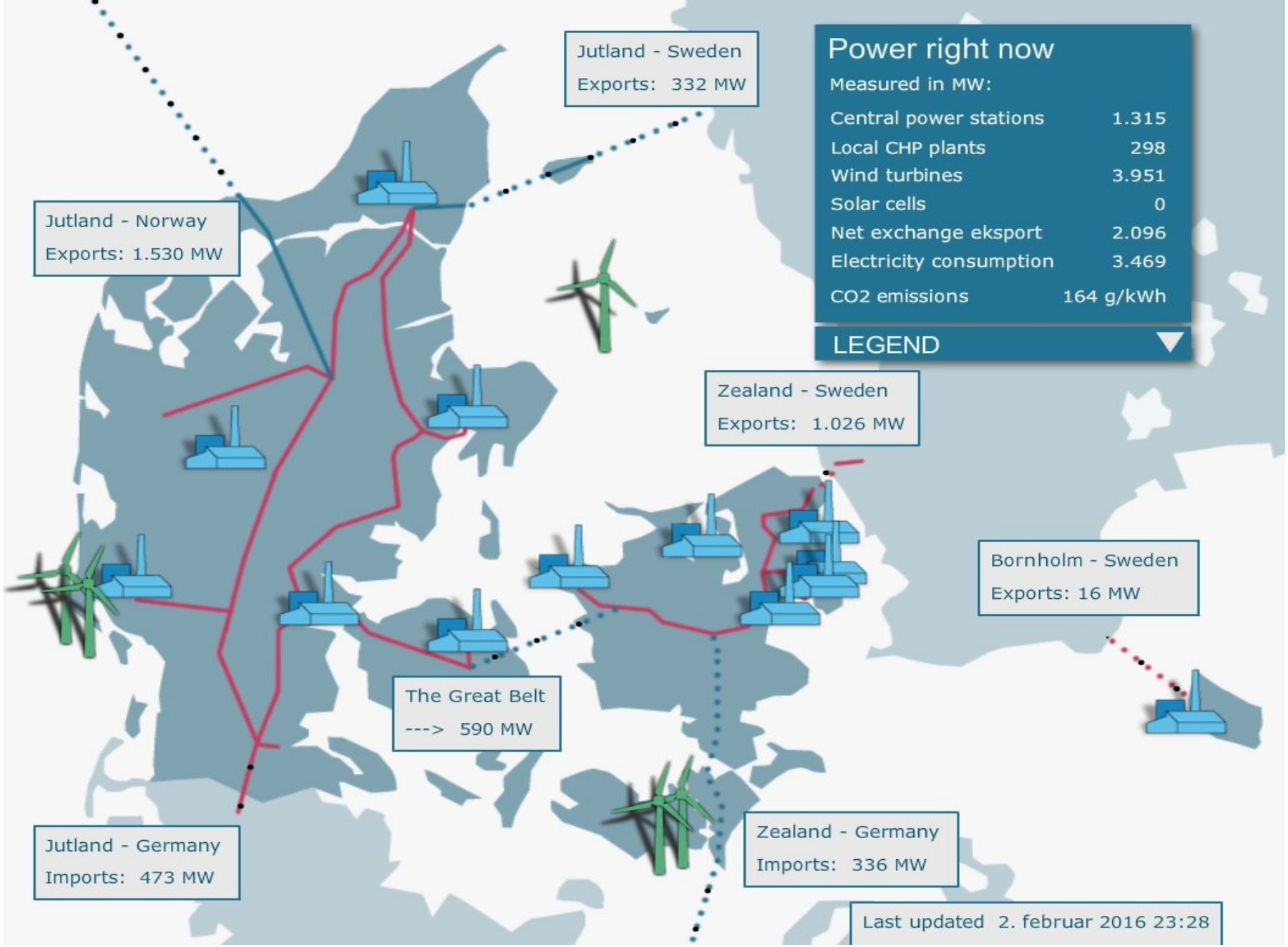
In 2008 wind power did cover the entire demand of electricity in 200 hours (West DK)



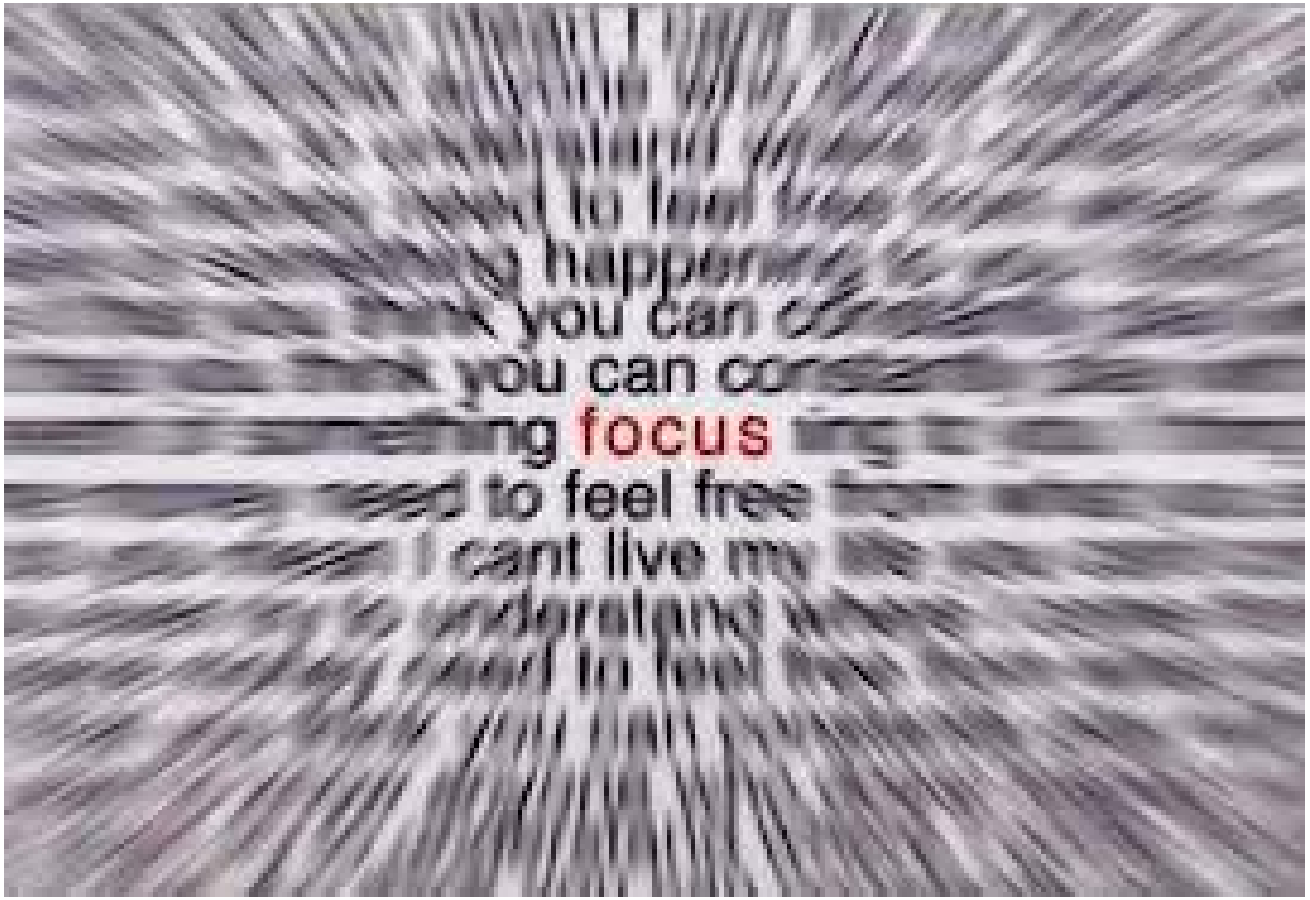
In the first six month of 2017 more than 44 pct of electricity load was covered by wind power.

For several days the wind power production was more than 100 pct of the power load.

July 10th, 2015 more than 140 pct of the power load was covered by wind power


Jutland - Sweden
Exports: 332 MW
Power right now
Measured in MW:
Central power stations 1.315
Local CHP plants 298
Wind turbines 3.951
Solar cells 0
Net exchange eksport 2.096
Electricity consumption 3.469
CO2 emissions 164 g/kWh
LEGEND
Jutland - Norway
Exports: 1.530 MW
Zealand - Sweden
Exports: 1.026 MW
Bornholm - Sweden
Exports: 16 MW
The Great Belt
---> 590 MW
Jutland - Germany
Imports: 473 MW
Zealand - Germany
Imports: 336 MW
Last updated 2. februar 2016 23:28

How can we make a difference ?



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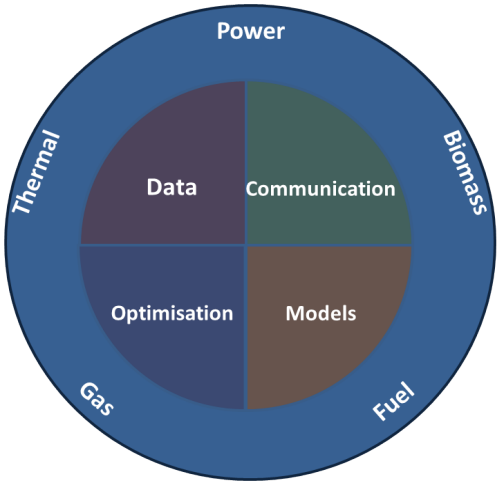
Assumptions, Goals and Methods

Energy Systems Integration

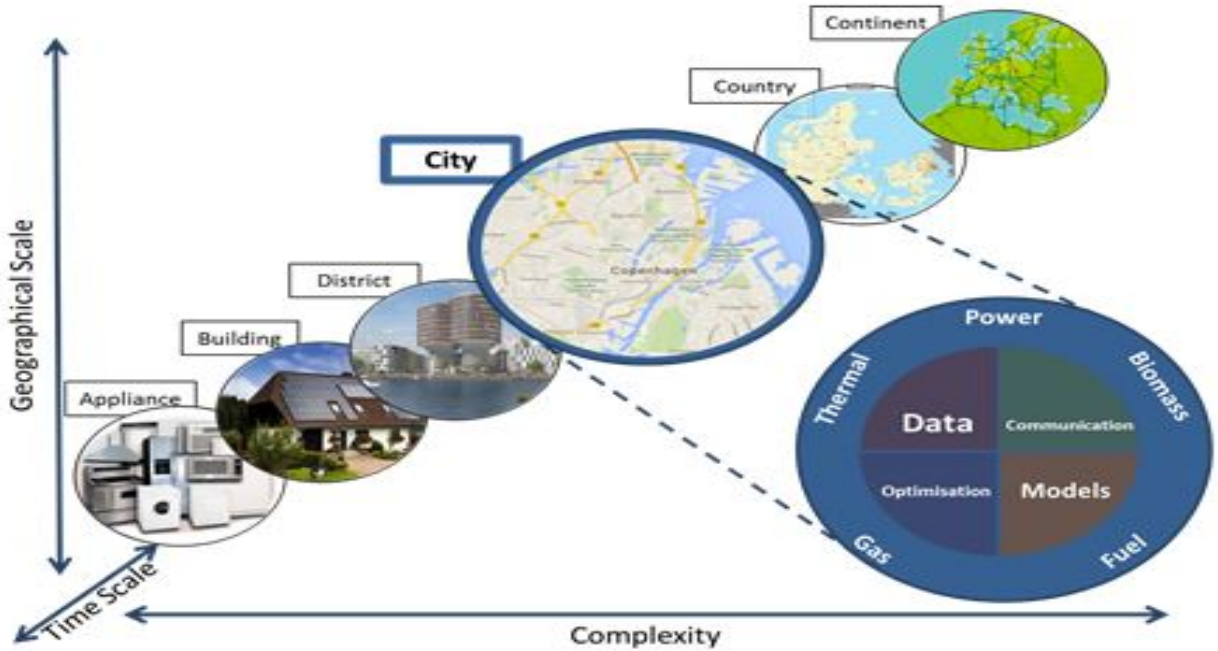


The **central hypothesis** is that by **intelligently integrating** currently distinct energy flows (heat, power, gas and biomass) using **data intelligence** we can balance very large shares of renewables, and consequently obtain substantial reductions in CO2 emissions.

Intelligent integration will (for instance) enable lossless ‘virtual’ storage on a number of different time scales.

CITIES – Research Challenges

To establish methodologies and solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales in Smart Cities



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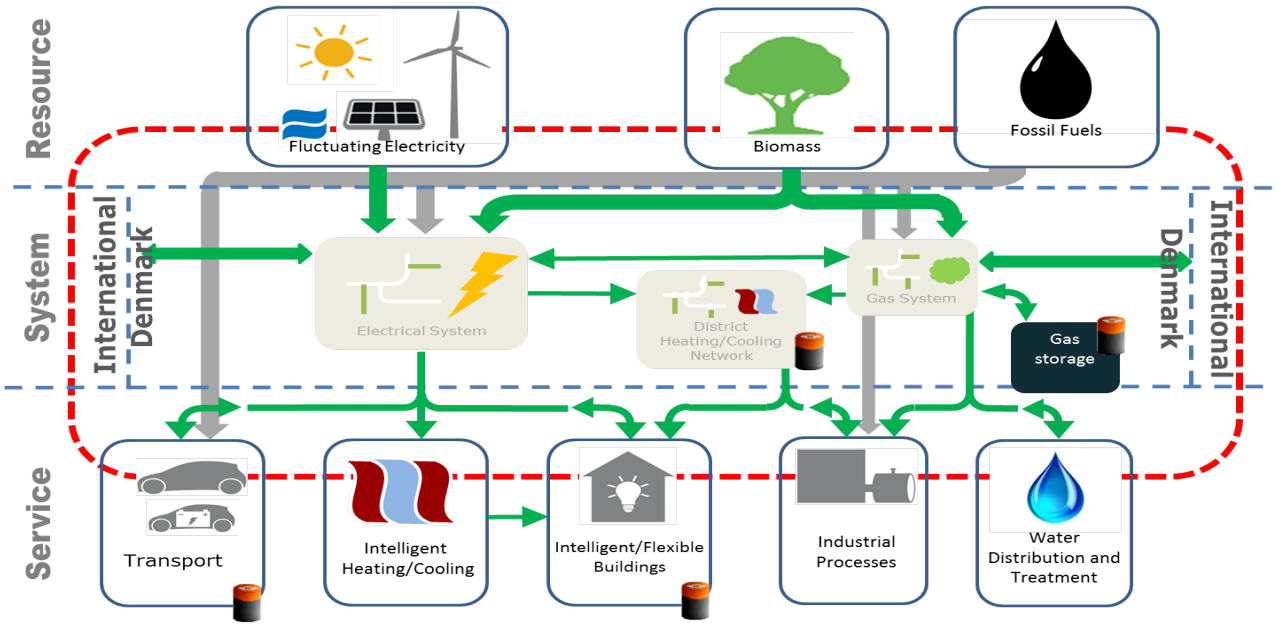
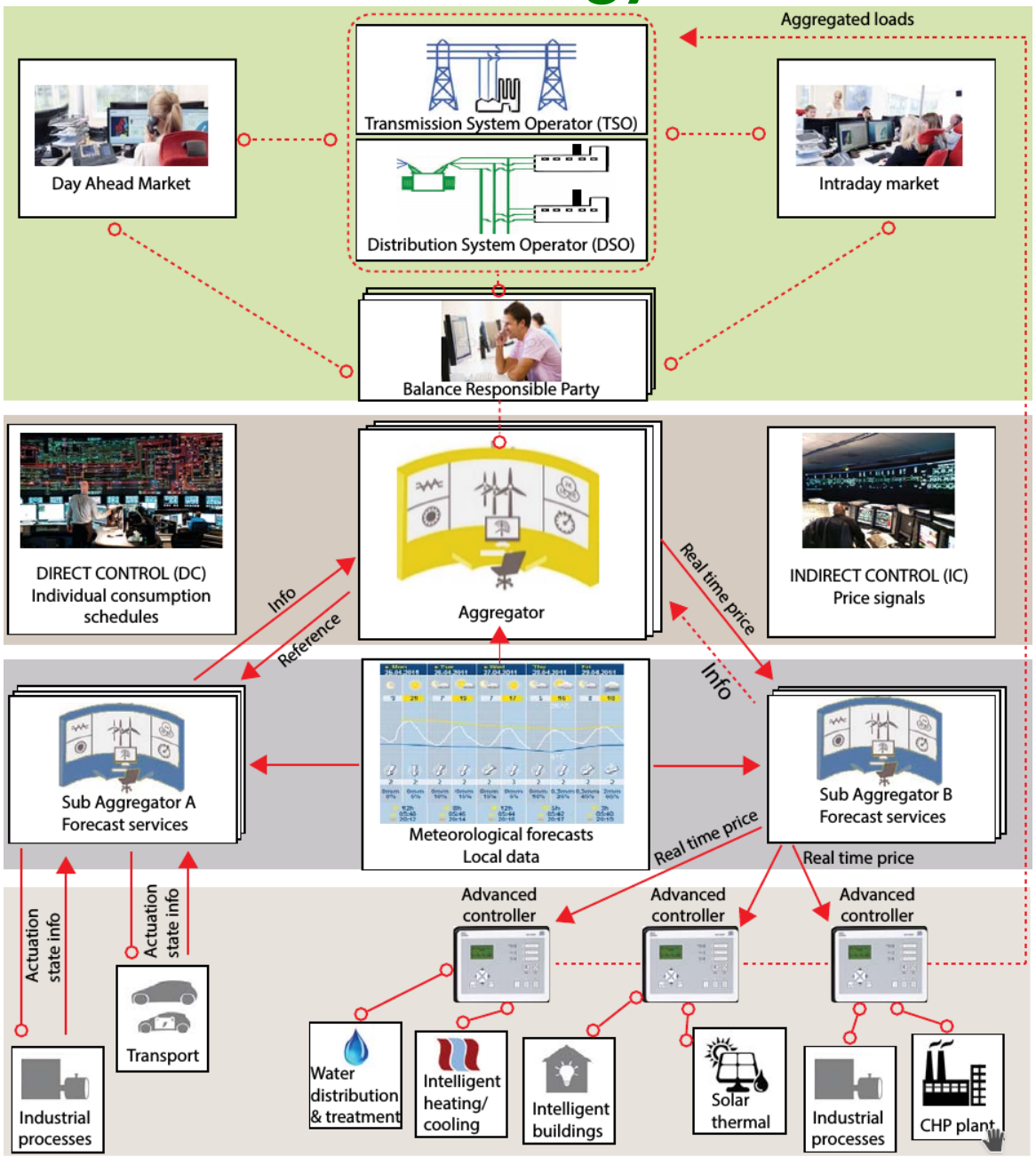
CITIES – Concept Challenges

Energy Systems Integration using data and IT solutions leading to **models and methods for planning and operation of future electric energy systems in Smart Cities**



Smart-Energy OS



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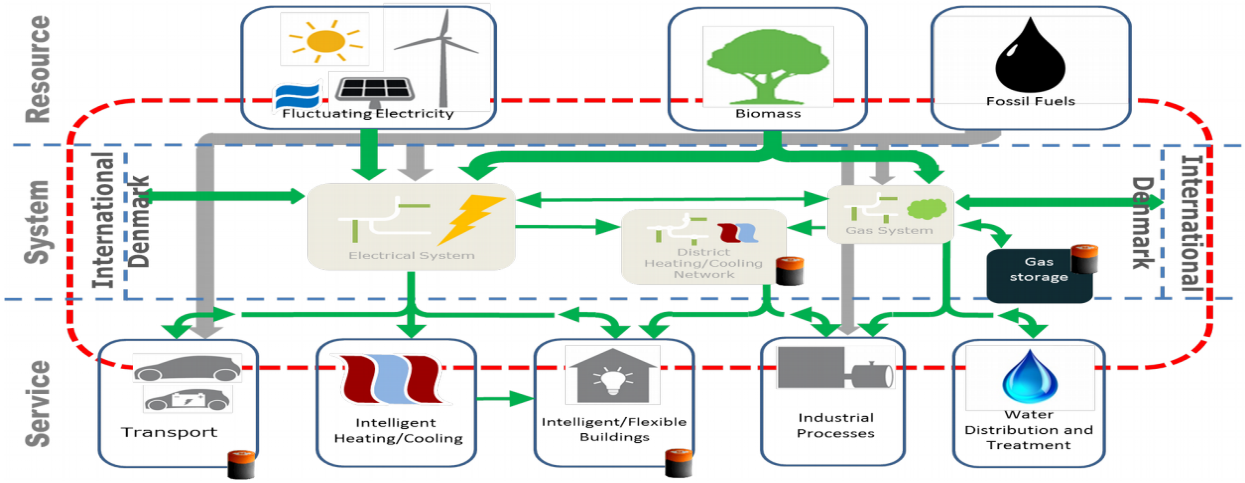
```
38
39  # Try to parallelize anyway
40  require(multicore)
41  numcores<-multicore:::detectCores()
42  mclapply(
43    1:N,
44    function(i,data) {
45      print(paste(i, "/", N))
46
47      # Find the indices of rows corresponding to
48      j <- which(data$dt_agg %in% aggdata$dt[i])
49
50      # Filter out those who are NA
51      j <- j[!is.na(data$last_one_min_power[j])]
52
53      # Count number of readings
54      aggdata$num_readings[i] <- length(j)
```

(Virtual) Storage Solutions



- **Flexibility (or virtual storage) characteristics:**
  - Supermarket refrigeration can provide storage 0.5-2 hours ahead
  - Buildings thermal capacity can provide storage up to, say, 5-10 hours ahead
  - Buildings with local water storage can provide storage up to, say, 2-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - DH systems with thermal solar collectors can often provide seasonal storage solutions
  - Gas systems can provide seasonal/long term storage solutions

CITIES INNOVATION CENTER

Integrated energy systems powered by intelligent data

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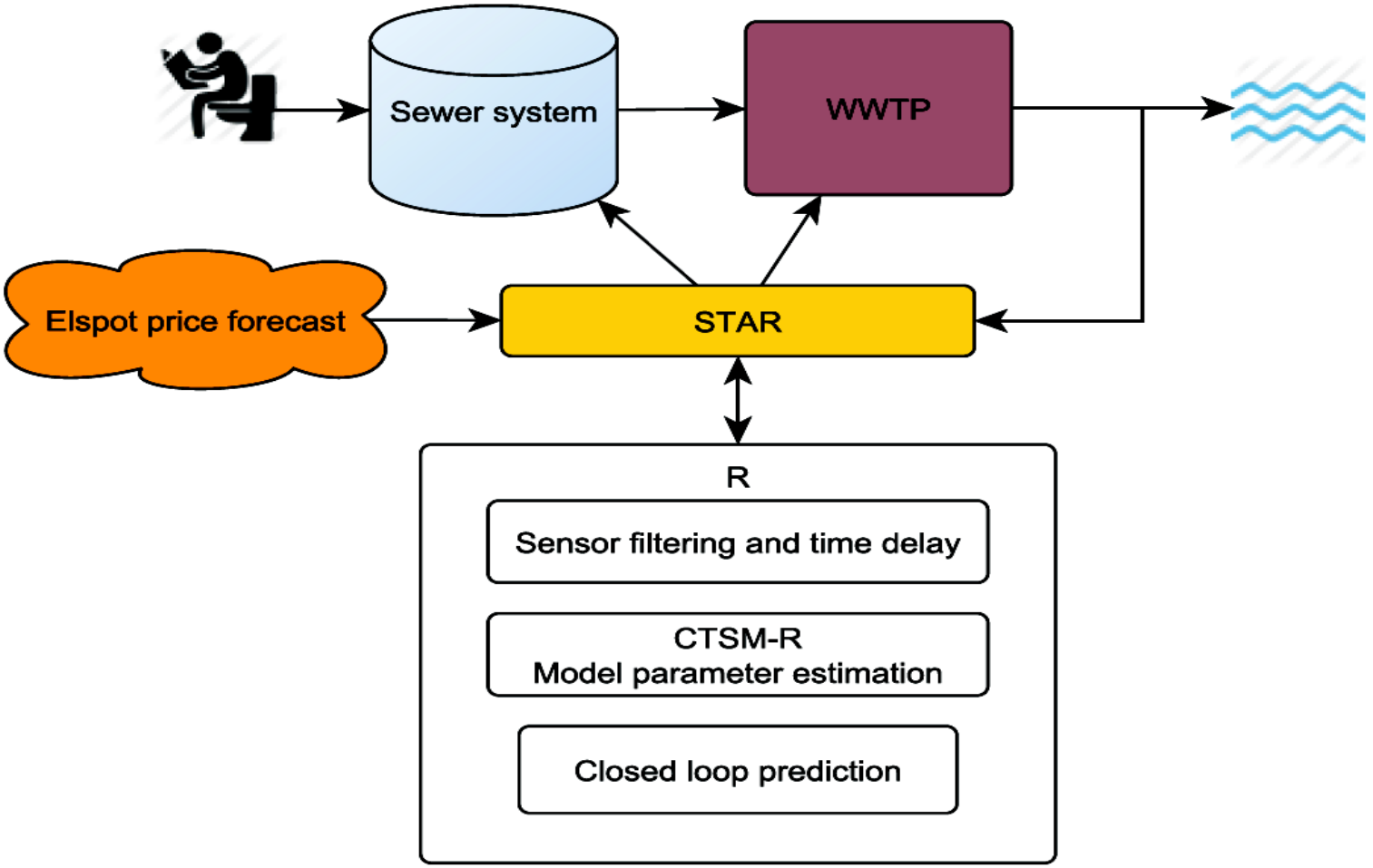
Topics

Case study

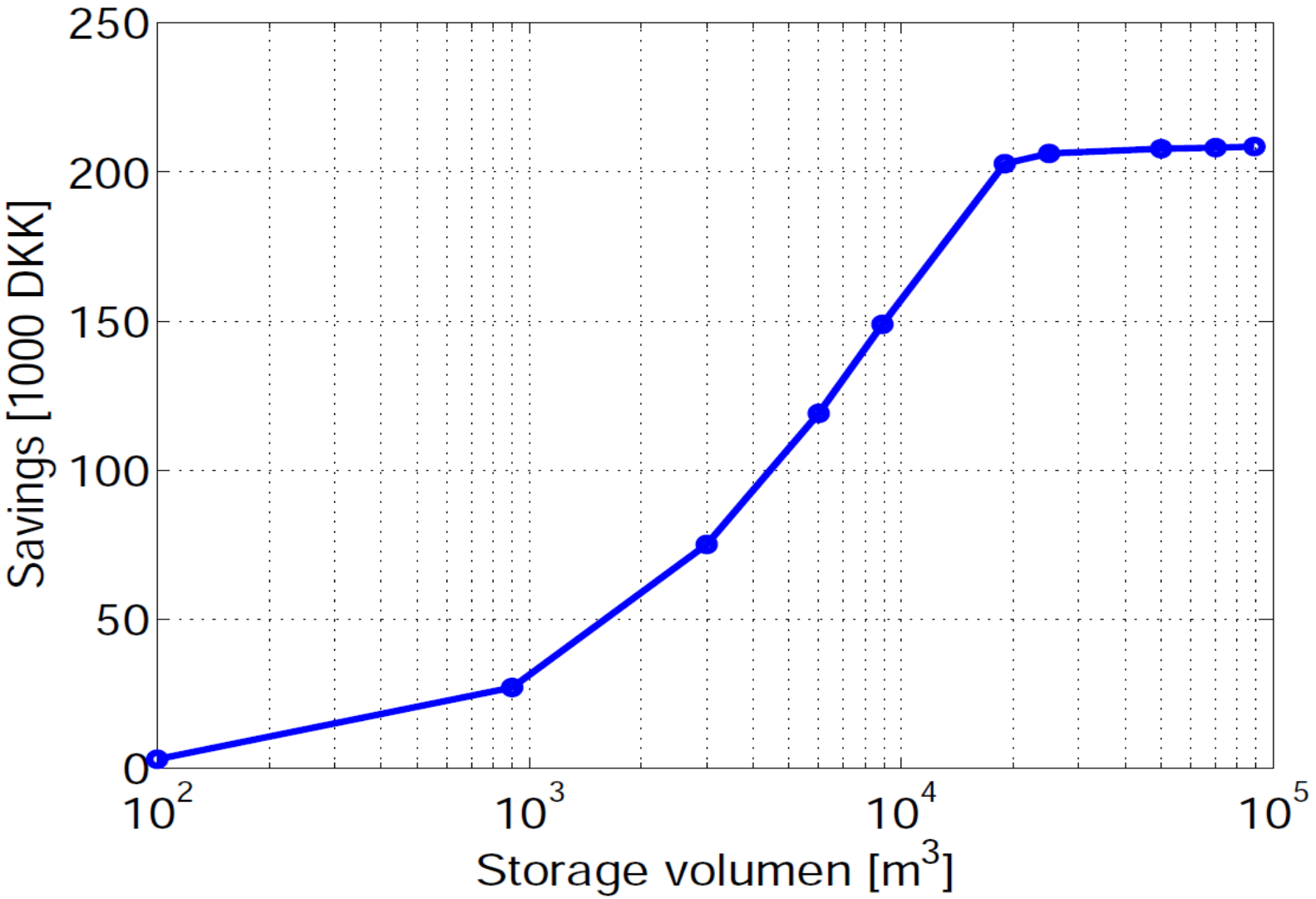
Wastewater Treatment Plants

Kolding WWTP

Energy Flexibility in Wastewater Treatment



Sewer System Annual Elspot Savings



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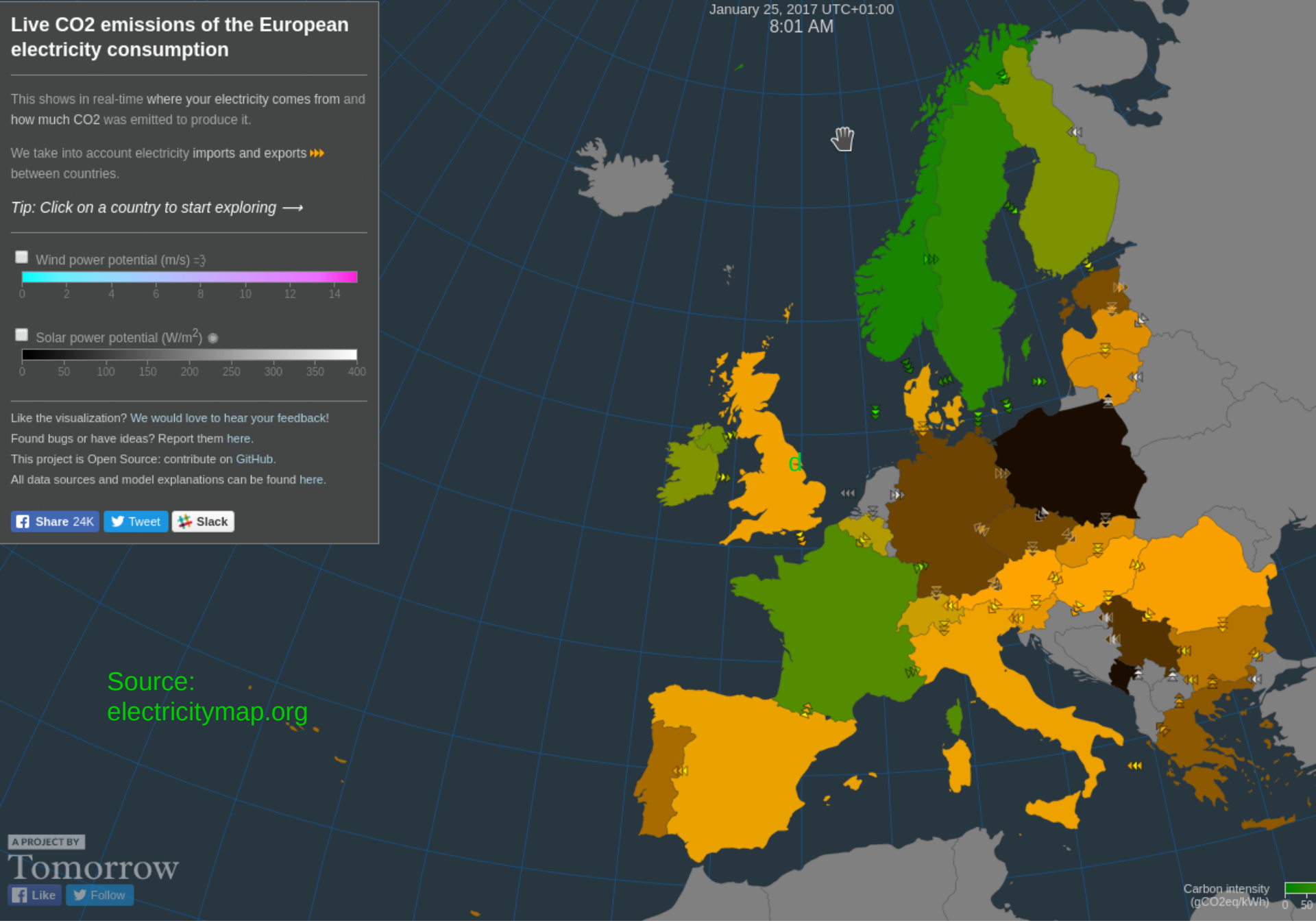
Case study

Using swimming pools to store wind power



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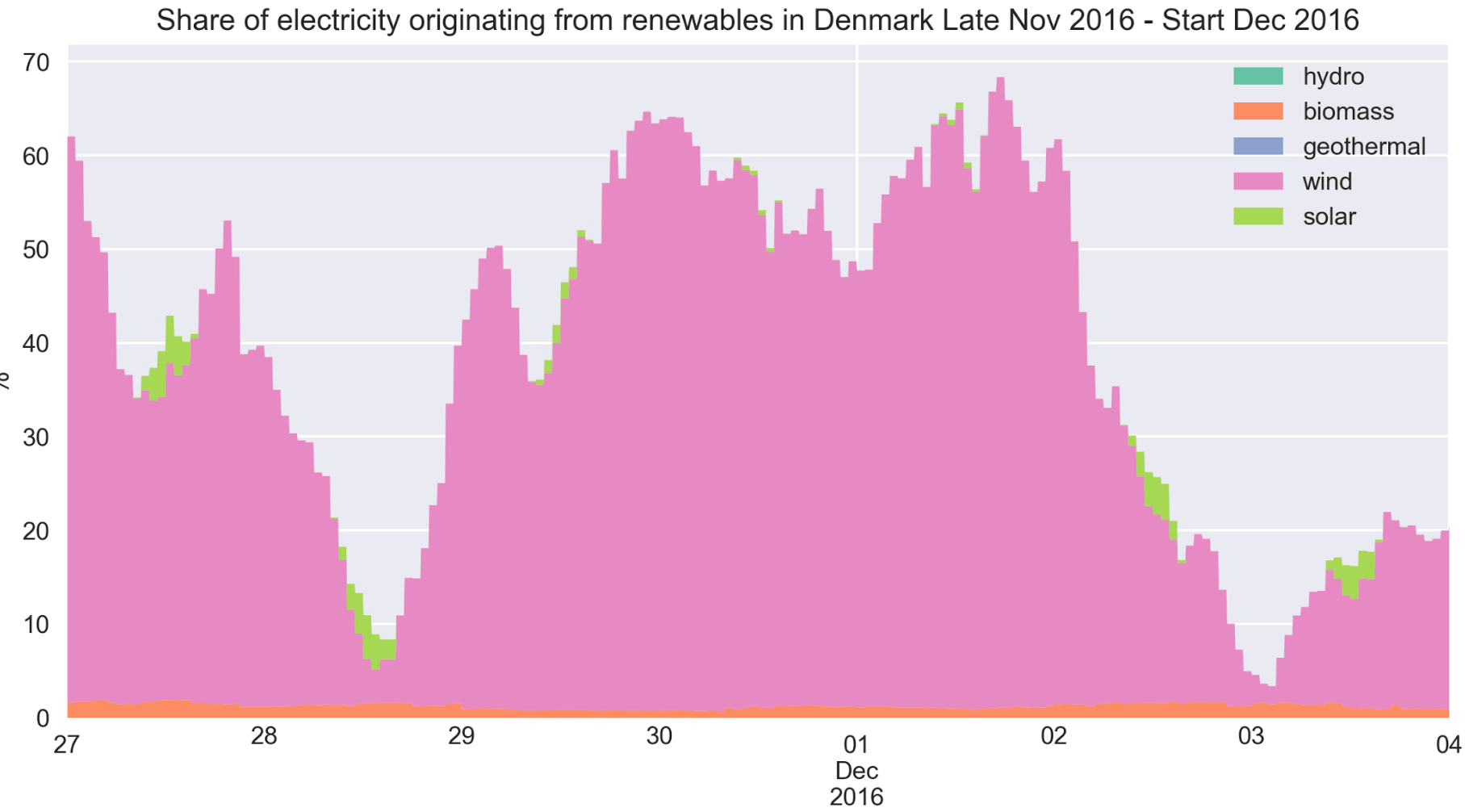
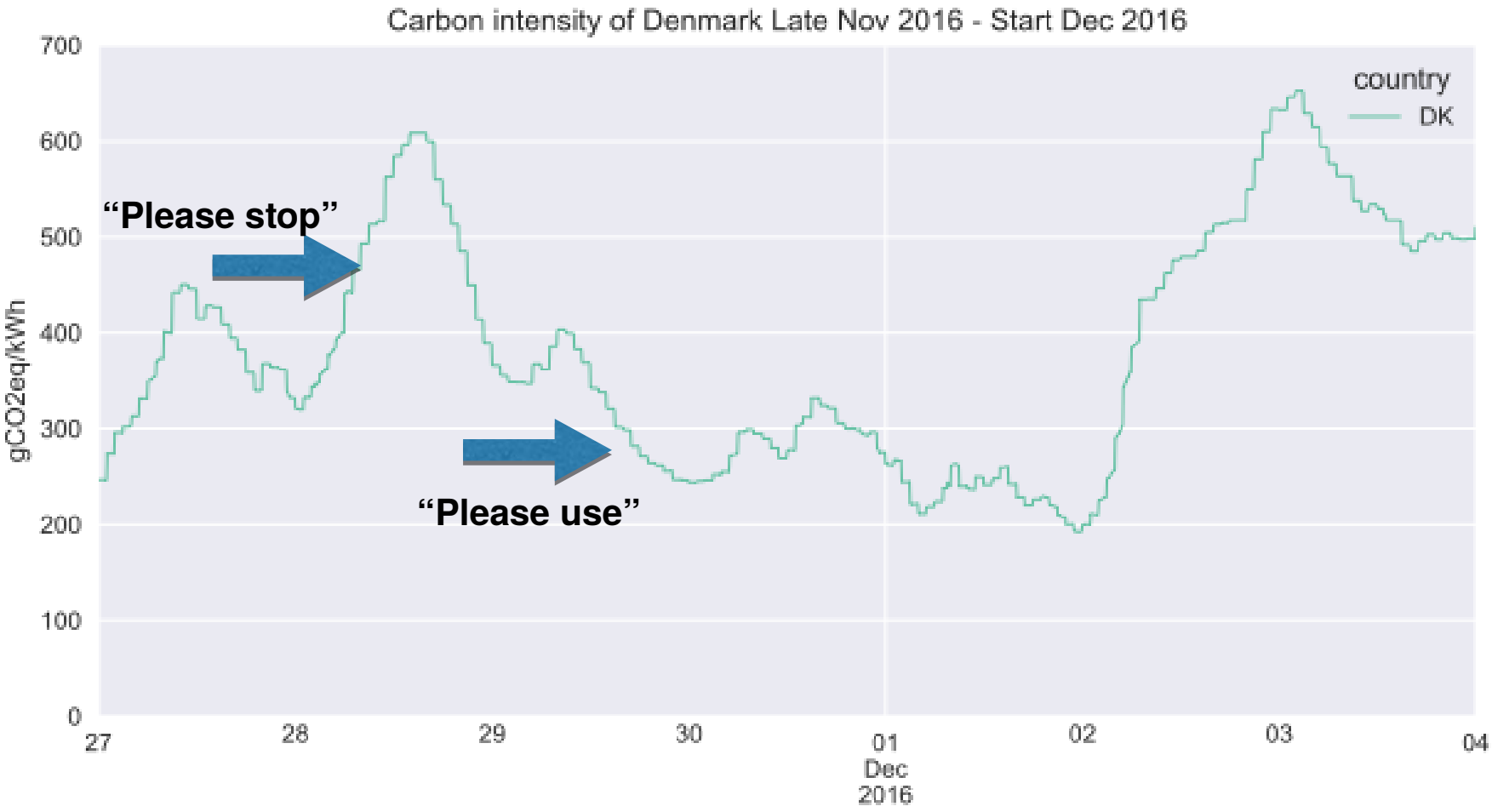
Nordic Smart Cities Live, Stockholm 2017



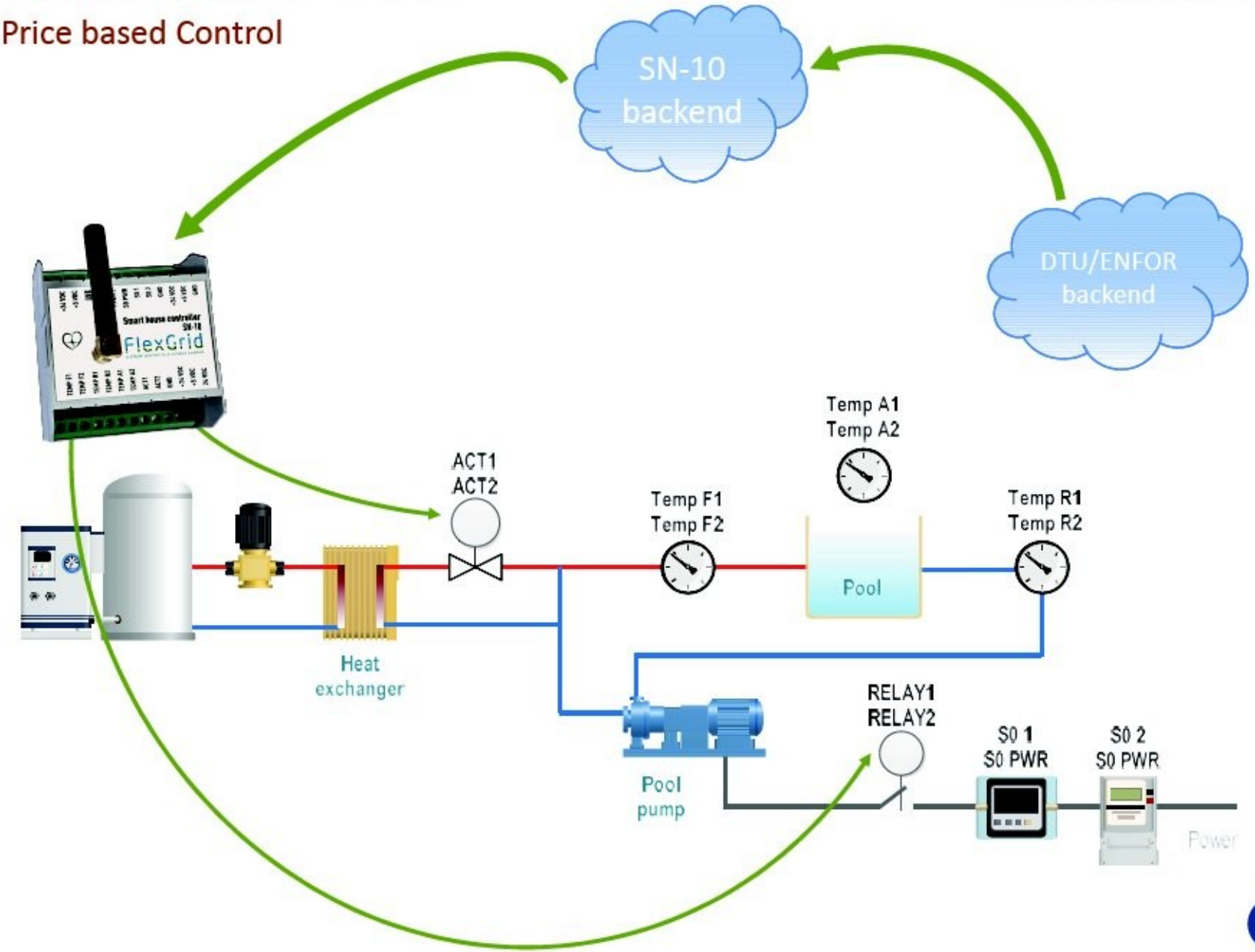
Source: pro.electicitymap.org

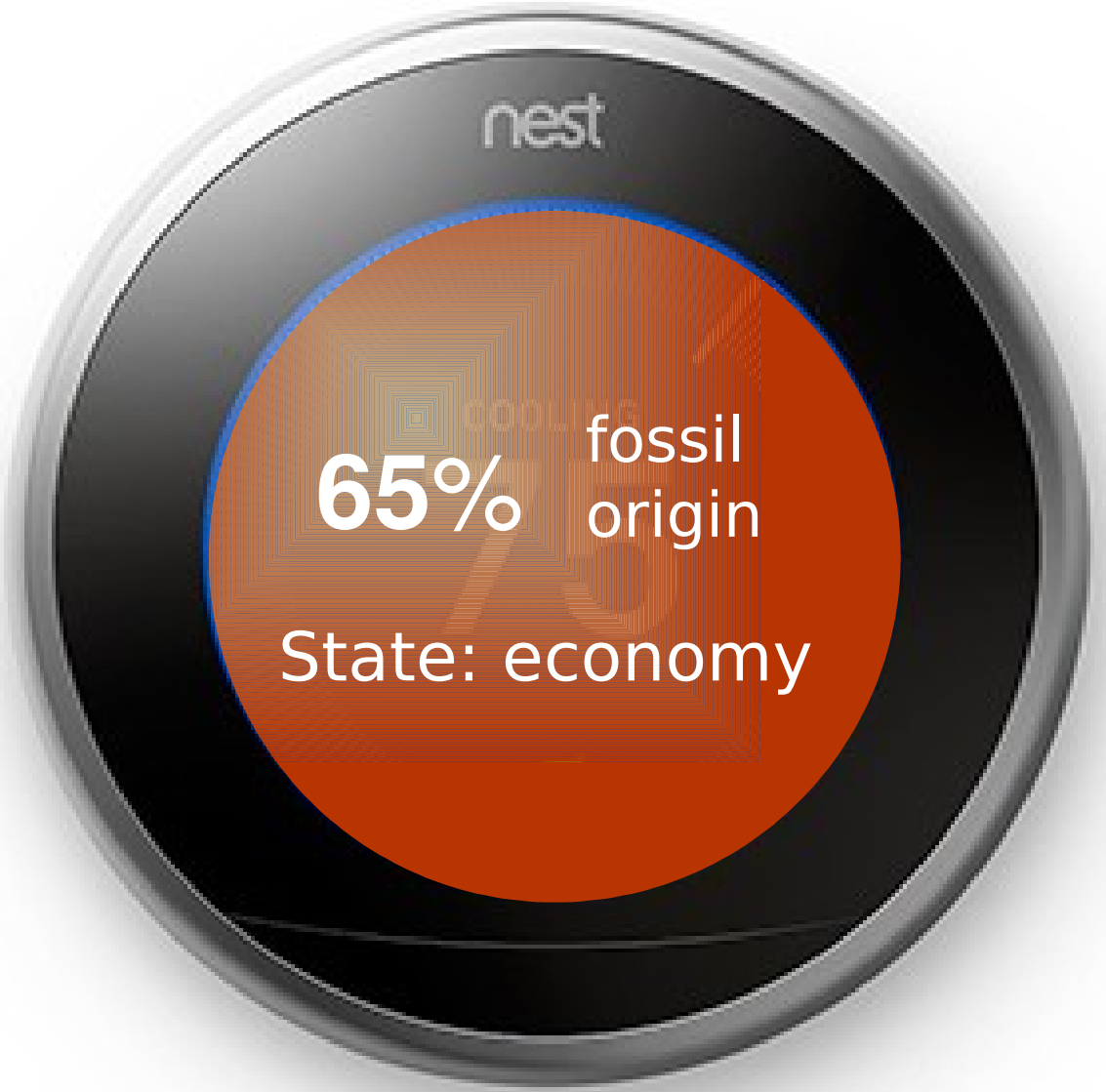


Source: pro.electicitymap.org

How does it work?

Price based Control





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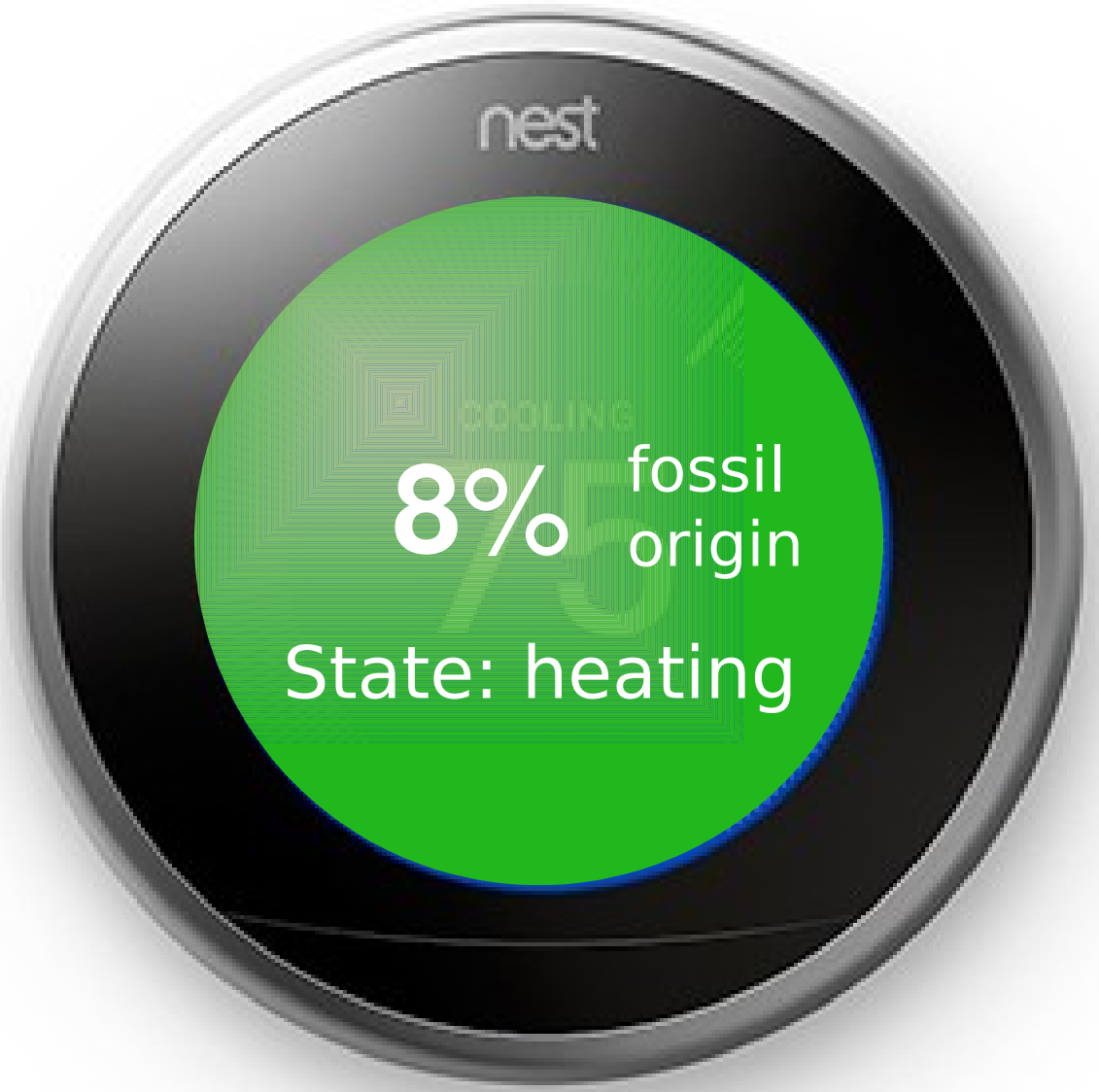

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Summary

- Smart Cities is a part of a Smart Society
- CITIES have a number of low carbon solutions for smart cities …
- Smart-Energy OS: Let you focus on Energy Efficiency, Emission or Energy Costs
- It is our impression that by intelligent energy systems integration we could rather easily obtain a fossil-free society, however ….
- We need stronger decision makers …
- Intelligent Energy Systems Integration can provide virtual storage solutions (… less need for physical storages)
- District heating (or cooling) systems can provide flexibility on the essential time scales (up to a few days)

Thanks for your attention !