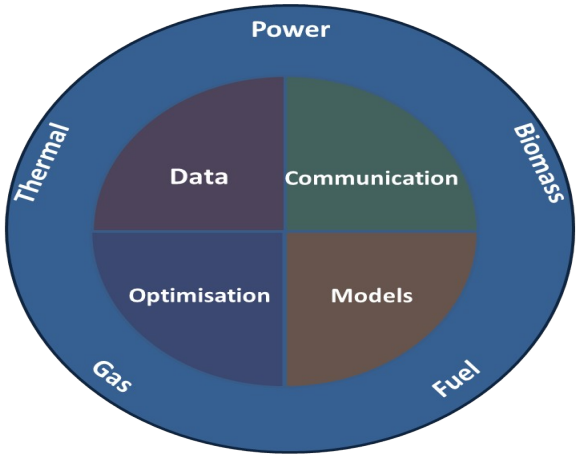
ESI in Denmark:
A Solution with More than 40 pct Wind Power

Panel Session on Energy Systems Integration



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PES, Denver Colorado, July 2015

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?

Potentials and Challenges for renewable energy

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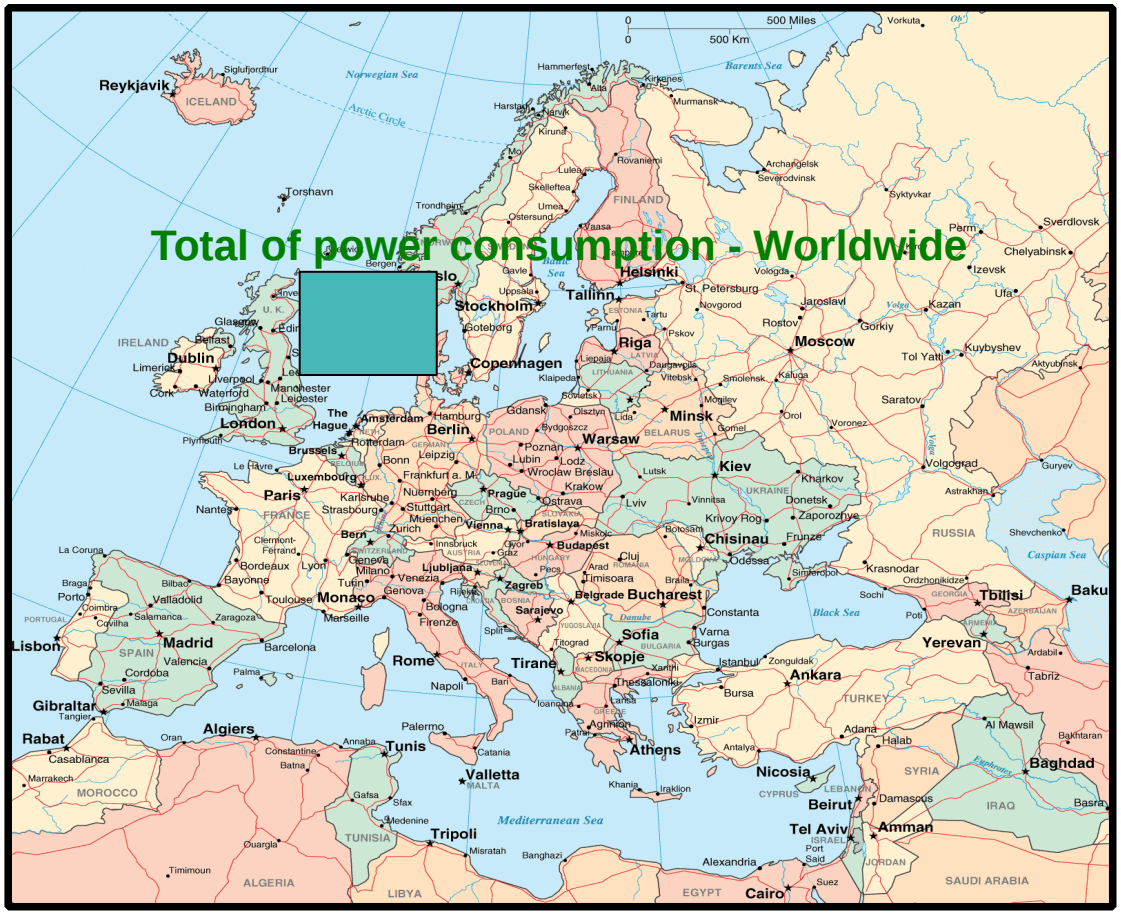
- How large an area should be covered by wind turbines?
- **Conclusion**: Use intelligence ....
- Calls for **IT / Big Data / Smart Cities / Models / Energy Systems Integration**



Danish Energy Policy and Planning in short:

1973-74: WAKE-UP call

- ***2 countries in the world were >95% dependent on imported energy****: Japan and Denmark (oil and coal)*
- *The oil crisis made it a matter of national priority to embark new alternative solutions**.***

How did Denmark achieve that?

Today: (40 years later)

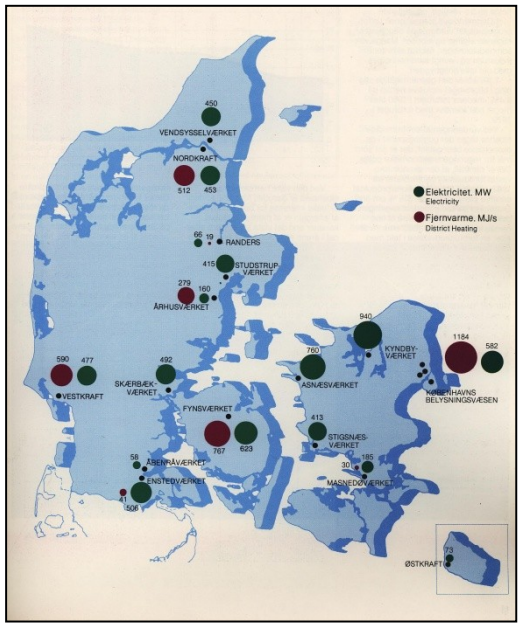
- ***Lowest energy consumption*** *per GDP-unit in the EU*
- ***Highest contribution from new renewables*** *(non-hydro) to electricity in the world*
- ***Leading*** *nation in* ***advanced energy solutions*** *(****CHP****,* ***wind, multi-fuel, energy saving****s…)*

The rough phases of Danish energy policy

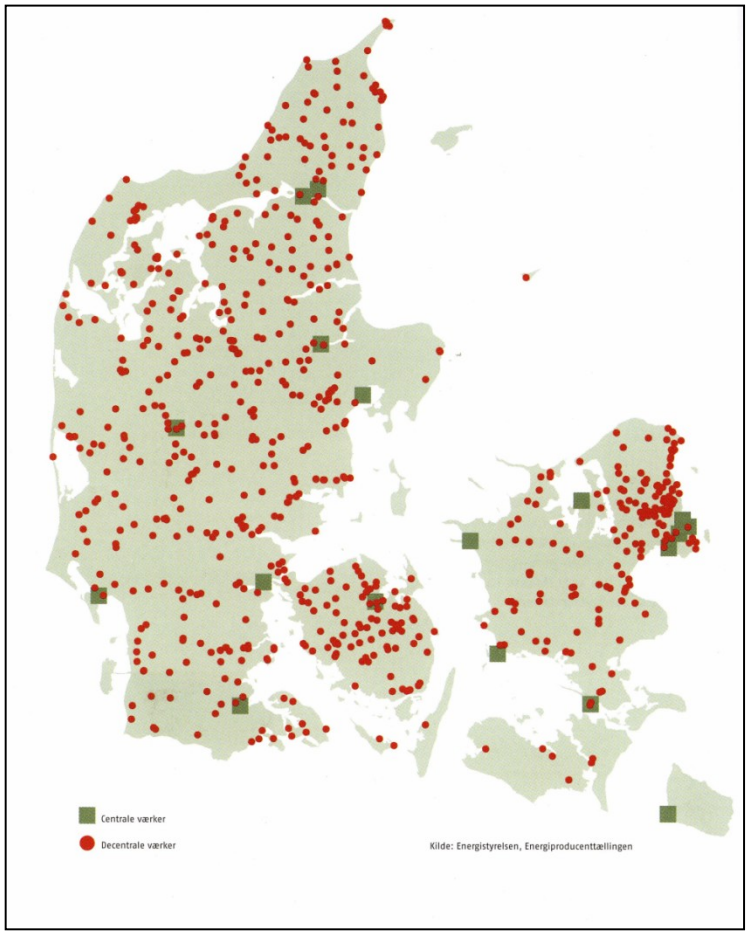
before 1973	No specific energy policy
	"Supply whatever is needed" by a regulated, public-owned industry
1976-1981	First strategic energy plans, focus on energy security and socio-economic thinking
	Energy Plan 81: § Energy Conservation (De-couple consumption from economic growth) § Different technology alternatives (Nuclear, Renewable, Gas…)
1982-1986	Development of the renewable energy option
	The visionary Hvelplund report (1983)
1987-1995	Climate change response: action plan approach
	'Energy 2000' (1990): CO2 reductions focus (savings, CHP, renewables)
1996-2010	Focus on liberalisation and competition
	Electricity Supply Act (1999): Open market, unbundling, free choice of supplier
2011-….	New momentum towards a sustainable energy system

From large central plants to Combined Heat and Power (CHP) production

1980

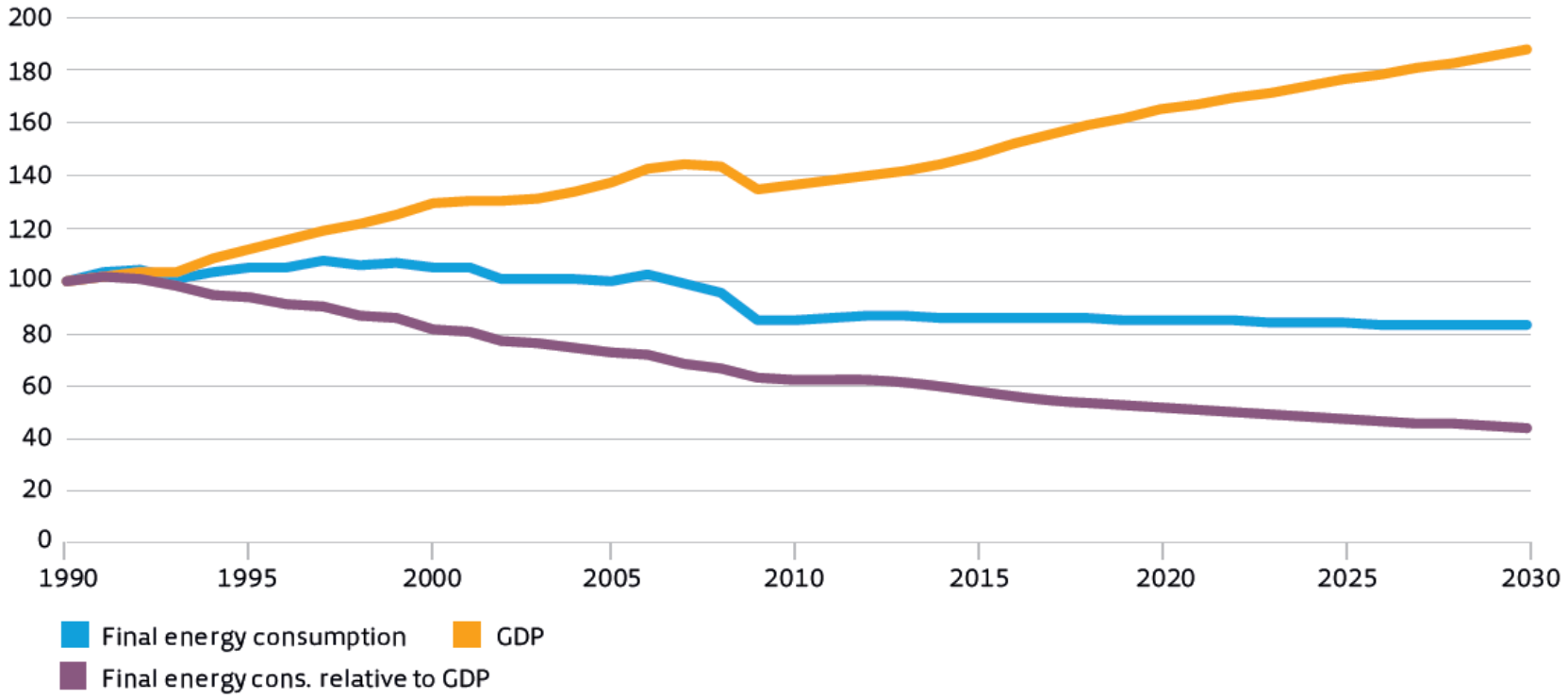


Today



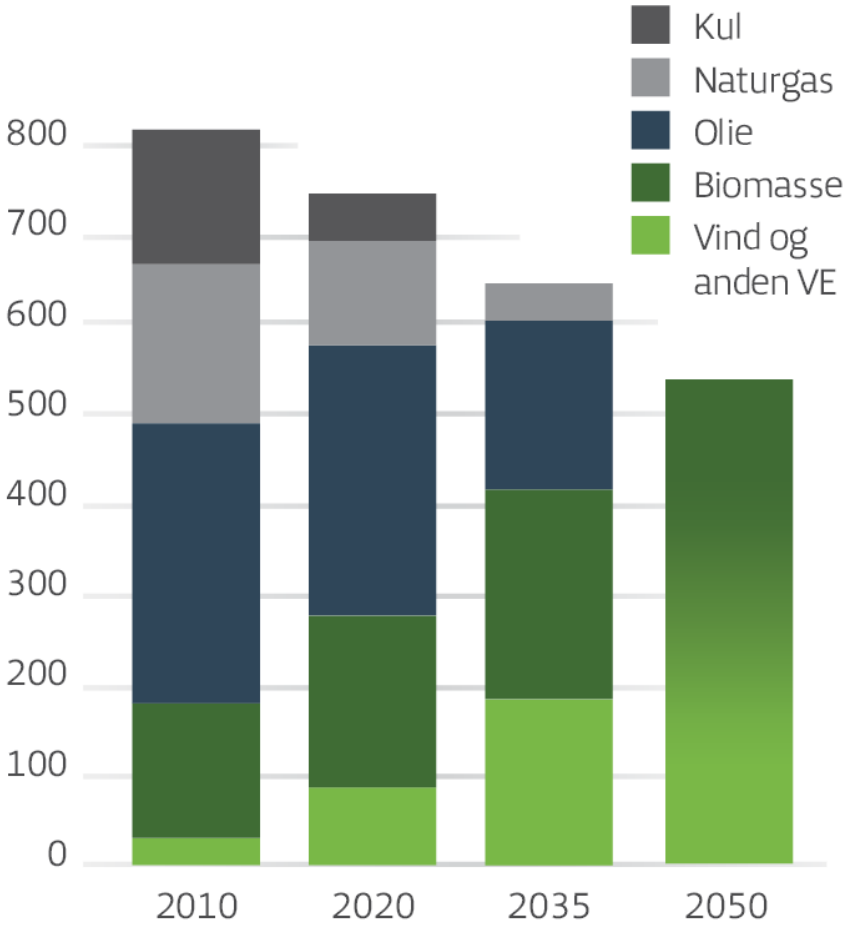
*From a few big power plants to many small **combined heat and power** plants – however most of them based on coal*

What has since been achieved: De-coupling of consumption and GDP growth



Source: Energy Policy in Denmark. Danish Energy Agency. December 2012

The Danish Vision



Figur 3.8 Anvendelse af fossile brændsler og VE (PJ)

2020: 50% of Danish Power consumption is supplied by Wind Power

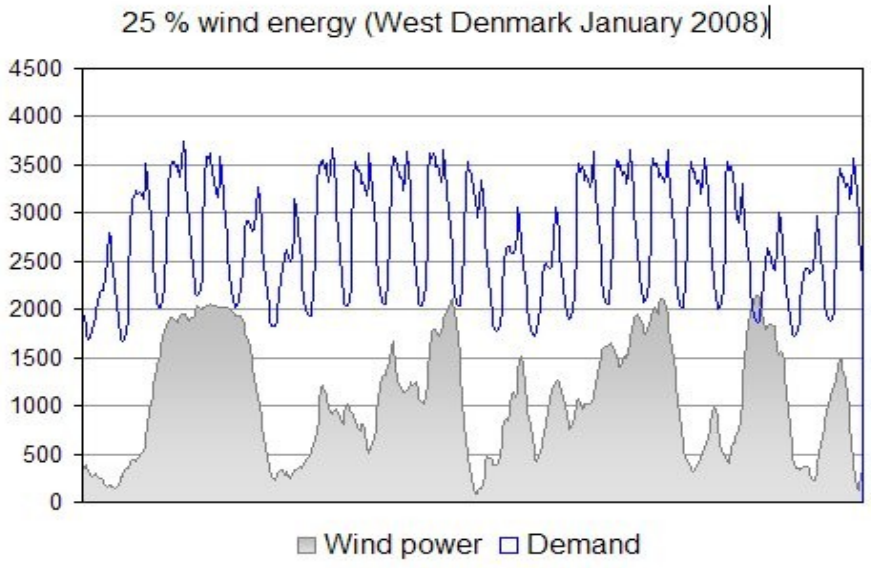
2030: No use of coal in Danish Power plants – no oil boilers

2035: All heat and power consumption is supplied by renewables

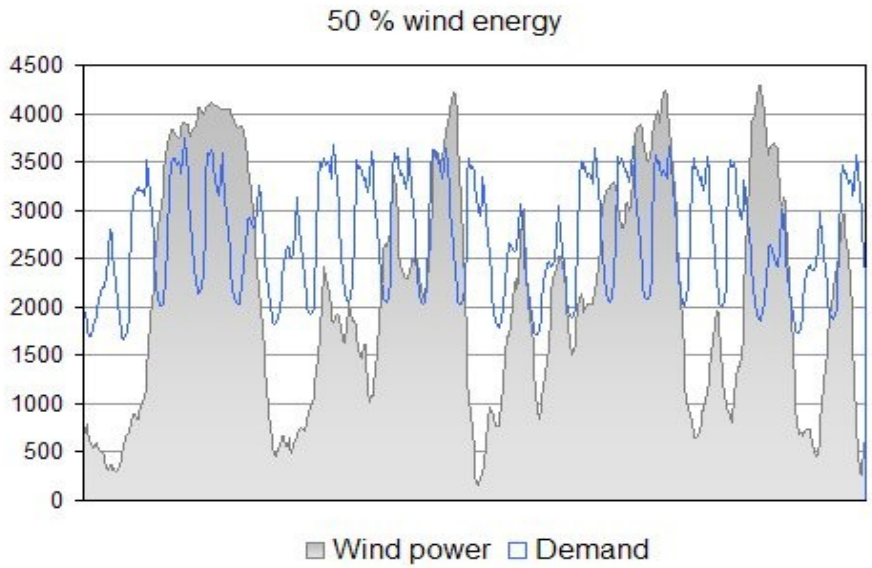
2050: The entire Danish energy consumption is supplied by renewables

The Danish Wind Power Case

.... balancing of the power system



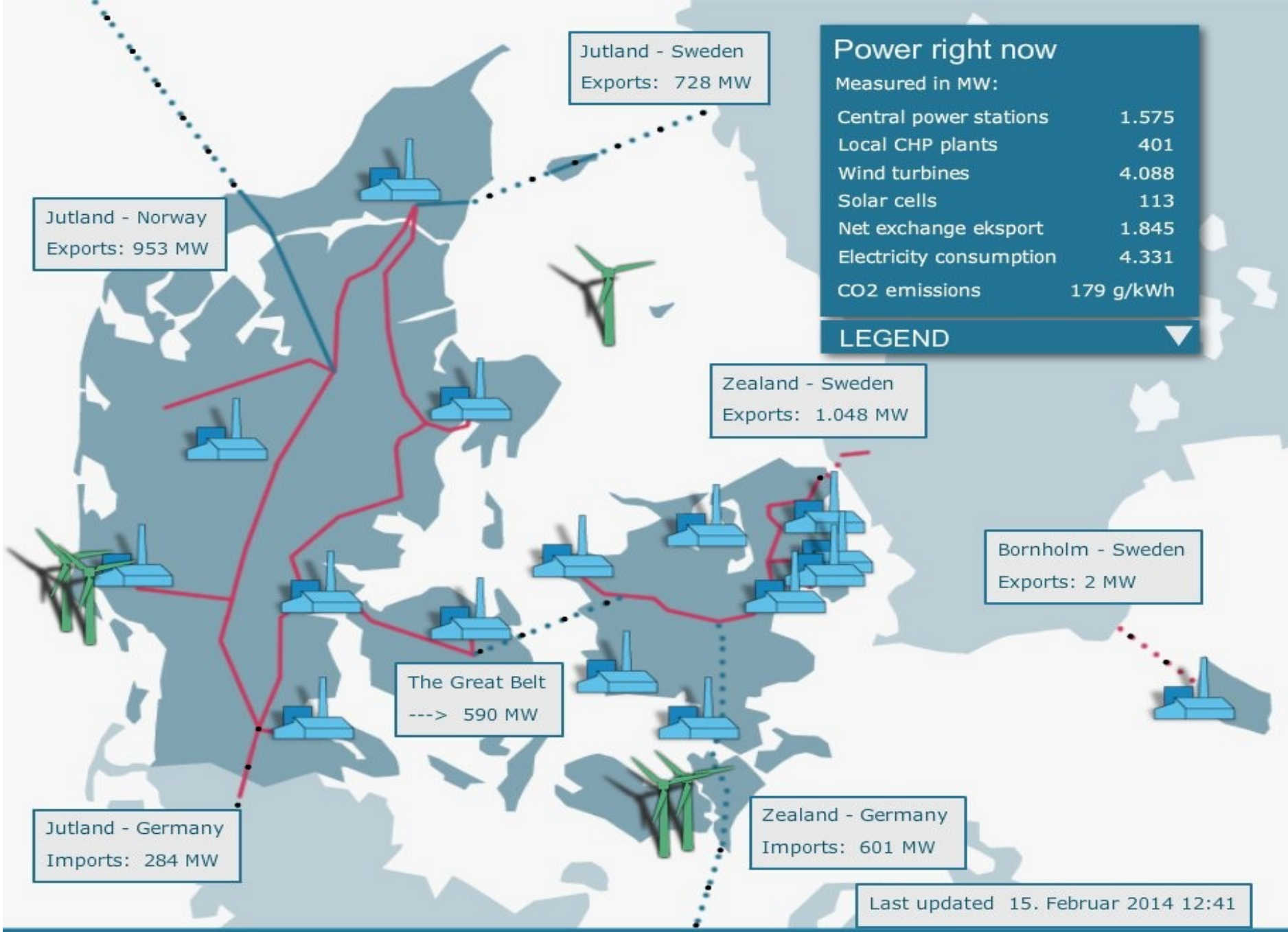
In 2008 wind power did cover the entire demand of electricity in 200 hours (West DK)



In 2014 more than 40 pct of electricity load was covered by wind power.

For several days in 2014 the wind power production was more than 120 pct of the power load.

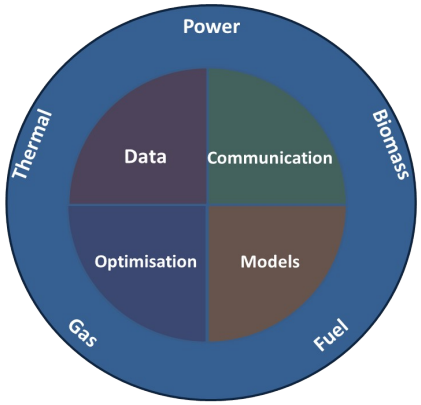
July 14th, 2015 more than 140 pct of the power load was covered by wind power


Jutland - Sweden
Exports: 728 MW
Power right now
Measured in MW:
Central power stations 1.575
Local CHP plants 401
Wind turbines 4.088
Solar cells 113
Net exchange eksport 1.845
Electricity consumption 4.331
CO2 emissions 179 g/kWh
LEGEND
Jutland - Norway
Exports: 953 MW
Zealand - Sweden
Exports: 1.048 MW
Bornholm - Sweden
Exports: 2 MW
The Great Belt
---> 590 MW
Jutland - Germany
Imports: 284 MW
Zealand - Germany
Imports: 601 MW
Last updated 15. Februar 2014 12:41
Power right now
Natural gas right now
Locations

ESI Hypothesis

The **central hypothesis of ESI** is that by **intelligently integrating** currently distinct energy flows (heat, power, gas and biomass) in we can enable 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.

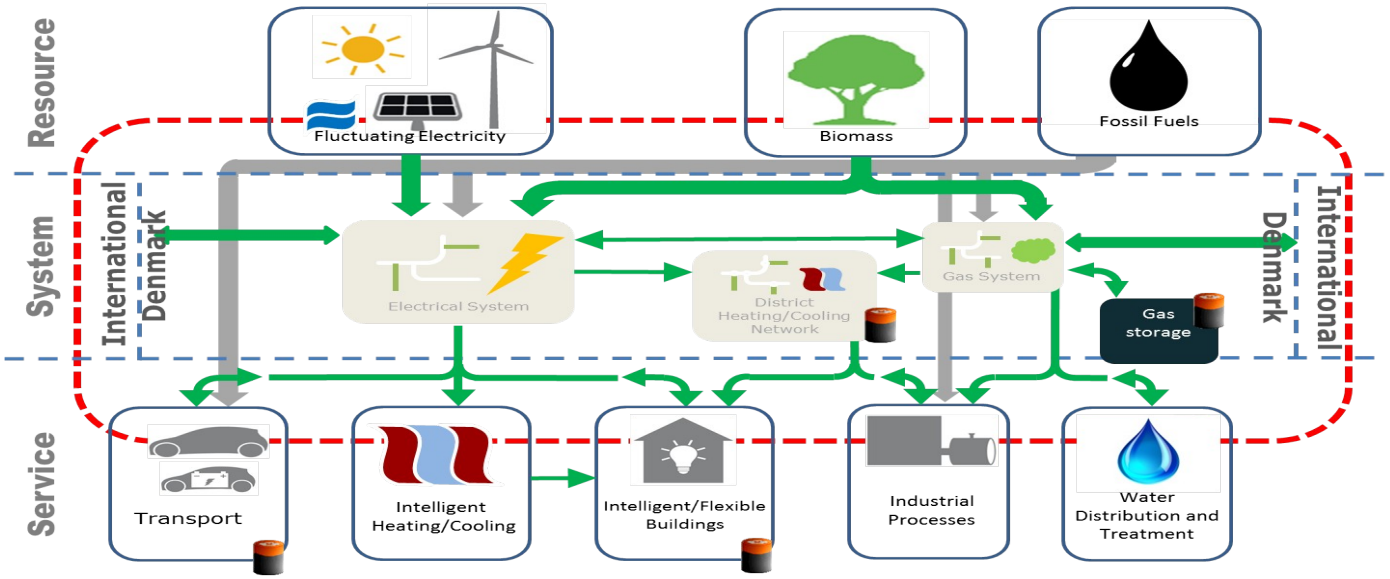


ESI Solutions

The ***Center for IT-Intelligent Energy Systems in Cities (CITIES)*** is aiming at establishing methodologies and solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales.

This Center is the largest Smart Cities and ESI research project in Denmark – see http://www.smart-cities-centre.org .

Example: Storage by Energy Systems Integration



- **Denmark (2014): 48 pct of power load by renewables (> 100 pct for some days)**
- **(Virtual) storage principles:**
  - Buildings can provide storage up to, say, 5-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - Gas systems can provide seasonal storage

Conclusions

- In Denmark on average about 50 pct of the power load is now covered by renewables. Sometimes more than 120 pct of the power load is covered by wind. This is possible by an increased focus on decentralized CHP plants.
- ESI can provide virtual and lossless storage solutions (so maybe we should put less focus on physical storage solutions)
- ESI might be able to solve many of the problems Europe now is trying to solve by Super Grids (some of these huge investments might not be needed)
- Europe should put less focus on super-grids – I assume that ESI can solve a major part of the issues (the planned investements are huge – and maybe we don't need them)
- Focus on zero emission buildings – and less on zero energy buildings (the same holds supermarkets, wastewater treatment plants, etc.)
- District heating (or cooling) provide virtual storage on the essential time scales (up to a few days)
- We see a large potential in Demand Side Management combined with ESI. Automatic solutions and end-user focus are important
- We see large problems with the tax and tariff structures in many countries (eg Denmark). Coupling to prices for carbon capture could be advantageous.
- Markets and pricing principles need to be reconsidered; we see an advantage of having a physical link to the mechanism (eg. nodal pricing, capacity markets)