Energy system flexibility and integration

- precondition for large scale integration of VRE (wind) in the Danish power system

iiESI
Imperial College
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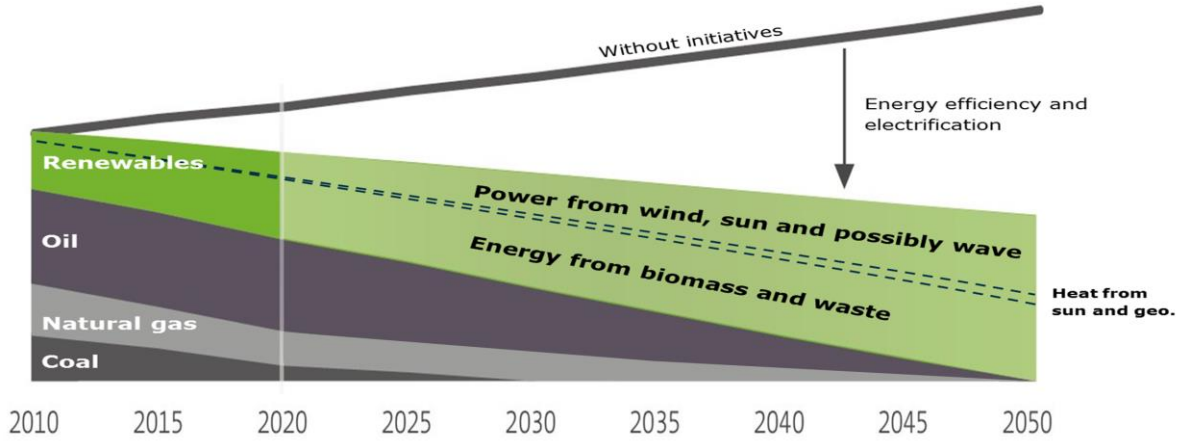
Agenda

- The Danish power system – overview of large scale integration of wind (VRE)
- Energy integration of VRE within connected power systems
- Energy integration across energy sectors

Energy consumption in Denmark towards 2050

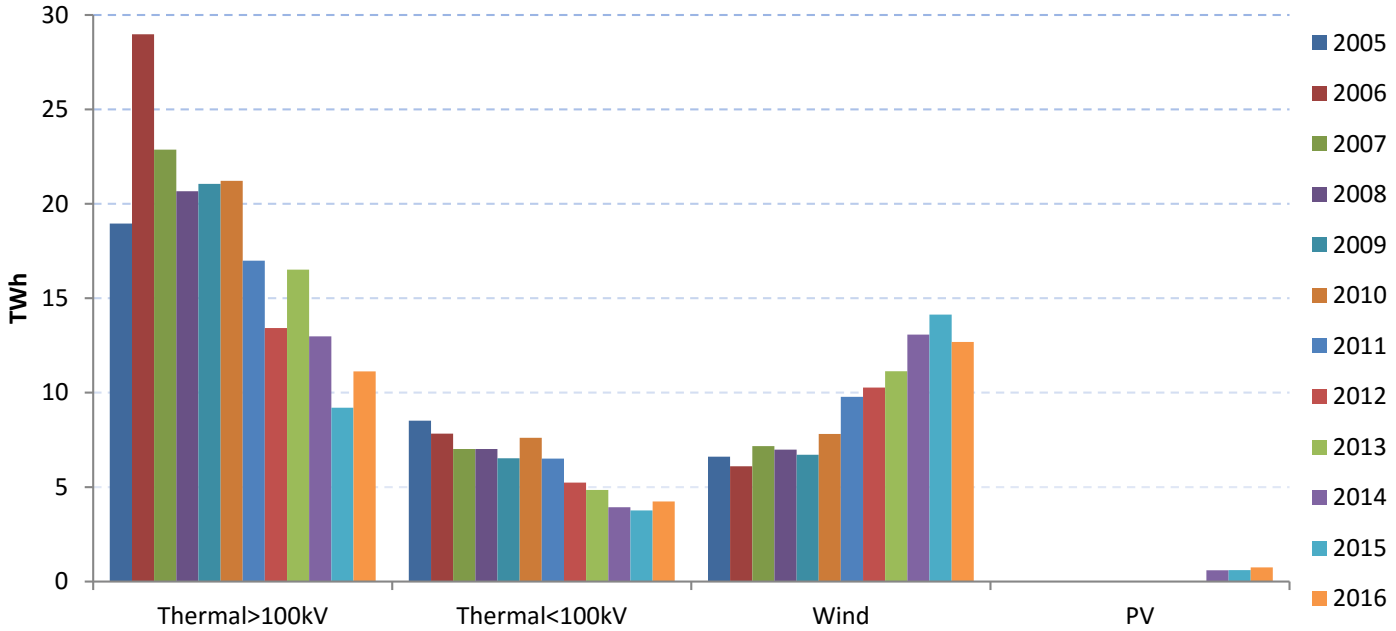
The Green Energy Transition in Denmark is primarily based on:

1. Highly increased energy efficiency – especially through electrification
2. Much more fluctuating power production from especially wind (– and sun)

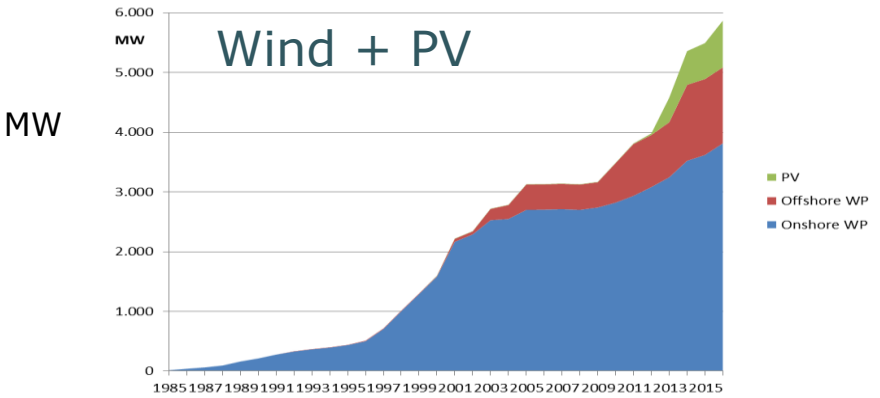


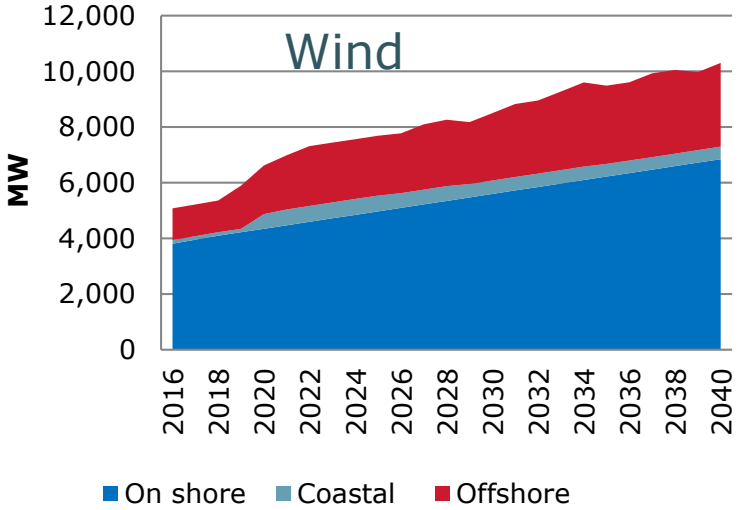
- 2020: DK wind power will constitute 50% of the electricity consumption
- 2050: Denmark must be independent of fossil-fuels

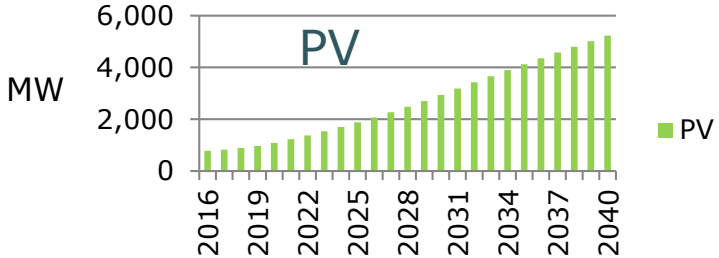
DK Generation of thermal and wind 2005-16; 2016: wind generation approx. 40 % of yearly demand



Development of Wind Power and PV in Denmark





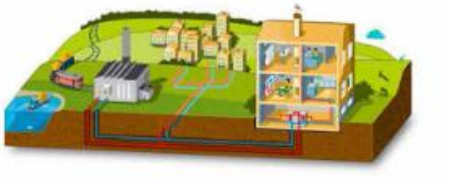


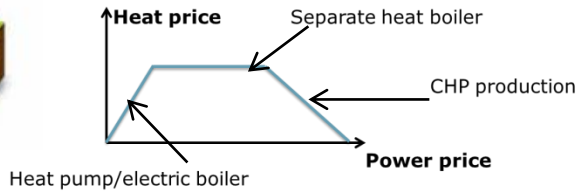
Danish Renewable Energy systems

Large scale integration of VRE (wind and PV) needs flexibility.

Flexibility measures:

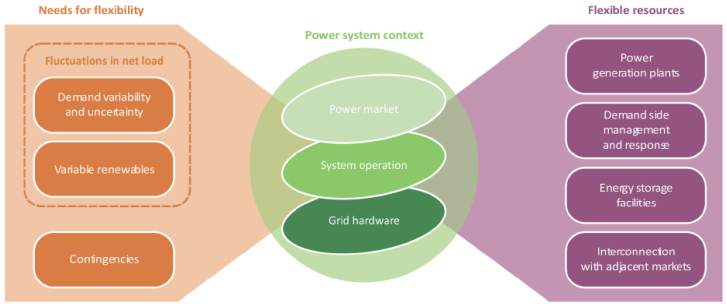
- **A)** Within European integrated power systems
- **B)** Across different energy sectors:
  - Power system
  - Heat system
  - Transport system
  - Natural gas system
  - ……





Flexibility of power system

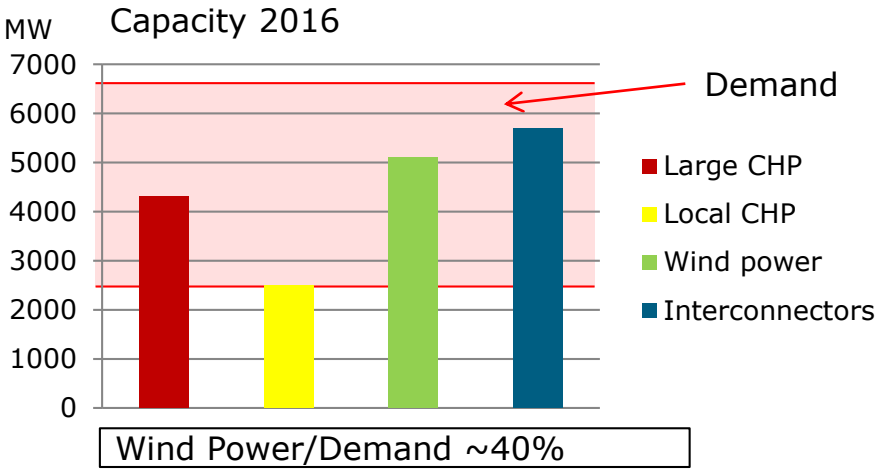
- Physics (**"hardware"**)
  - **Generation**
  - **Demand**
  - **Storage**
  - **Transmission**
- **Market** (facilitator) is the **"software"** that dispatches the physical resources (short term) and gives incentives for new investments (long term)
- System operation (facilitator), e.g. good forecasts reduce need for reserves

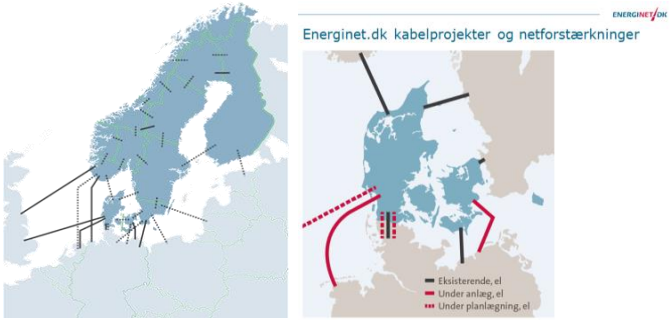


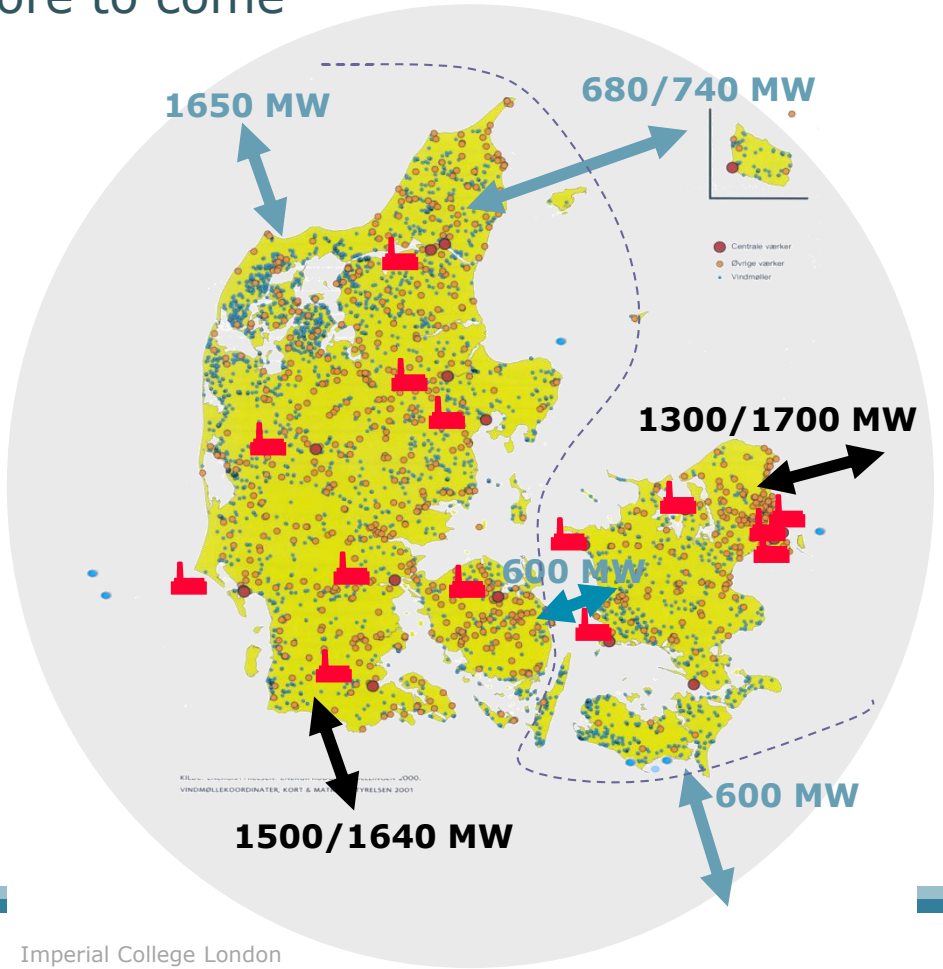
Existing and new flexibility needs can be met by a range of resources in the electricity system – facilitated by power system markets, operation and hardware.

The ability of a power system to handle variaility and uncertainty in generation and demand whil maintaining satisfactory reliability

A) The Danish electricity system has strong connections abroad and more to come



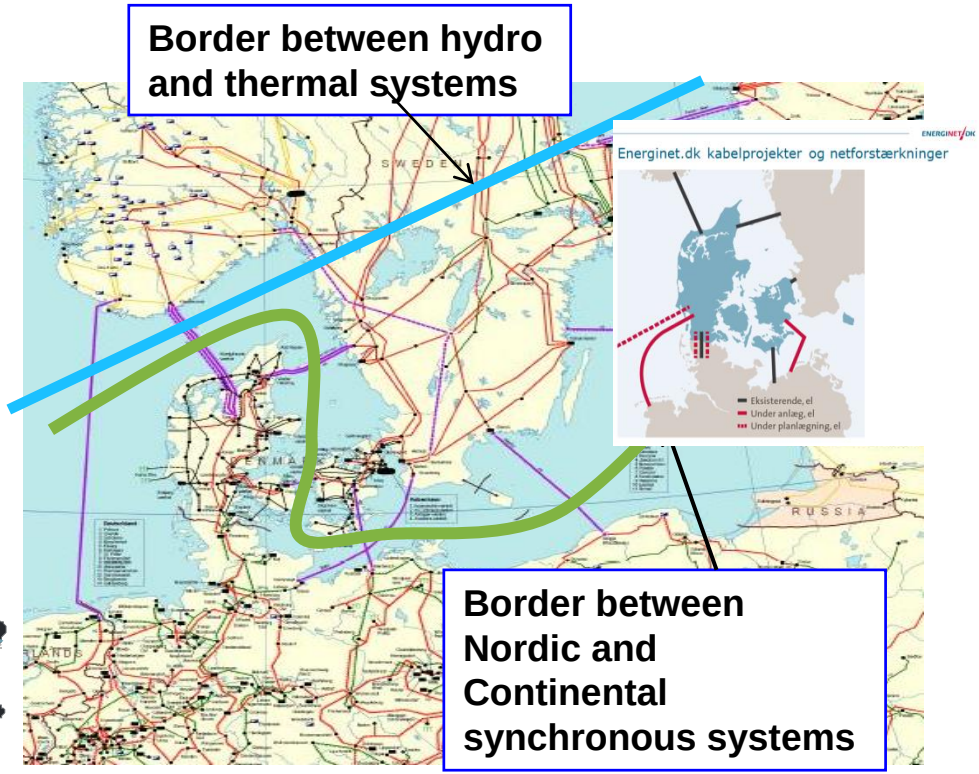




A)

Denmark has important storage opportunity in Norway/Sweden (flexibility)

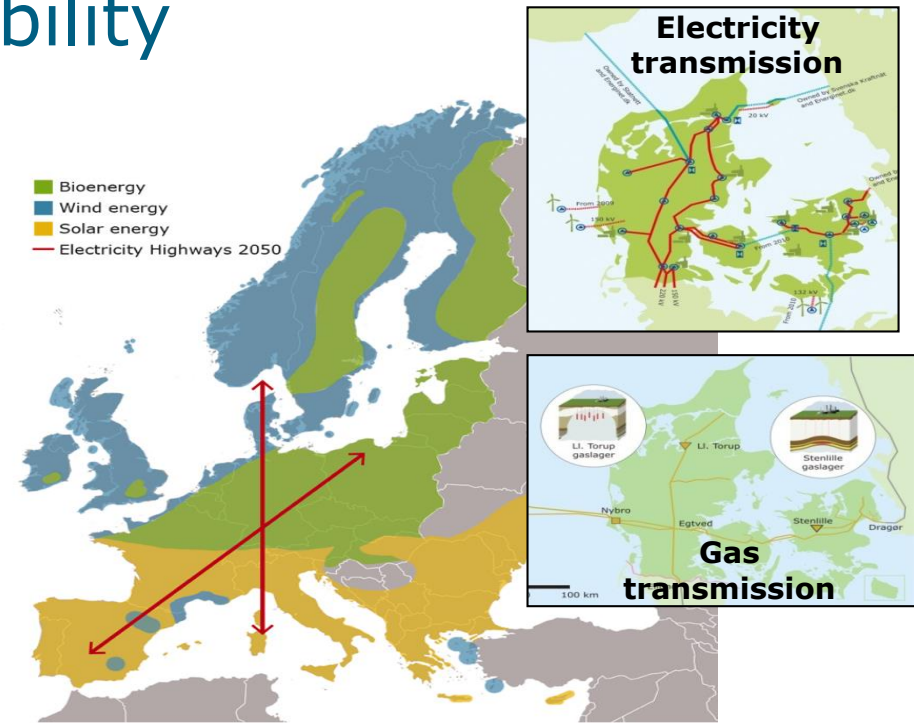
Denmark is a bridge between the hydro-dominated Norway/Sweden and the thermal dominated European Continental power system



European Transmission Planning -grid is facilitator of flexibility

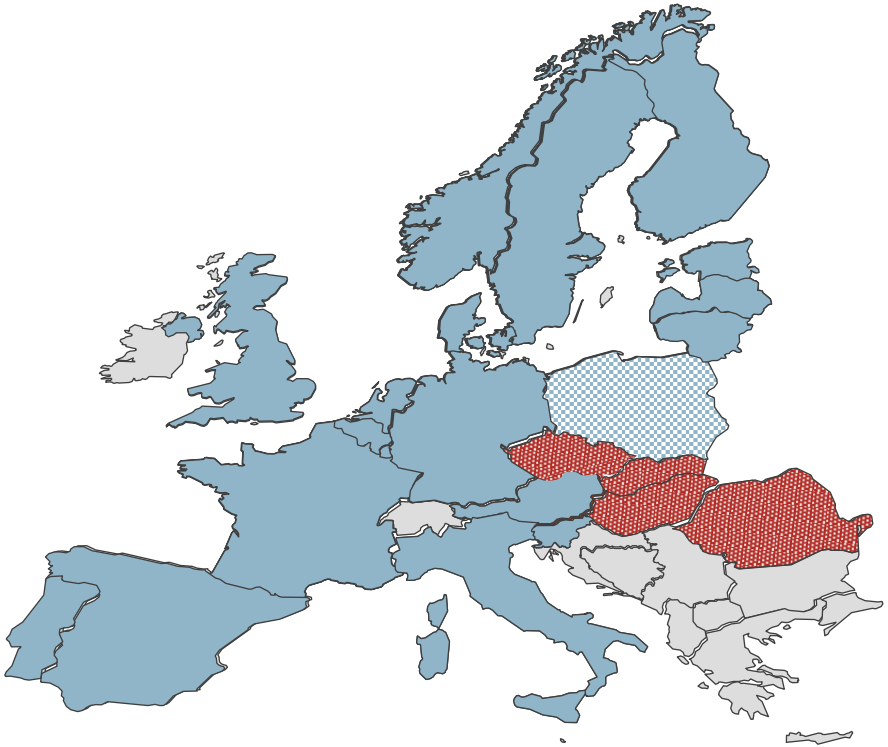
- Transmission provides basis for flexibility
- Transmission is necessary hardware for balancing generation resources with demand
- Regional distribution of large scale RES calls for regional (European) transmission planning and solutions

Energinet.dk TSO for power and gas systems in DK



A)

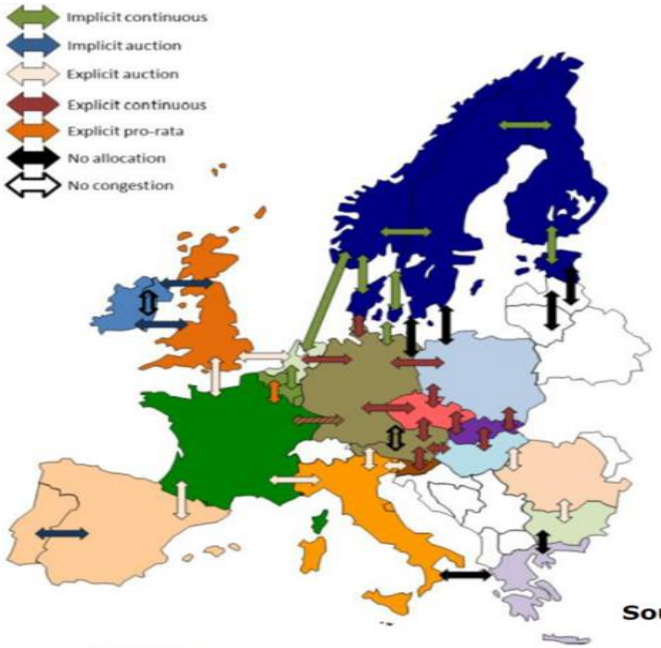
European common day-ahead market - facilitates flexibility



	Nordic Region	Price coupling since 1999 (Eastern Denmark 2000)
	Belgium, France, Netherlands (TLC)	Price coupling since 2006
	Nordic region-Germany (operated by EMCC)	Volume coupling since November 2009
	Central West Europe (CWE)	Price coupling since November 2010
	CWE-Nordic region (+ Estonia) Flow calculated by EMCC Prices calculated by PXs	Interim solution NWE: Interim Tight Volume Coupling (ITVC) since November 2010
	Nordic region– SwePol/ Nordic region-Lithuania/ Nordic region-Latvia	Price coupling since Dec. 2010 / June 2012/ June 2013
	North West Europe (NWE) - One price calculation for entire area	Price coupling since February 2014 = target model
	NWE+SWE = MRC (multi regional coupling) One price calculation	Price coupling since May 2014
	MRC + Italian borders	Price coupling since February 2015
	4M – not yet coupled to MRC	Price coupling since November 2014

European intraday markets – facilitates flexibility

Today's ID markets

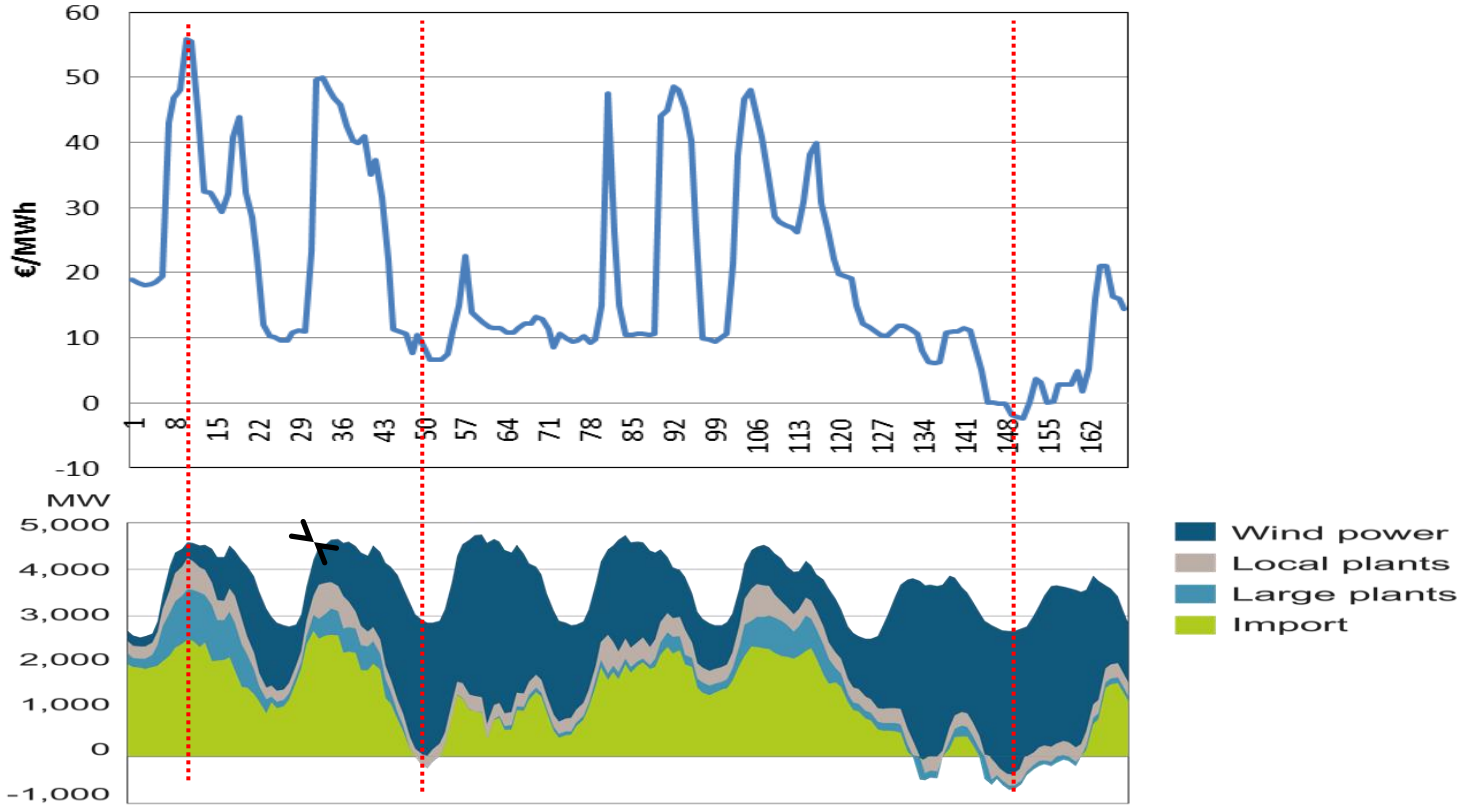


Source: ACER

One intraday market from Q1-2018

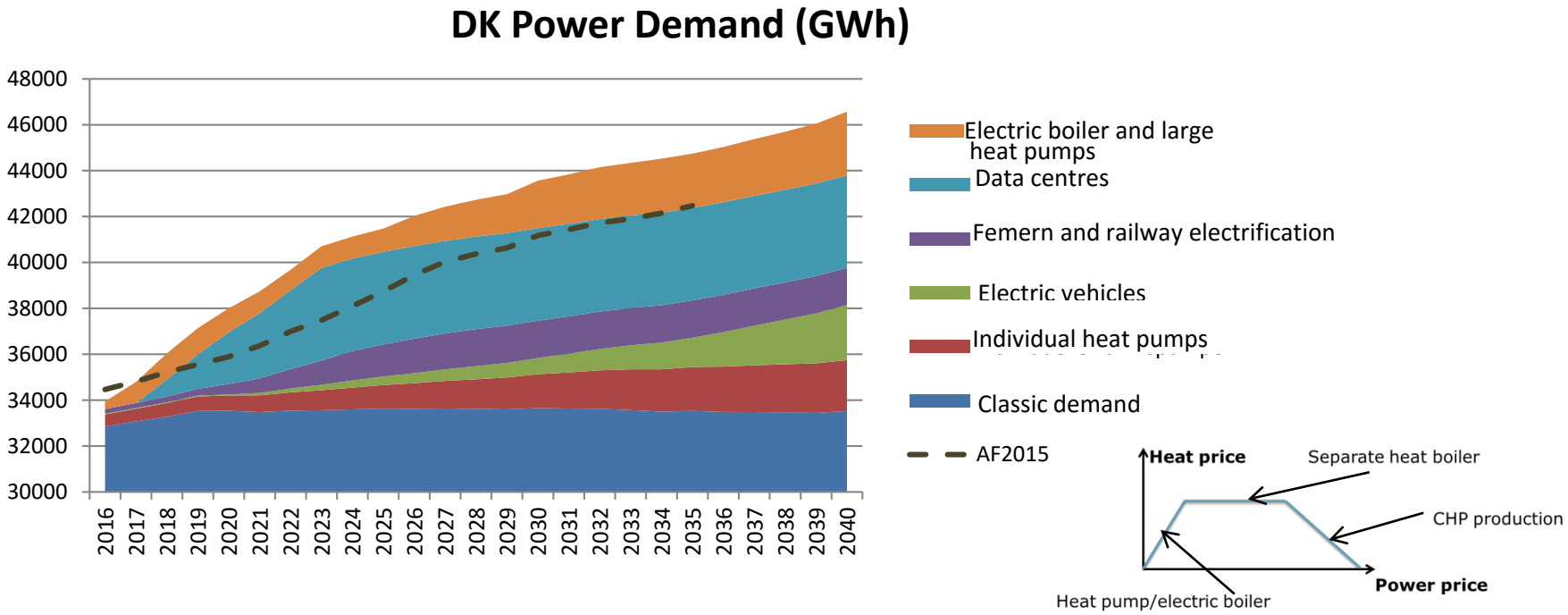
A) CASE DK: 1 week in September 2015

Spot price, wind power and market dynamics



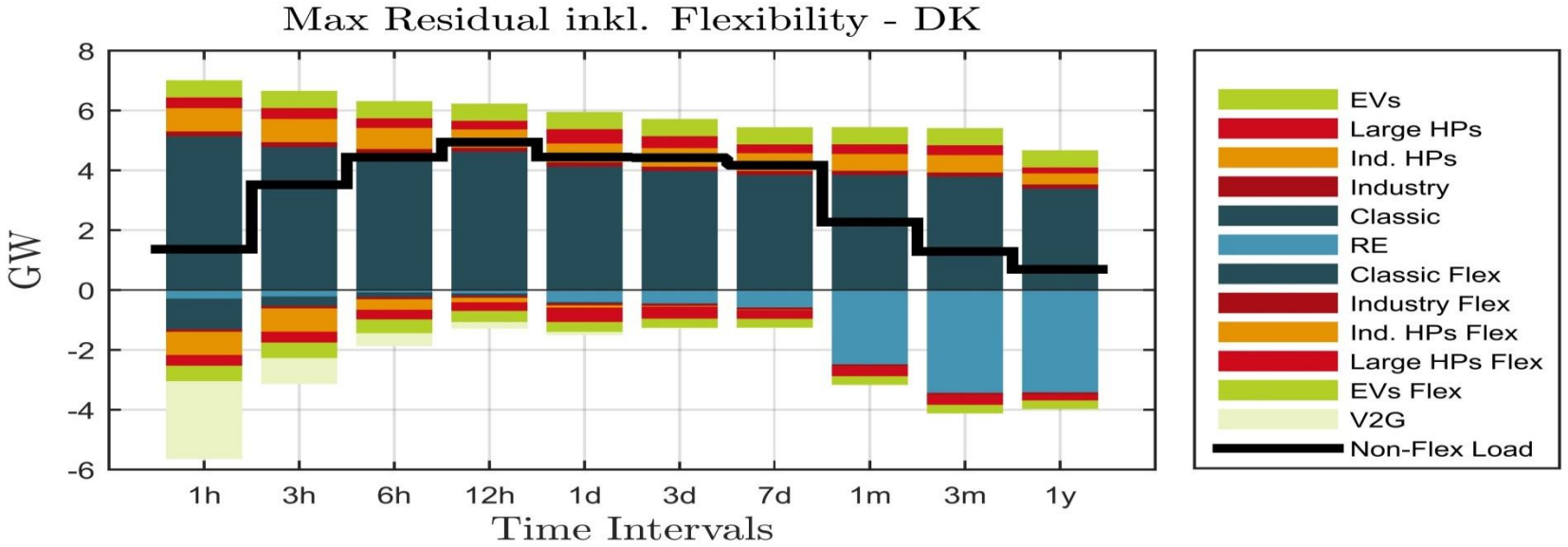
Flexibility across energy sectors

DK: 30 % increase by 2030 due to non classic demand



Use of flexible demand to reduce peak residual load

Max residual load for averaging periods of 1 hour to 1 year (2035 scenario)



Max residual load is in a 12 hours period

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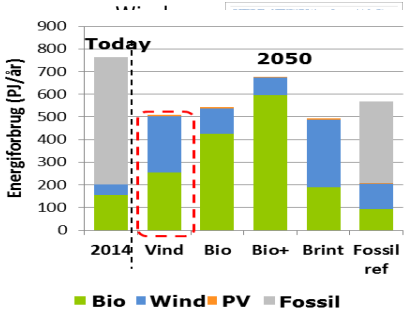
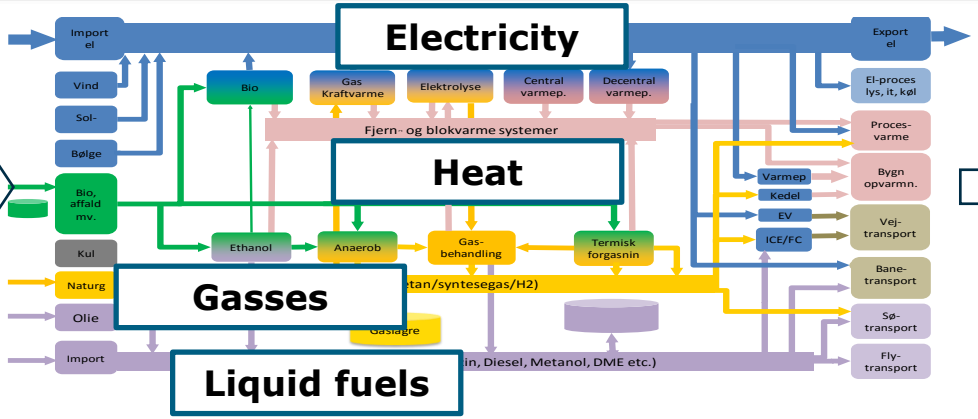
DK: Integration across energy sectors

Energy ressource → **Energy system** → **Energy service**





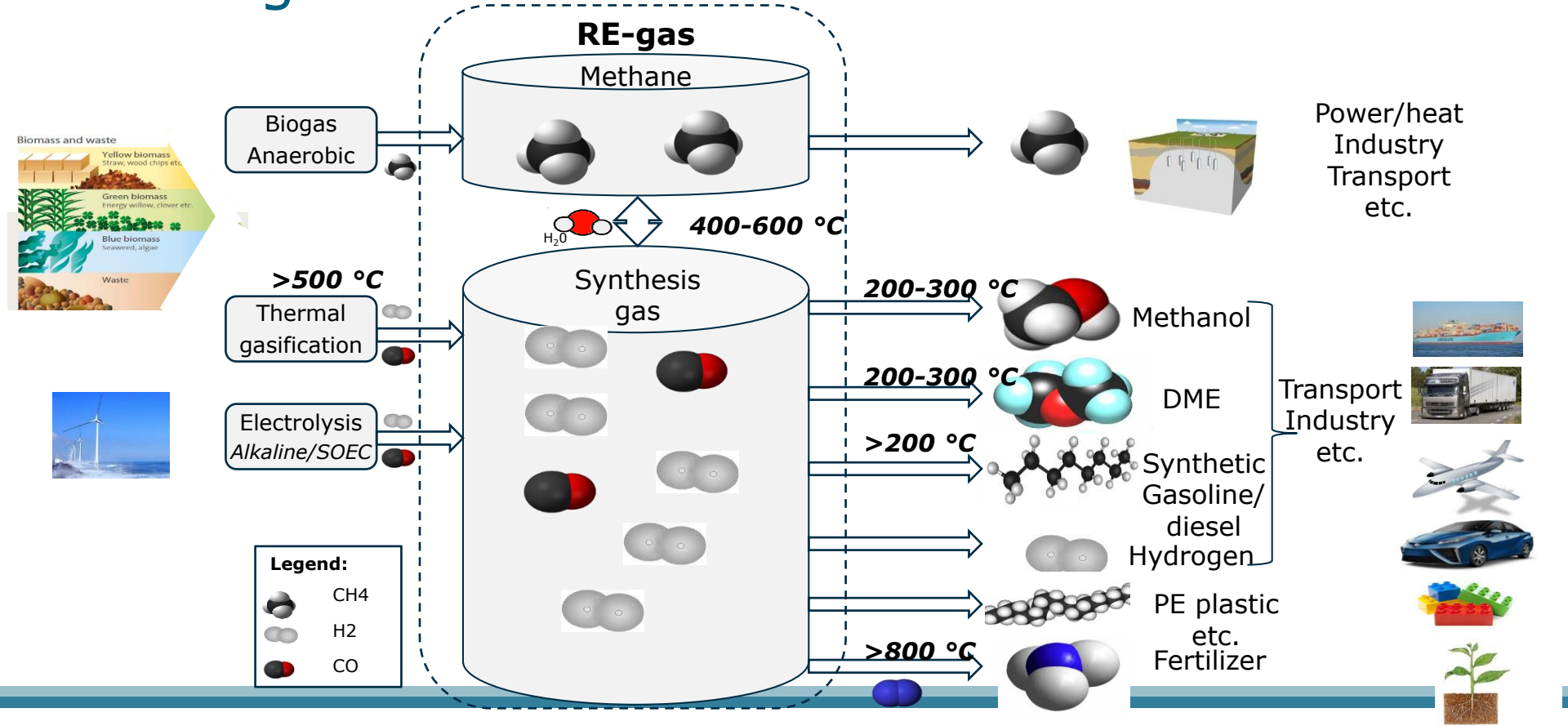
- Heating
- Process heat
- Electrical services (Light, cooling, IT, process etc.)
- Transport

Sustainable resources	***Integrated energy system creates flexibility***	***Minimized, low and stable costs***

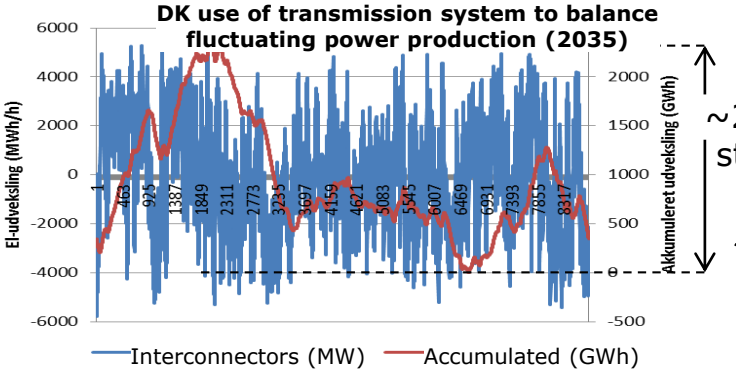
Performance of integrated system is key (economic and technical analysis)

B)

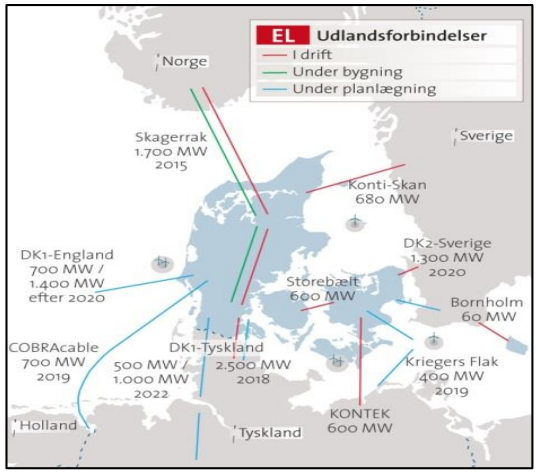
RE-gas as feedstock for fuels etc.



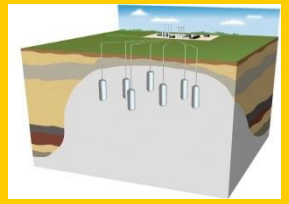
Cross energy sector balancing

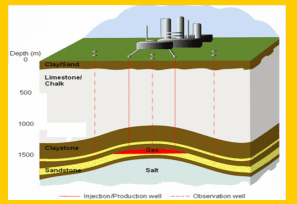


~2.3 TWh storage



DK Gas storage (11 TWh methane-gas)





Transmission system:
Interconnectors yearly accumulated energy in 2035
(2.3 TWh)

District heating storage

EV and hybrid, case 2035

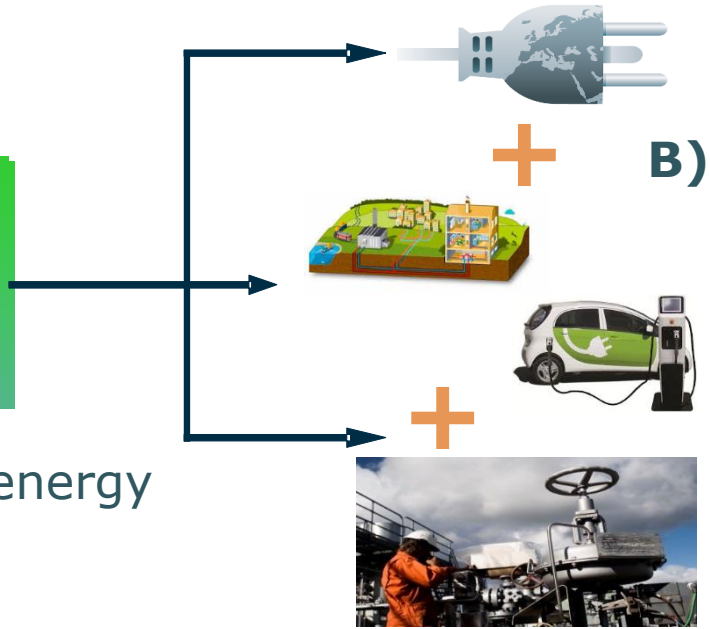
Measures of large scale RES integration

A) Within European integrated power systems

B) Across different energy sectors

DK

50 % wind by 2020=> 100% VE by 2050



A)

- Strong grids, strong interconnectors
- Coupled European markets
- Flexibility in demand and generation

B)

Integration of power system with

- heat and gas
- transport sector
- .....

Longer term:

- stronger integration with the gas sector (electrolysis, H2, green gases, large scale gas storage)


Thank you for attention
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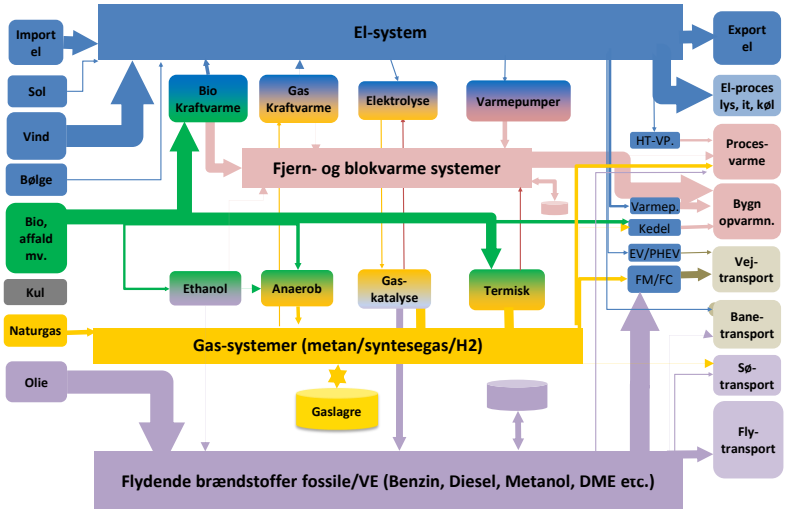
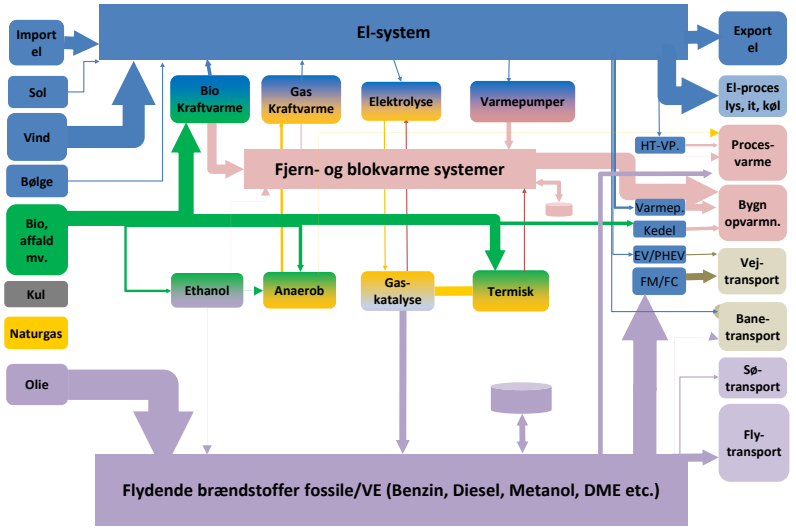
The gas system adds a socio- economic value of DKK 2-3 bn. per year (2035)

With gas in 2035- Storage and regional use of gas



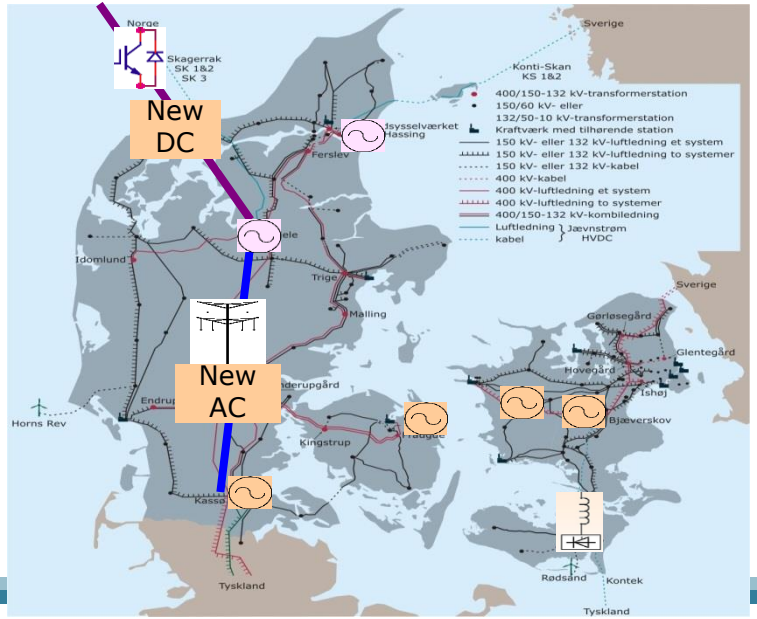
Without gas in 2035- Local use of gas



Operating the Danish power system without central stations

On **2nd September** 2015:

- Market did not schedule any central power station in DK-W to operate
- System stability by operating:
  - SK4 VSC (700 MW DK-NO)
  - Synchronous compensators :
    - 4 in DK-W
    - 2 in DK-E



A) CASE DK: 1 week in September 2015

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Wednesday, 2 September 2015, 2 am

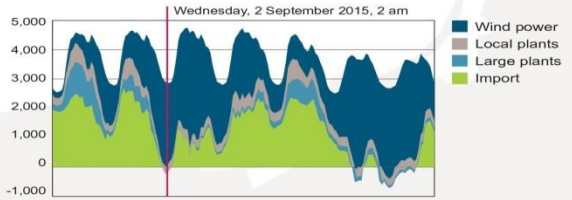
Large plants
10 MW

Local plants
246 MW

Wind power & PV
2,867 MW

Net exchange, export
210 MW

Demand
2,913 MW



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