The Danish Experience and View on Energy System Development

Energy Policy in Europe: objectives, achievements, and challenges

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Centre for IT-Intelligent Energy Systems in cities (CITIES, 1035-00027B, http://smart-cities-centre.org/)

Outline

1. How to become a frontrunner: Denmark's energy achievements
2. Where Danes are now: Current situation
3. The great ambition of a small nation: Goals and challenges ahead
4. Step by step: Energy initiatives in Denmark
5. Concluding remarks

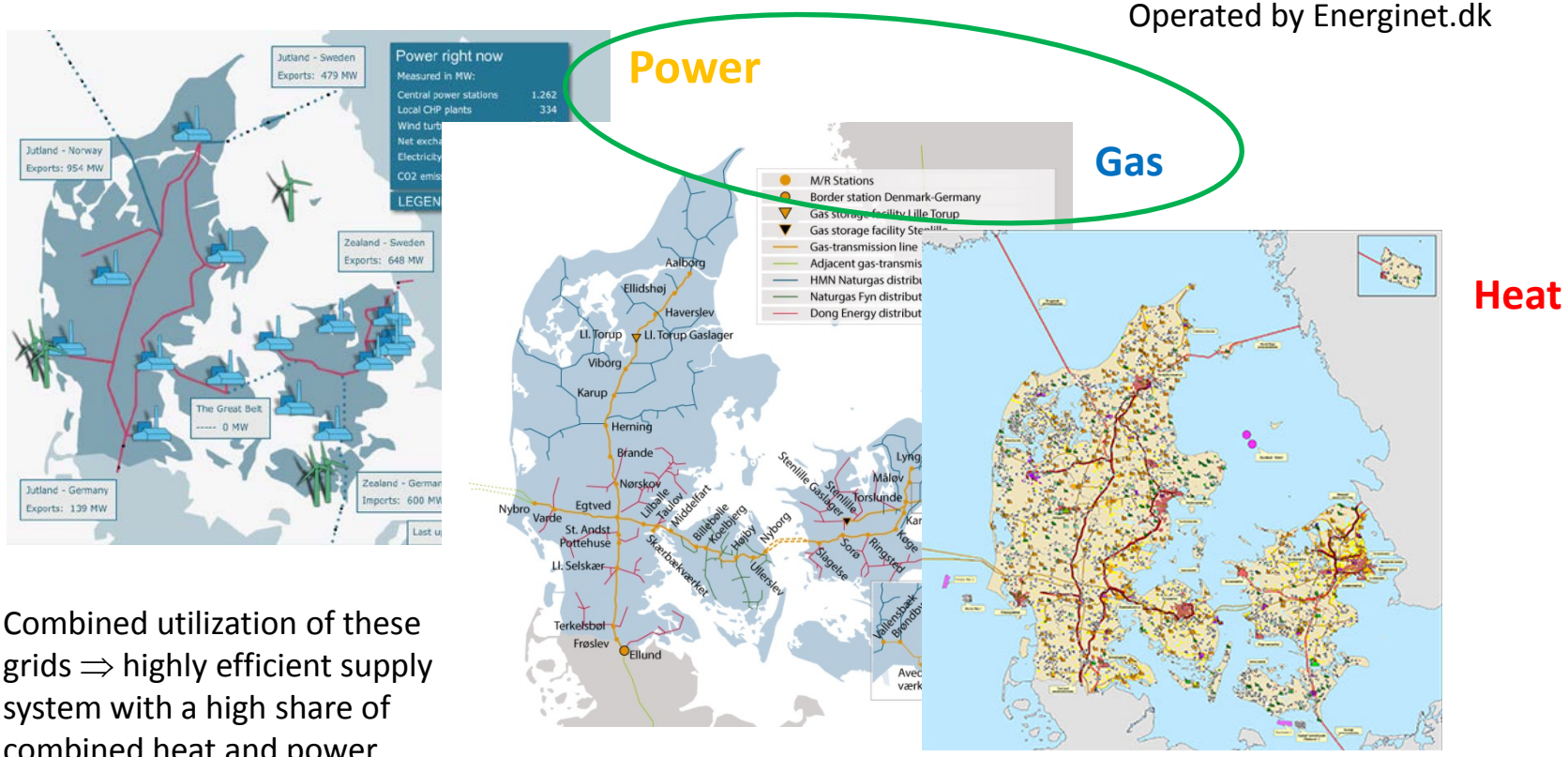
Area: 42,924 square kilometers

Population: 5.7 million

How to become a frontrunner

1. A highly diversified and distributed energy system, based upon three major national grids:

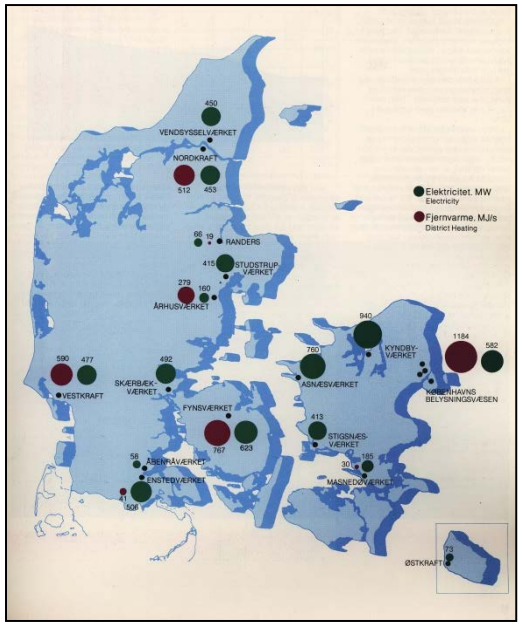
Operated by Energinet.dk



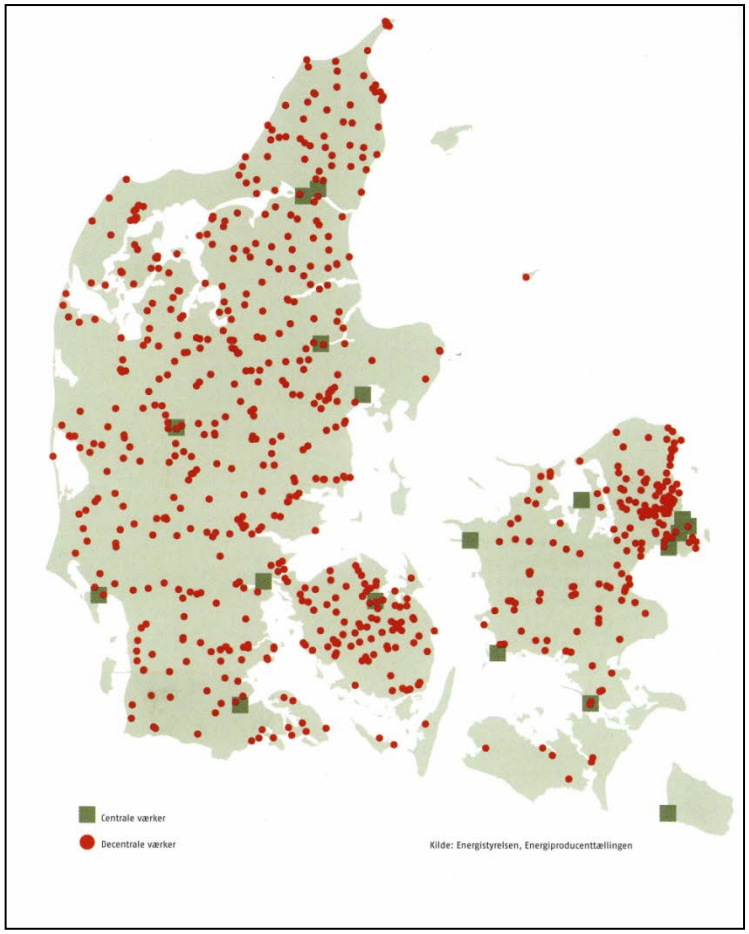
Combined utilization of these grids ⇒ highly efficient supply system with a high share of combined heat and power

How to become a frontrunner

1980



Today

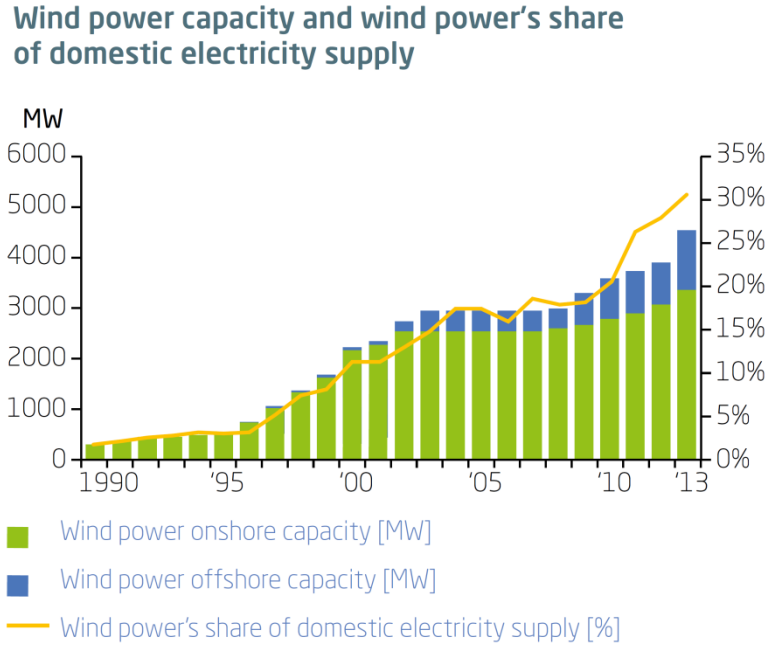


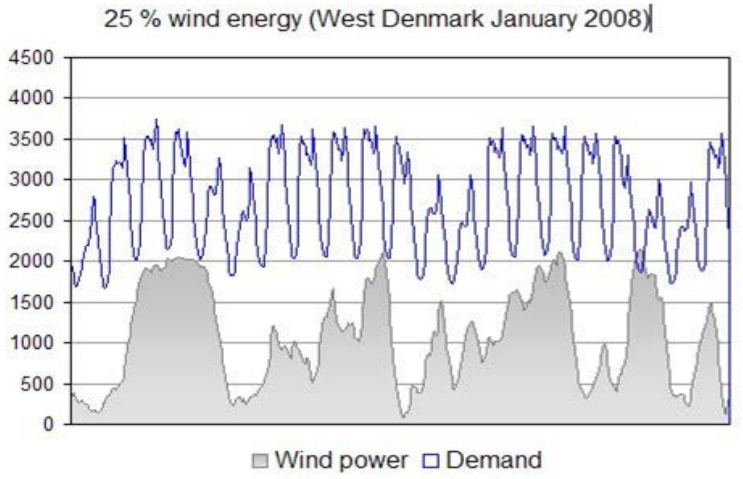
*From a few big power plants (mostly based on coal) to many small **combined heat and power** plants*

Denmark has enough excess heat to cover the entire need for heating

How to become a frontrunner

2. Increasingly important role of renewable energy technologies in the Danish energy system:





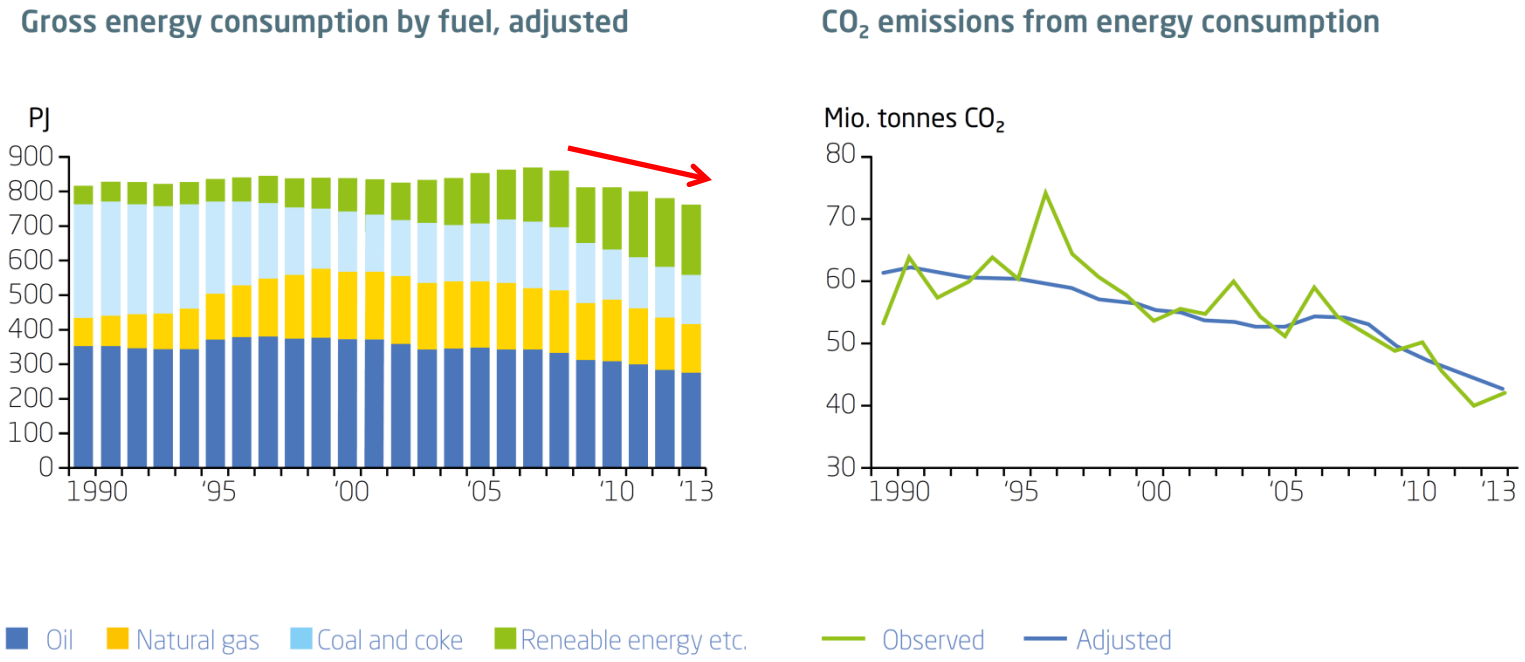
In 2008 wind power covered the entire demand of electricity in 200 hours (West DK)

Denmark is one of the global frontrunners in the development of offshore wind farms!

How to become a frontrunner

3. Successful decoupling of energy consumption and economic growth:

Source: Danish Energy Authority

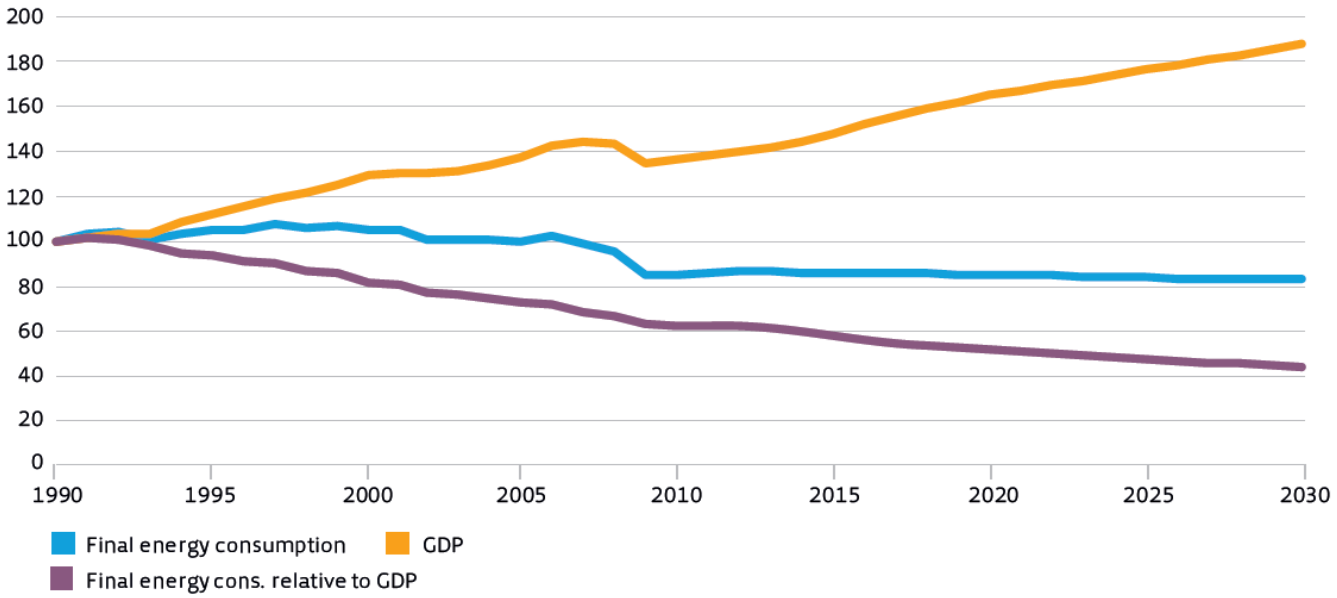


Gross energy consumption has been kept almost constant for more than 20 years

How to become a frontrunner

3. Successful decoupling of energy consumption and economic growth:

Source: Danish Energy Authority



In contrast, GDP has increased by more than 80% in the same time period!

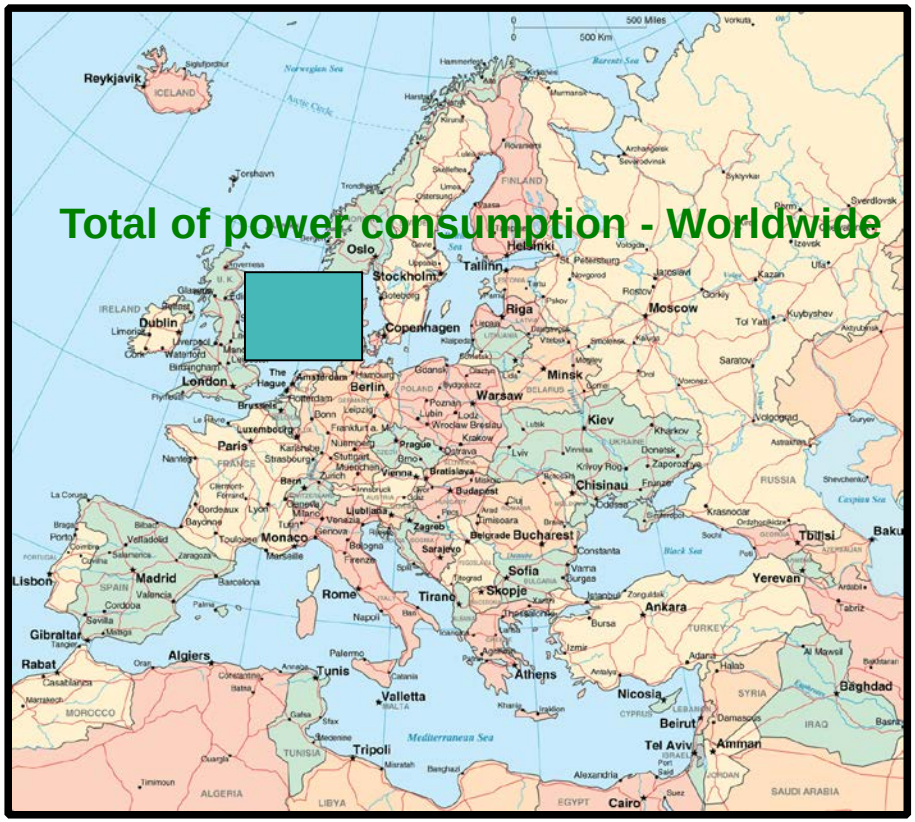
How to become a frontrunner

4. Most importantly: Since the 90's the issue of climate change has been the most important driver of Danish energy policy

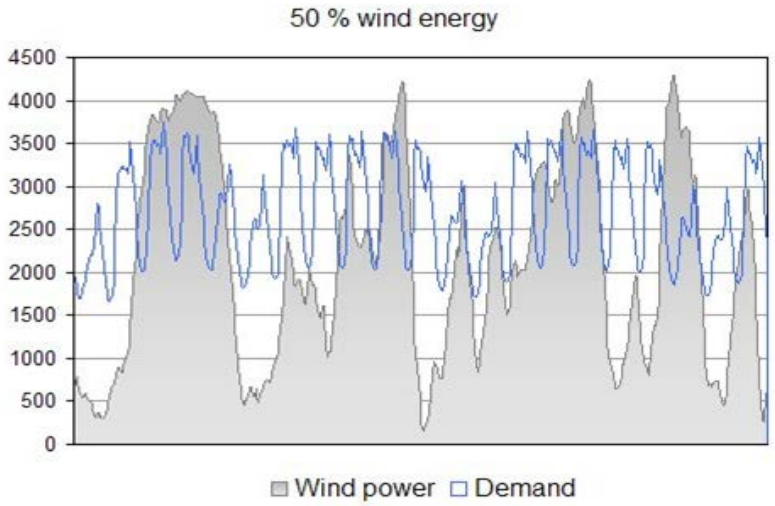
First simple rule in life:

If you don't go after what you want,

you'll never have it.



Current Situation

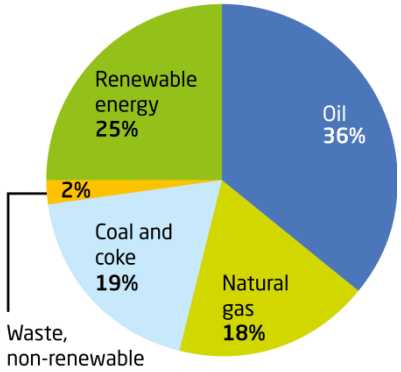


In 2015 more than 42% of electricity load was covered by wind power

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

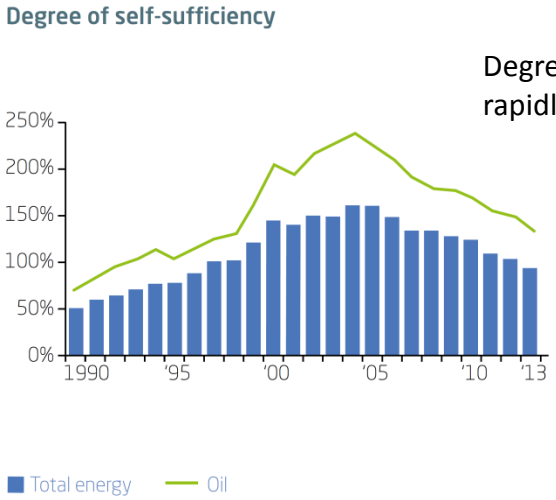
July 10th, 2015 more than 140 pct of the power load was covered by wind power

Distribution of fuels by 2013



Source: Danish Energy Authority

2013: production from Danish oil and natural gas fields in the North Sea fell below gross energy consumption for the first time in many years



Degree of self-sufficiency in **oil** is rapidly decreasing

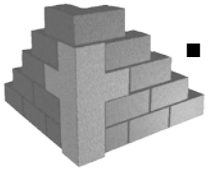
DK's energy situation is better off than most EU countries

Goals and Challenges Ahead

1. **Increased vulnerability** of the Danish energy supply: diminishing degree of self-sufficiency in oil and natural gas

   - Replace fossil fuels in the transport sector (major oil user) by RES

2. **Pernicious effect**: The high efficiency of the Danish energy system relies on CHP production + extensive district heating



   - The increasing penetration of wind power is gradually pushing CHP-plants out of the power market (low running hours, reduced profitability)
   - Electrification of the heating system → Installation of large heat pumps

3. Highly reliance on **variable and uncertain power supply**

   - Aiming for a wind-dominated energy system will call for innovative and advanced solutions

Goals and Challenges Ahead

- 2020: 50% of electricity from wind power, and 35%of total energy consumption from RES
- 2030: No use of coal in Danish power plants
- 2035: 100% of electricity and heating from RES
- 2050: 100% of all (electricity, heating, transport, industry) from RES

- Strong development of offshore wind power
- Energy conservation measures: total gross energy consumption is to be reduced 12% compared to 2006
- Shifting some of the existing coal-fired power plants to biomass

Goals and Challenges Ahead

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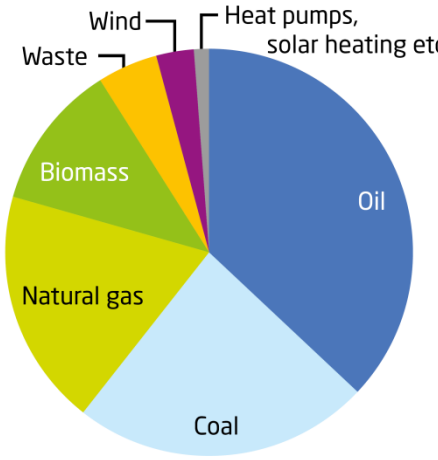
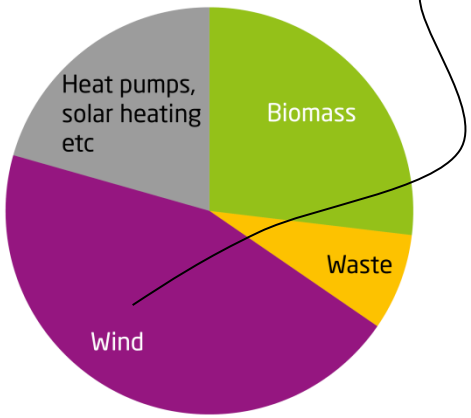


2008

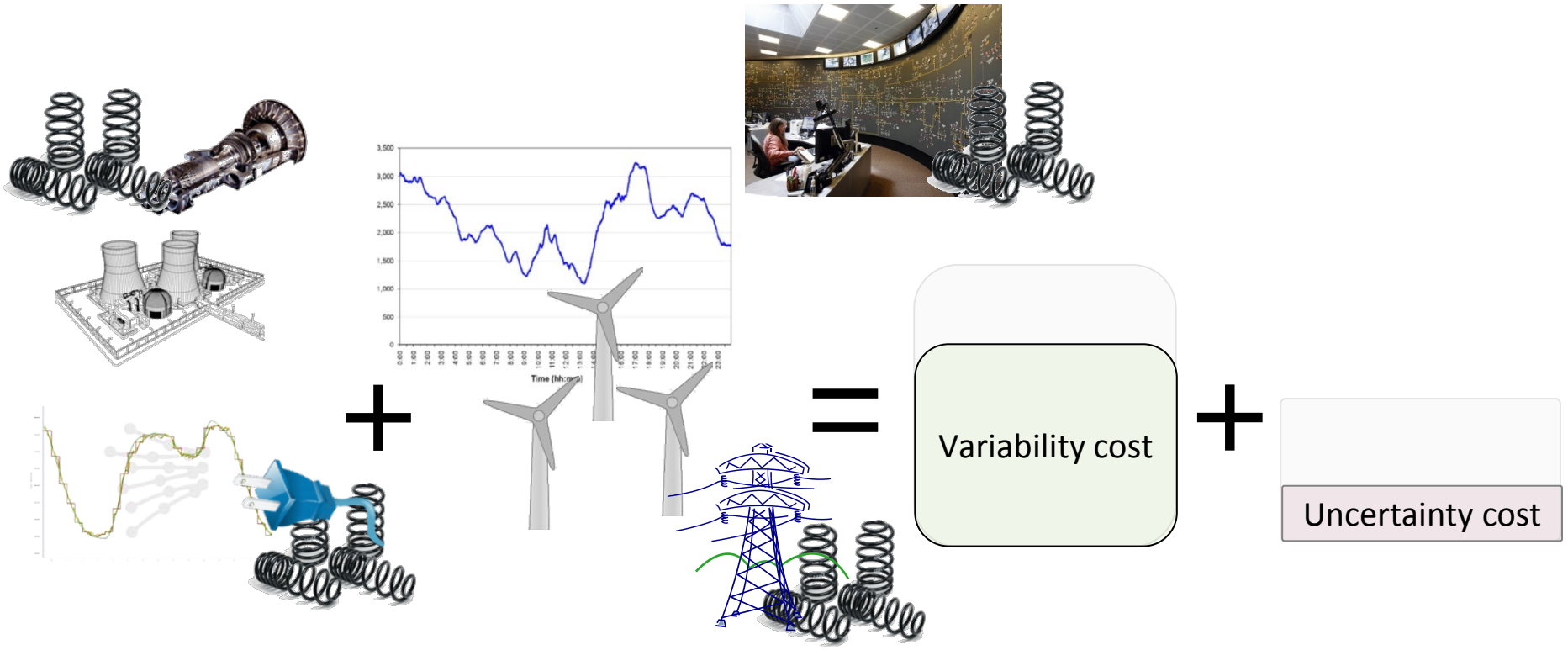
Source: Danish Energy Authority



2050

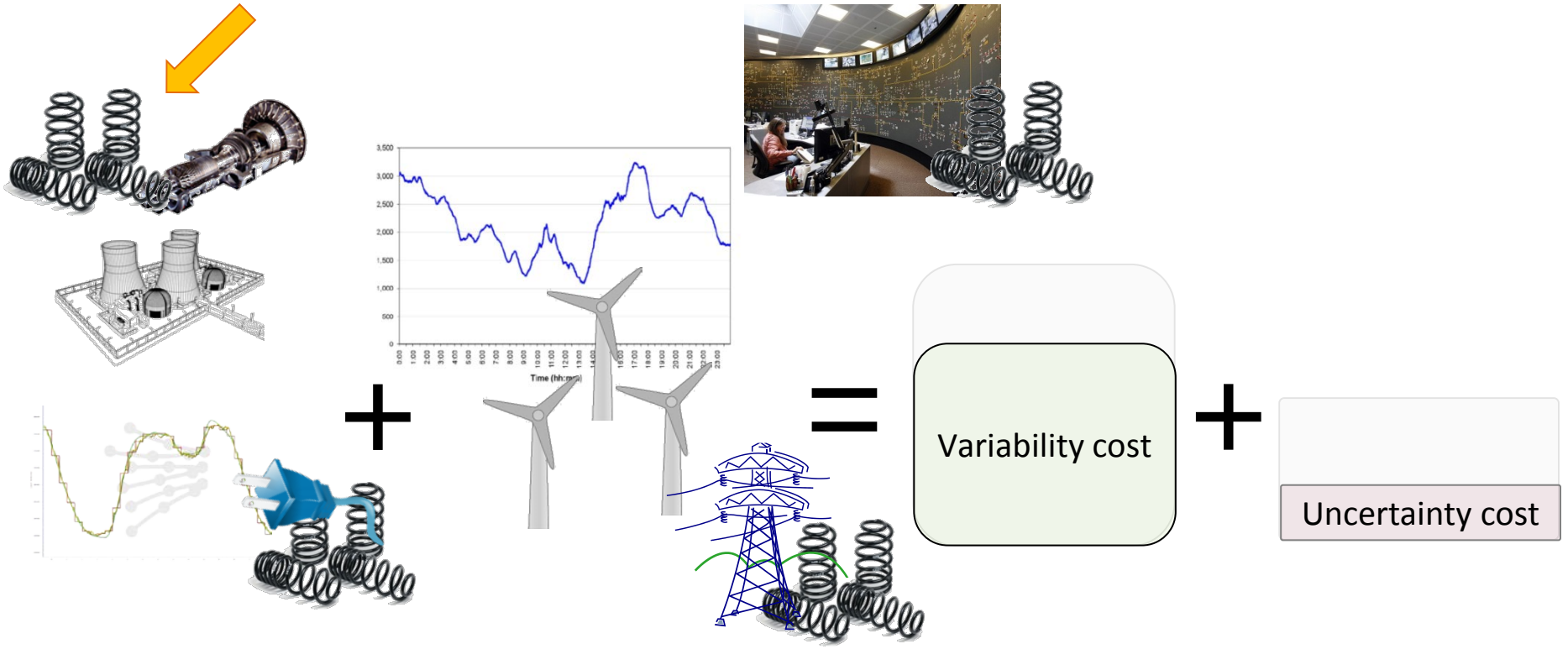
A great deal of variable and uncertain power production!

A wind-dominated energy supply



Flexibility is a must! → Integration and interaction of energy system components

Energy initiatives in Denmark



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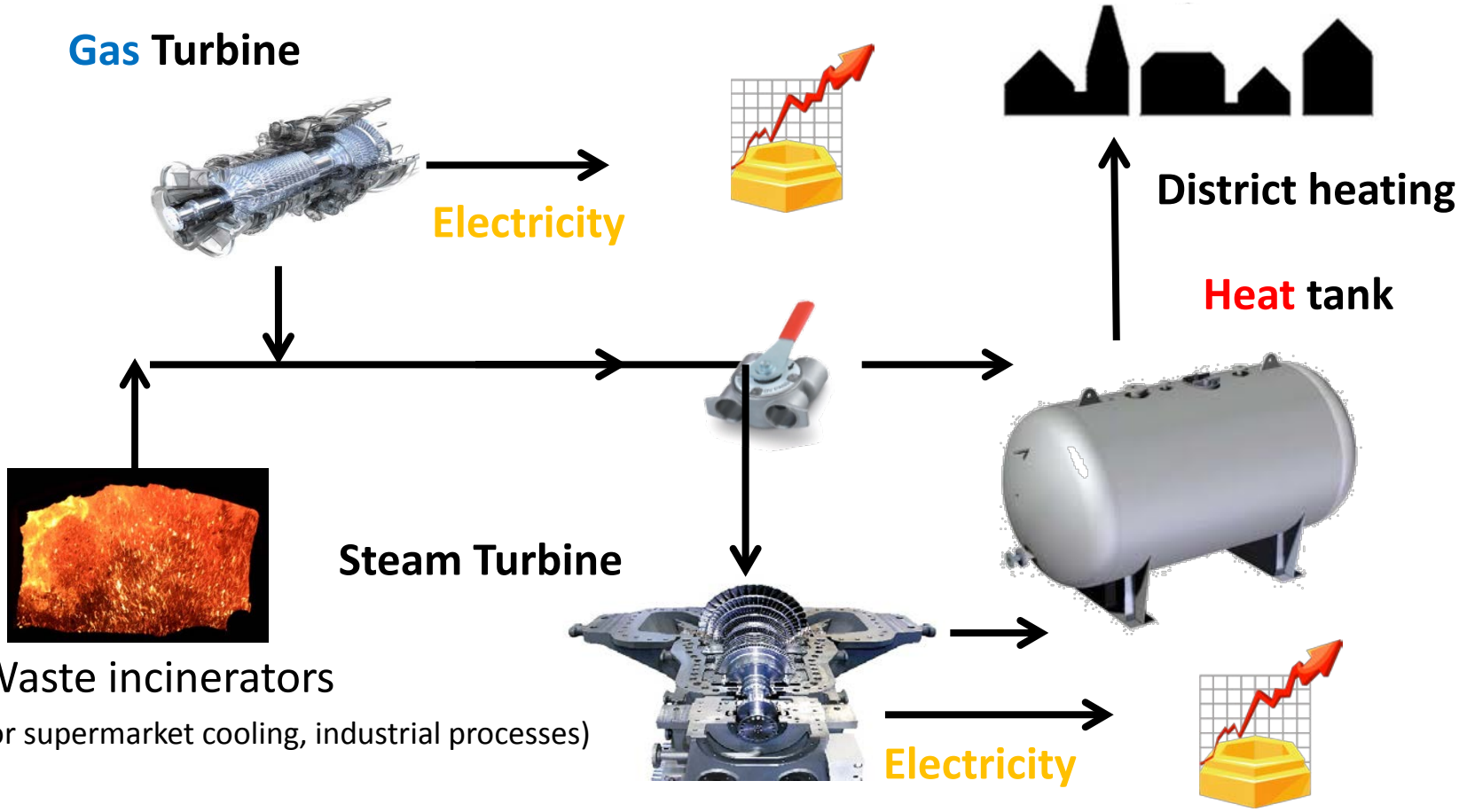
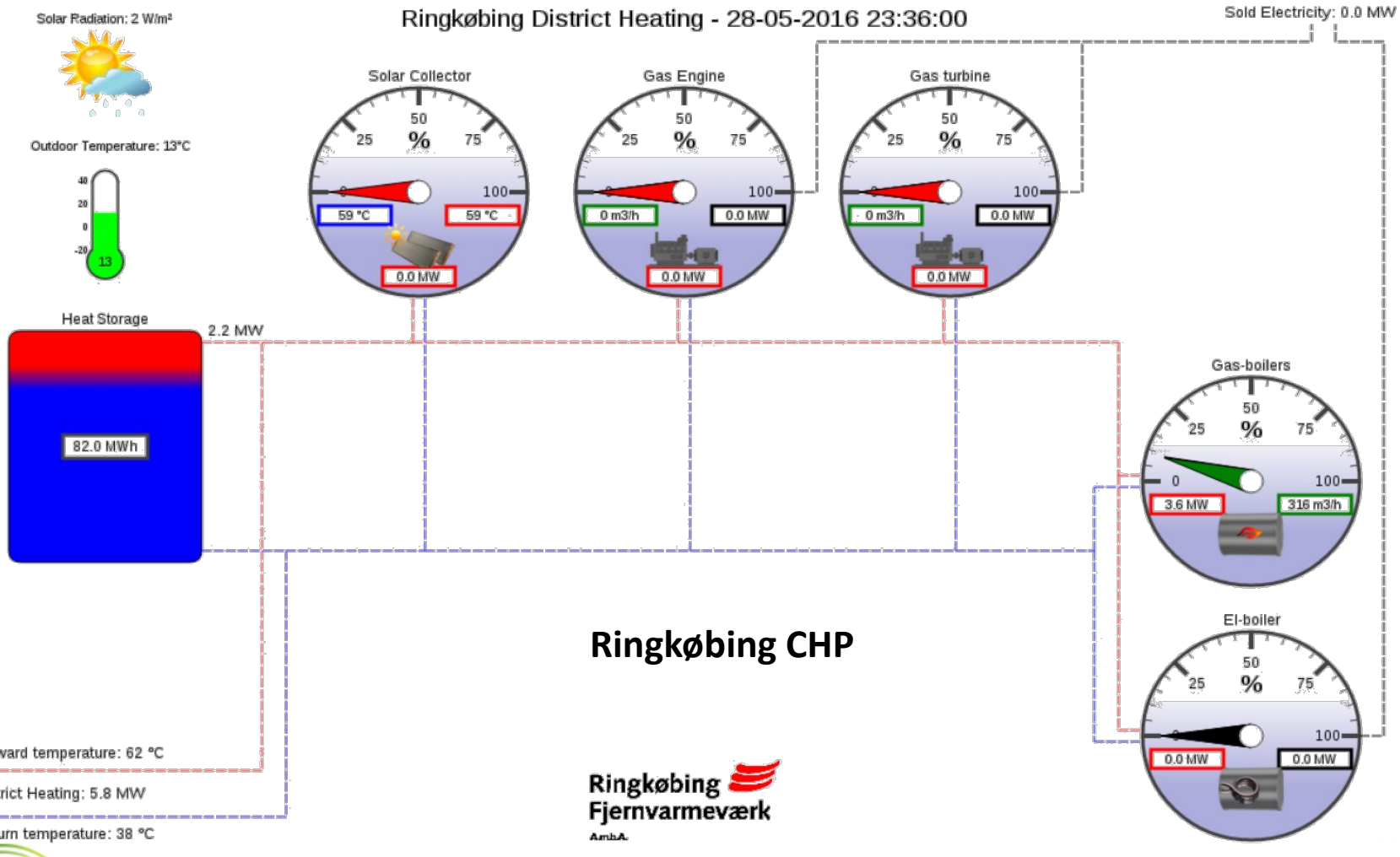


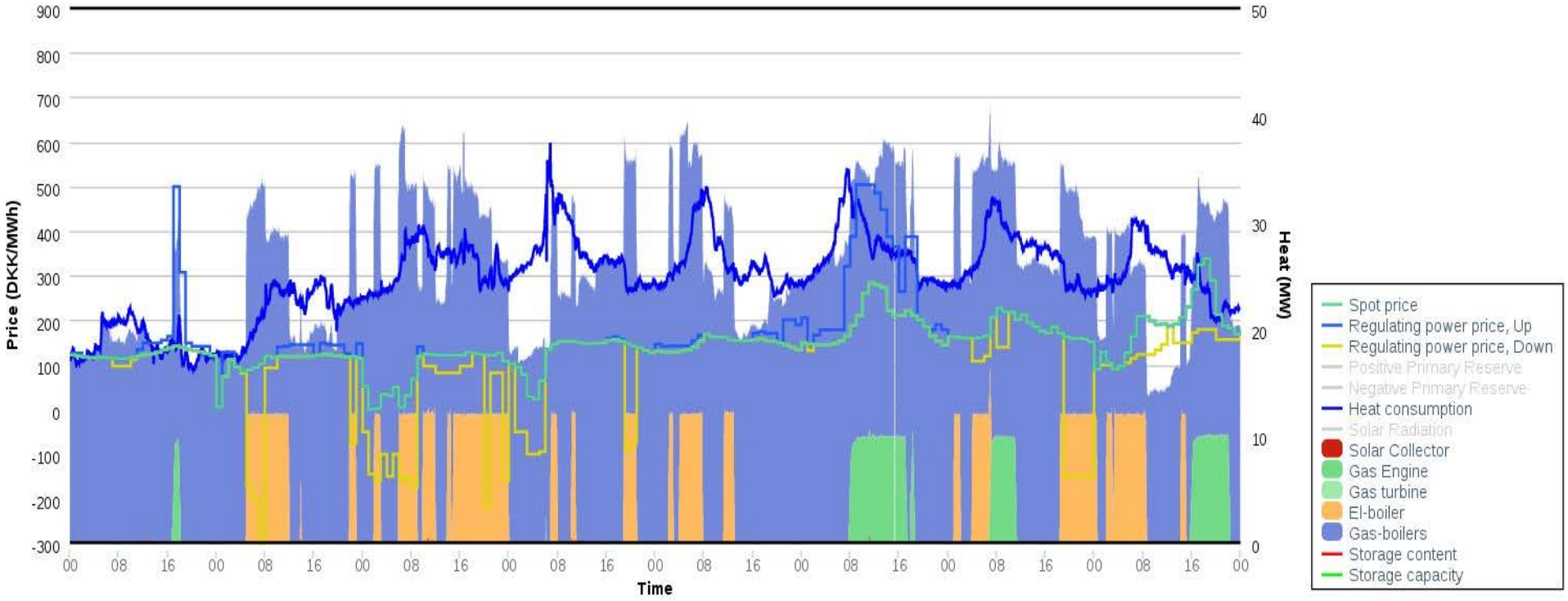
Smarter operation of CHP plants: increased profitability by the provision of more services (day-ahead/intraday electricity trading, power balancing, frequency regulation, heat …)

Energy initiatives in Denmark

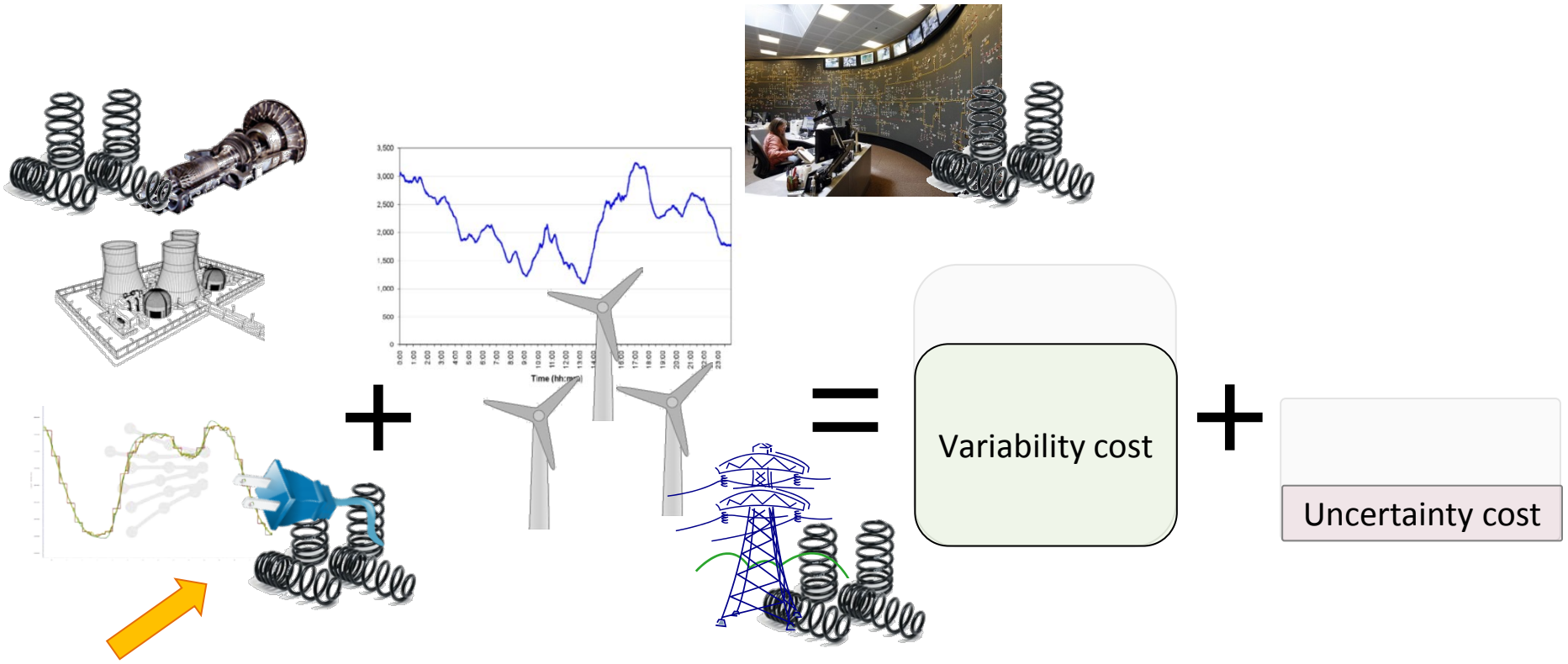


Energy initiatives in Denmark

Ringkøbing CHP



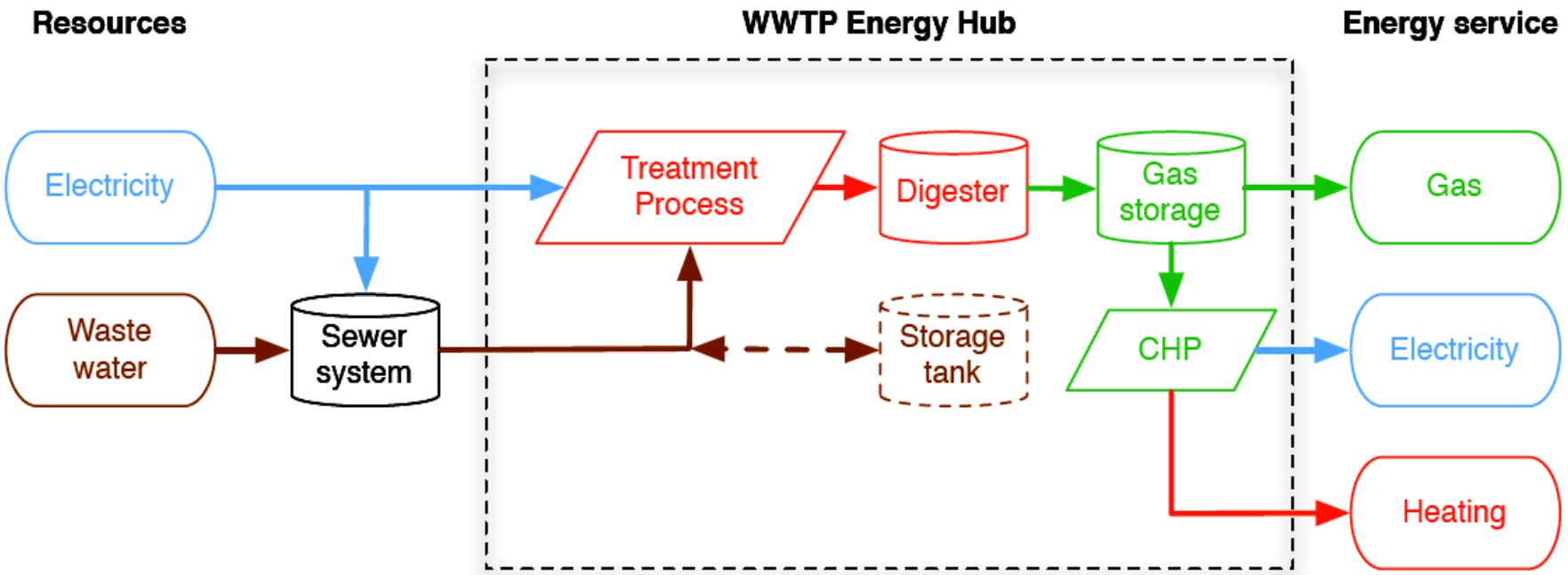
Energy initiatives in Denmark



Flexibility is a must! → Integration and interaction of energy system components

Energy initiatives in Denmark

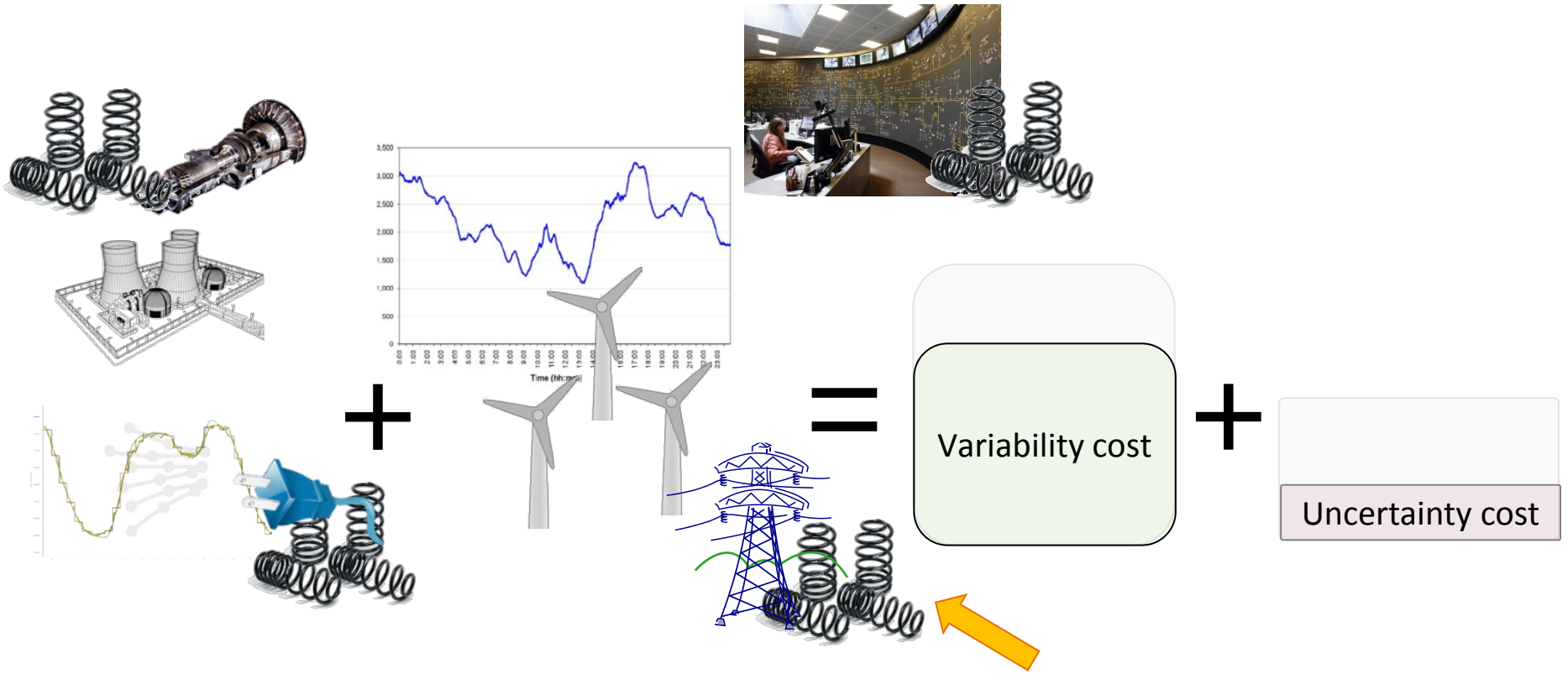
Waste-2-Energy



Energy initiatives in Denmark

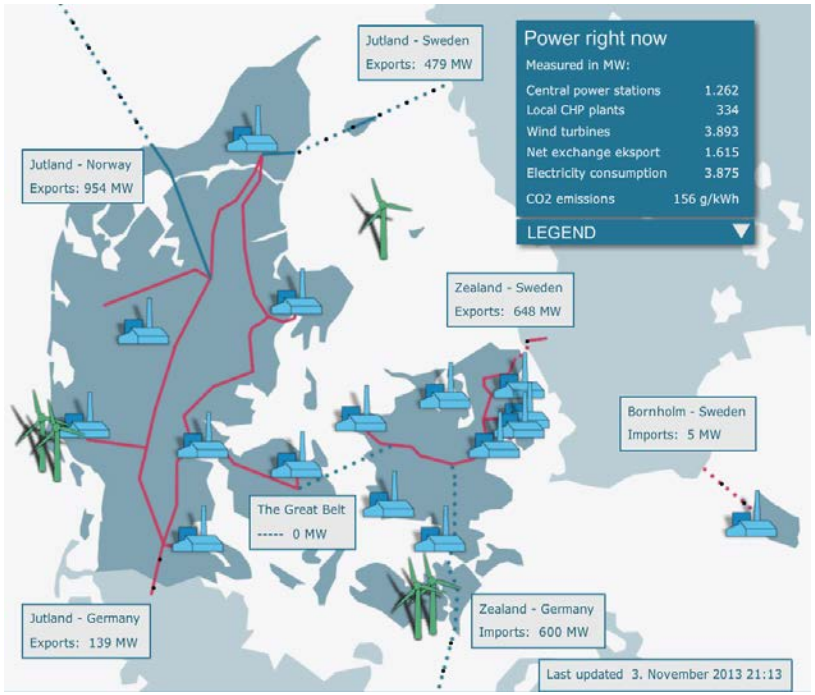
- Heat pumps (Grundfos, ENFOR, ..)
- Supermarket cooling (Danfoss, TI, ..)
- Summerhouses (DC, SE, Energinet.dk, ..)
  - Taking advantage of thermal inertia of indoor pools
  - SmartNet
- Green Houses (NeoGrid, Danfoss, F.Fyn, ...)
- EV charging (Eurisco, ED, ...)
- .....

Energy initiatives in Denmark



Flexibility is a must! → Integration and interaction of energy system components

Energy initiatives in Denmark



DK as a **buffer**: Strong power interconnections to:

1. Norway and Sweden (hydro-dominated Nordic System)
   - A new connection to Norway of 700-MW capacity in place since spring 2015

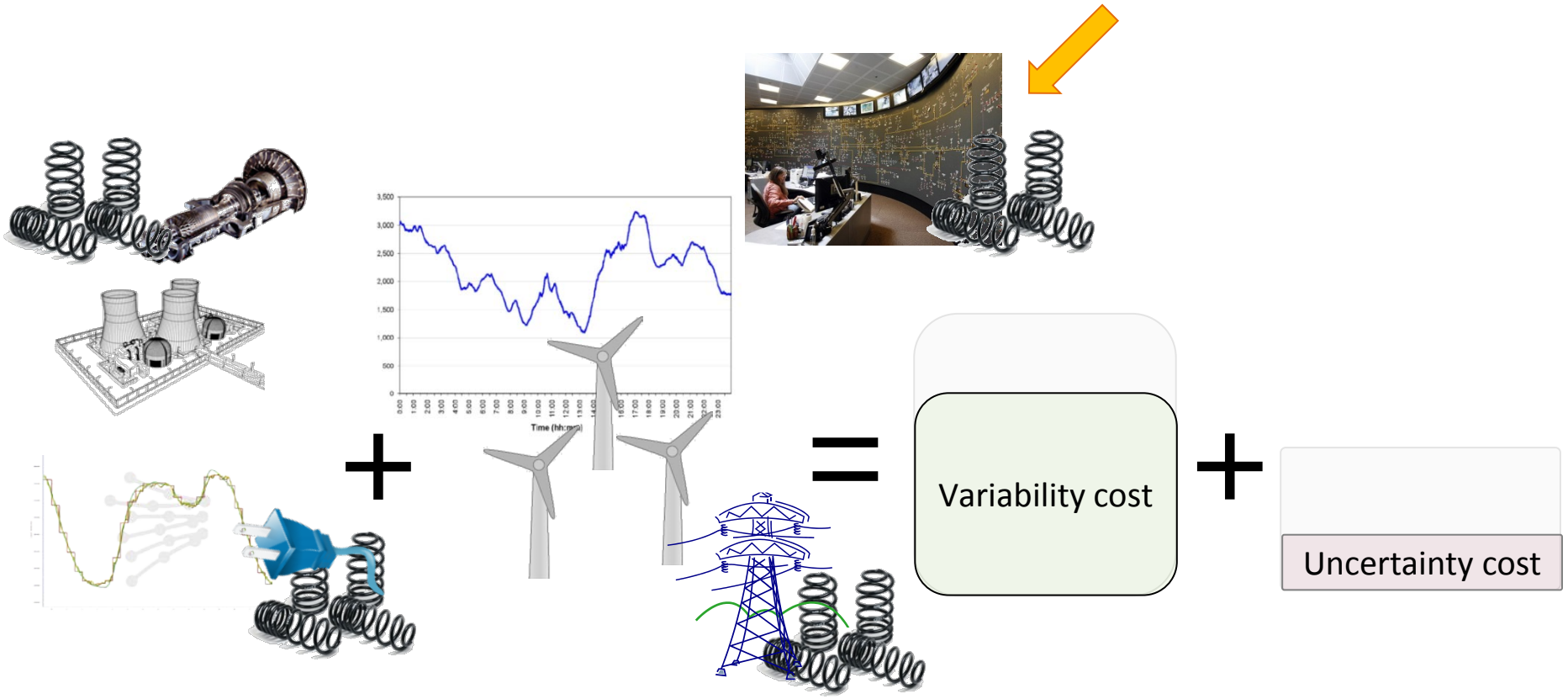
Danish wind-dominated system

Norwegian hydropower-dominated system

2. Germany (fossil-fuel-based power systems of central Europe)
   - Hampered by grid bottlenecks in central Germany

Denmark may also benefit from the planned new connection to the Netherlands (and to the UK?)

Energy initiatives in Denmark



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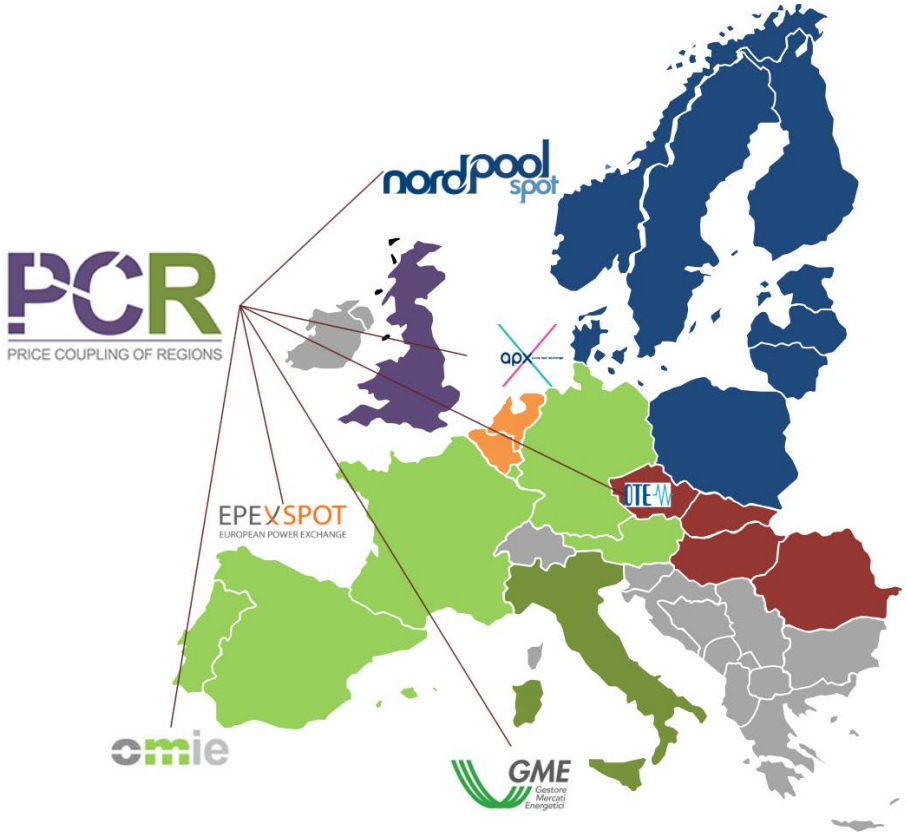
Energy initiatives in Denmark



Common European spot market:

- Denmark, as a member of Nordpool, is tightly connected with Central Western and Southern Europe through price coupling and implicit allocation of cross-border transmission capacity (since 2014)

Increased power trading with Central Western and Southern Europe!

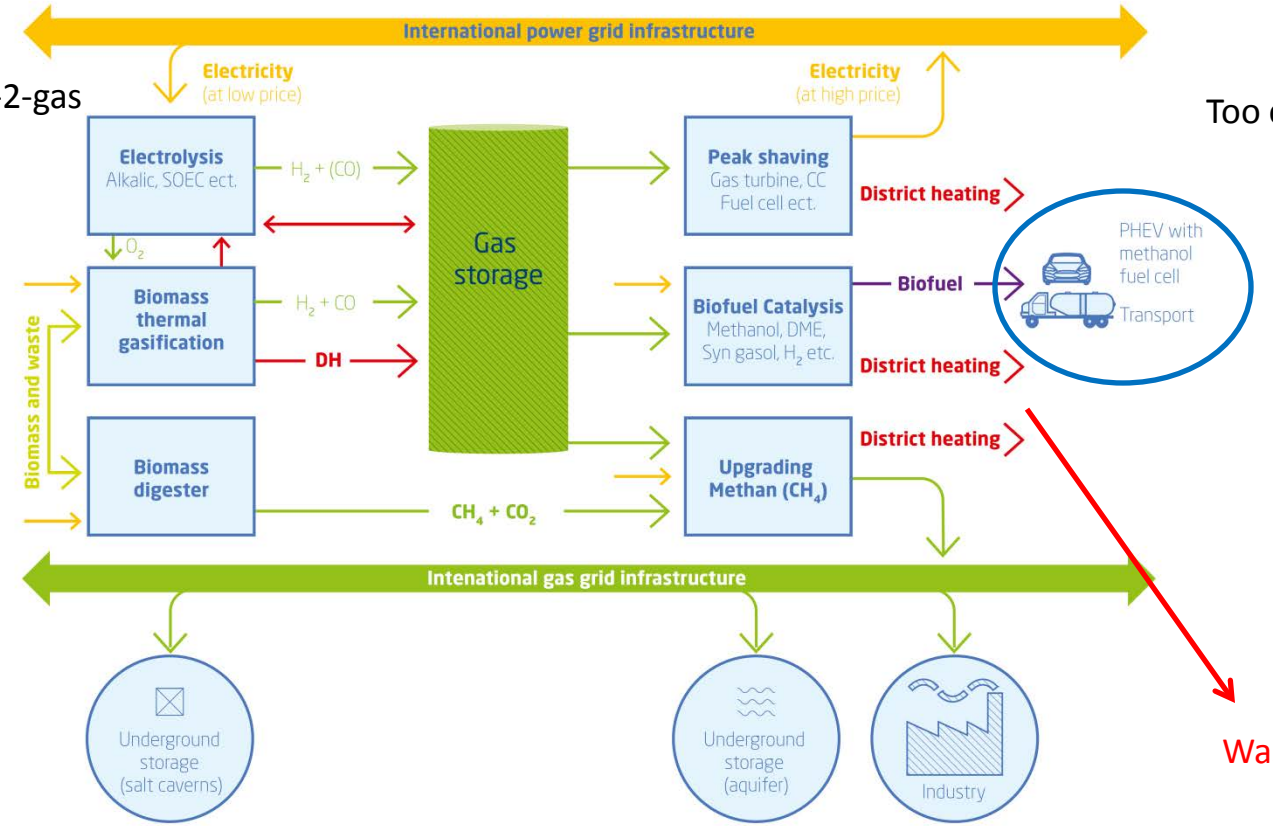
Energy initiatives in Denmark

1. **DataHub:** Central and independent IT system that is maintained by Energinet.dk and that gathers all information about Danish electricity consumption (measurements on power consumption, changes of supplier by customers, etc.)
   - Facilitate the billing process (single invoice handled by retailers), enable demand-side management and encourage competition in the retail market
2. **MarketModel 2.0**: Project led by Energinet.dk to investigate market solutions for renewables-based power systems
   - Analysis of markets for ensuring strategic reserve capacity in extreme situations
   - Analysis of capacity markets (direct payments for capacity) to guarantee capacity adequacy
3. **Varmelast.dk**: Tool to operate the district heating system in the Greater Copenhagen area in a cost-efficient manner
   - Consideration of implementing dynamic heat prices (through marginal pricing of heat) that would help to better capture electricity-heat interactions

Concluding Remarks

- Major opportunity to increase the flexibility of the Danish energy system: **exploit interactions among the three major energy networks**

Power-2-gas



Too costly?

Extremely important to increase the value of gas, as transport fuel is the most difficult to replace and has a fairly high cost

Waste heat

Source: DTU International Report 2015 (Chapter 10)

Concluding Remarks

- **District heating network as a storage facility** to absorb excess wind power
  - Existing hot water storage tanks + the large amounts of water in the grid as a buffer
  - Large heat pumps and electric boilers to store surplus of wind power as hot water
- The existing coal-based CHP-plants will be gradually converted to biomass or decommissioned. **New supplies of district heating** will be needed:
  - Renewables-based such as heat pumps, electric boilers, solar heating …
  - Waste heat from industrial processes and new products (previous slide)
  - Attractive taxation schemes are to be in place
- Grid interactions will make **energy systems much more complex**: advanced control and communications systems might be required