Analysis of scenarios for the Danish Energy system with Sifre

Cities General Consortium Meeting 24-25'th May 2016

DTU Lyngby

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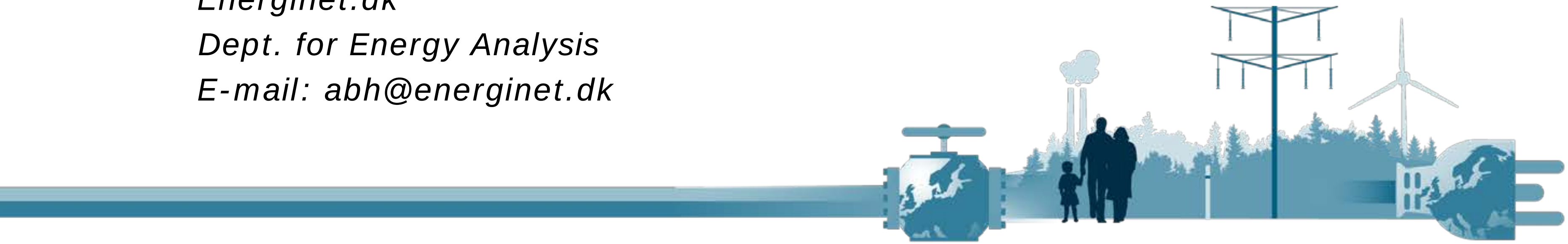

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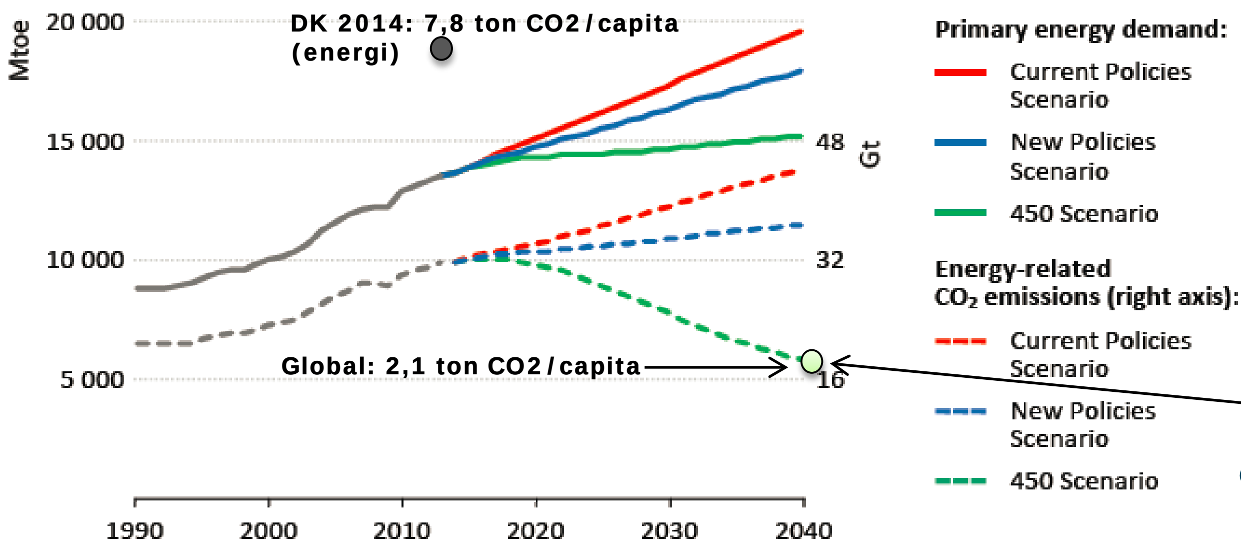
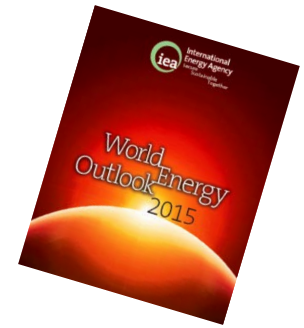
Global contekst – IEA WEO and COP 21

Figure 2.1 ▷ World primary energy demand and CO_2 emissions by scenario

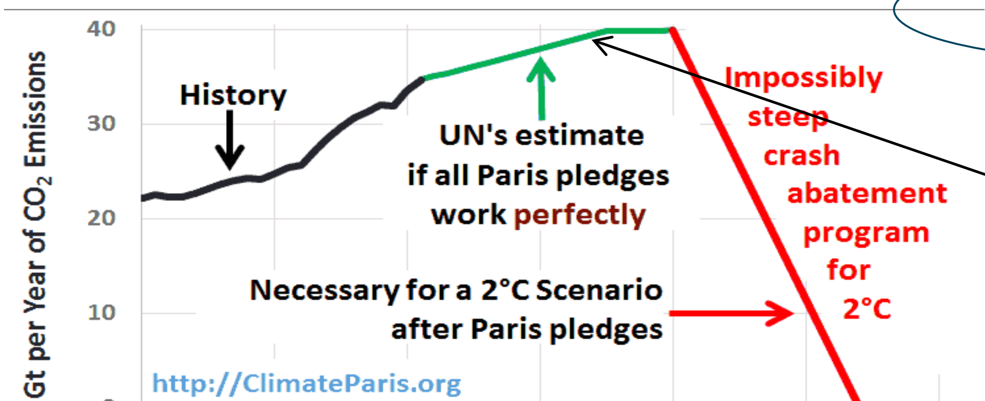




IEA 450 PPM ≈

Mission Innovation
More global R&D

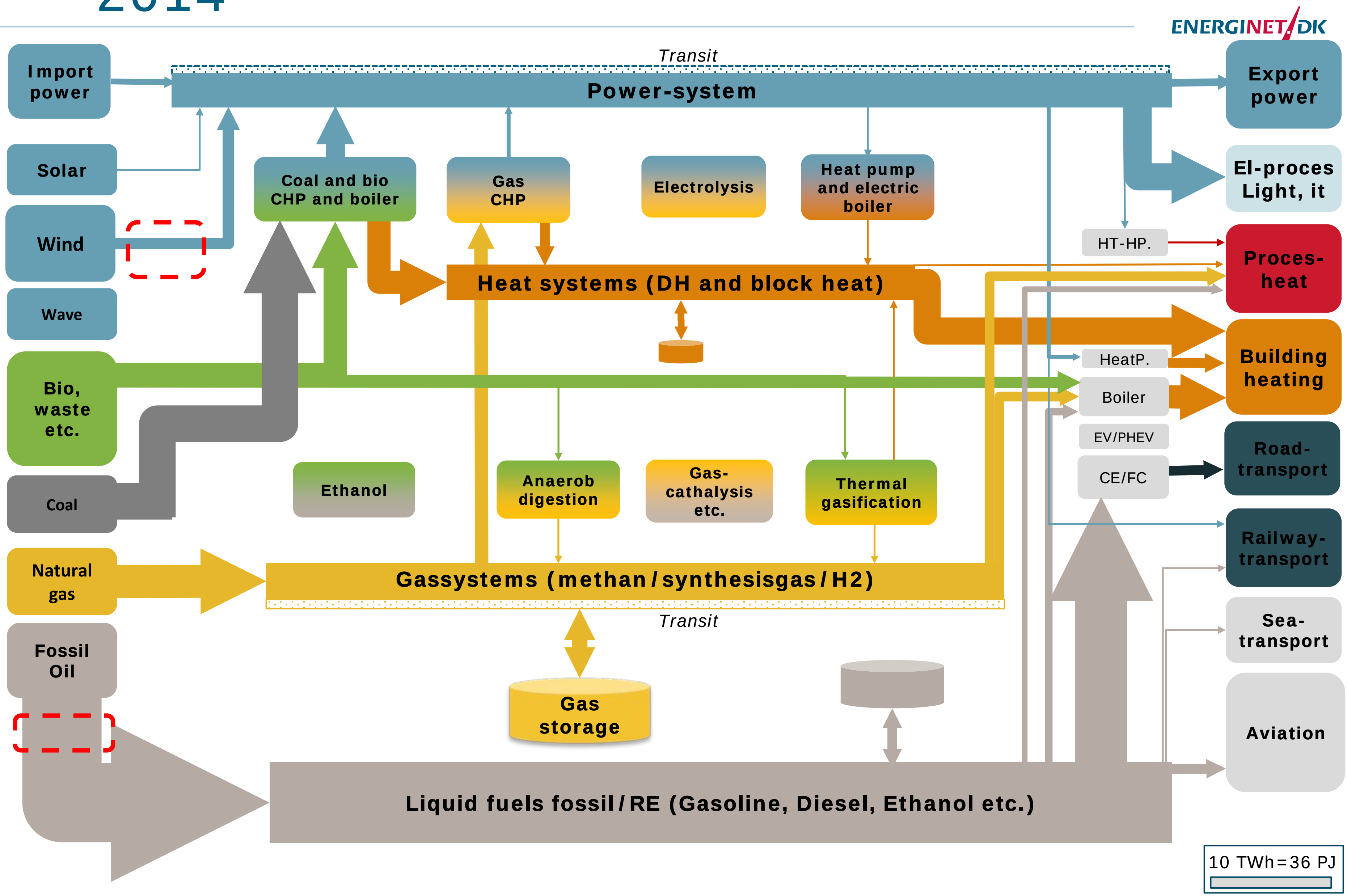
Target:
"Well below 2 degr."



INDC's

A tough challenge to realise Paris COP21 targets – significant CO2-reduction needed

2014


ENERGINET DK
Transit
Import power
Power-system
Export power
Solar
Wind
Wave
Coal and bio CHP and boiler
Gas CHP
Electrolysis
Heat pump and electric boiler
El-proces Light, it
HT-HP.
Proces-heat
Heat systems (DH and block heat)
Bio, waste etc.
HeatP.
Boiler
Building heating
EV/PHEV
CE/FC
Road-transport
Coal
Ethanol
Anaerob digestion
Gas-cathalysis etc.
Thermal gasification
Railway-transport
Natural gas
Gassystems (methan/synthesisgas/H2)
Transit
Sea-transport
Fossil Oil
Gas storage
Aviation
Liquid fuels fossil/RE (Gasoline, Diesel, Ethanol etc.)
10 TWh=36 PJ

Annual energy flow in energy system today

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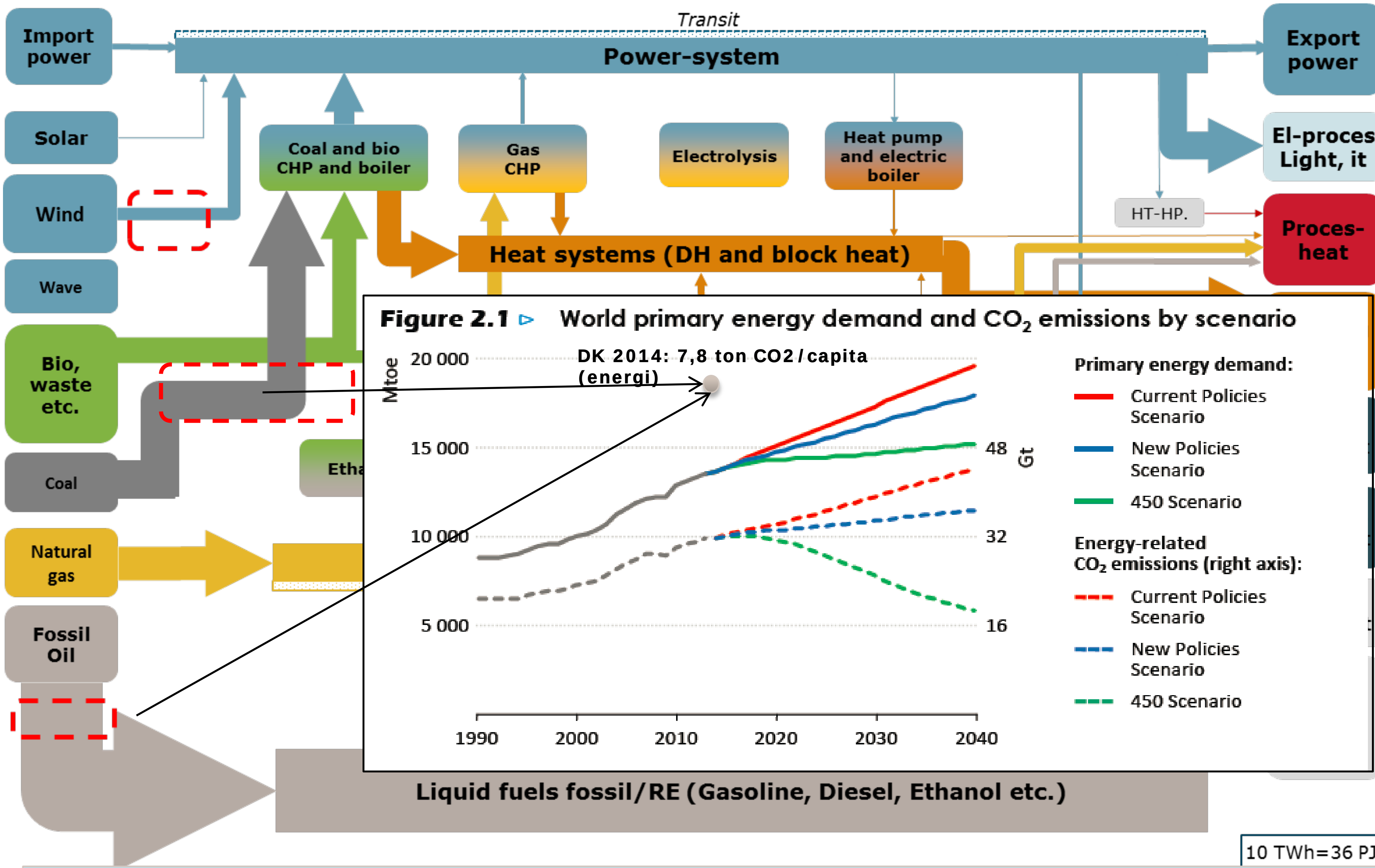
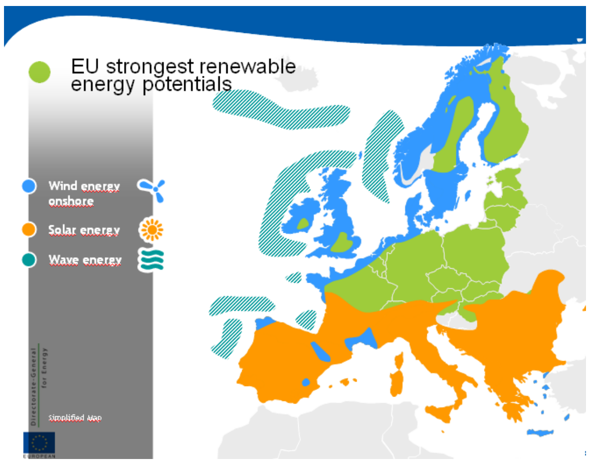


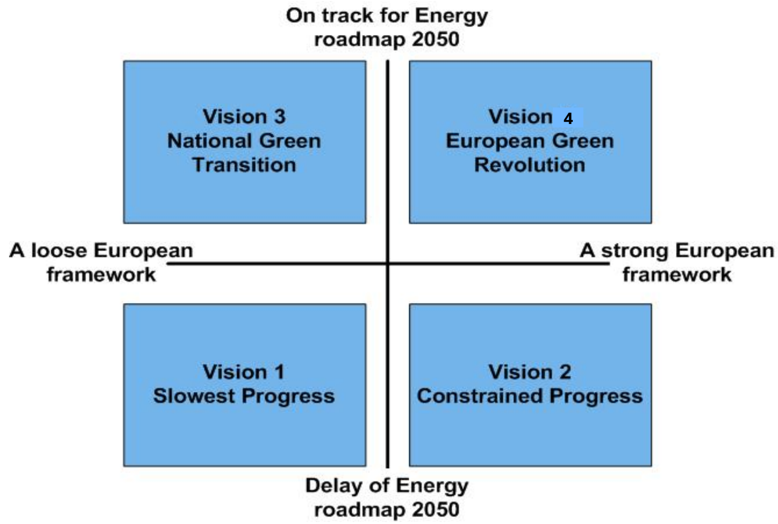
Transport almost totally based on fossil oil
– wind and solar still quite a small part of total gross energy

European Scenario Framework in the analysis



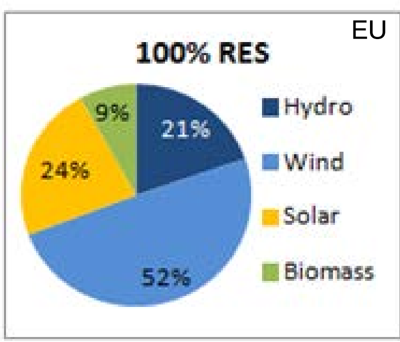
ENTSO-E Visions

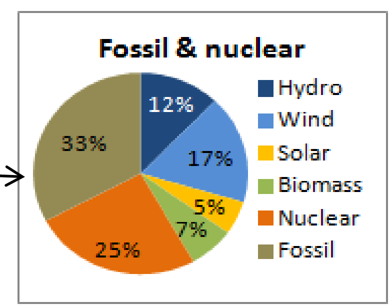
2030



e-Highway 2050 - Scenarios

2050





A framework of international scenarios used to evaluate robustness of strategic choices

TYNDP2016 Scenarios 2030 – average prices

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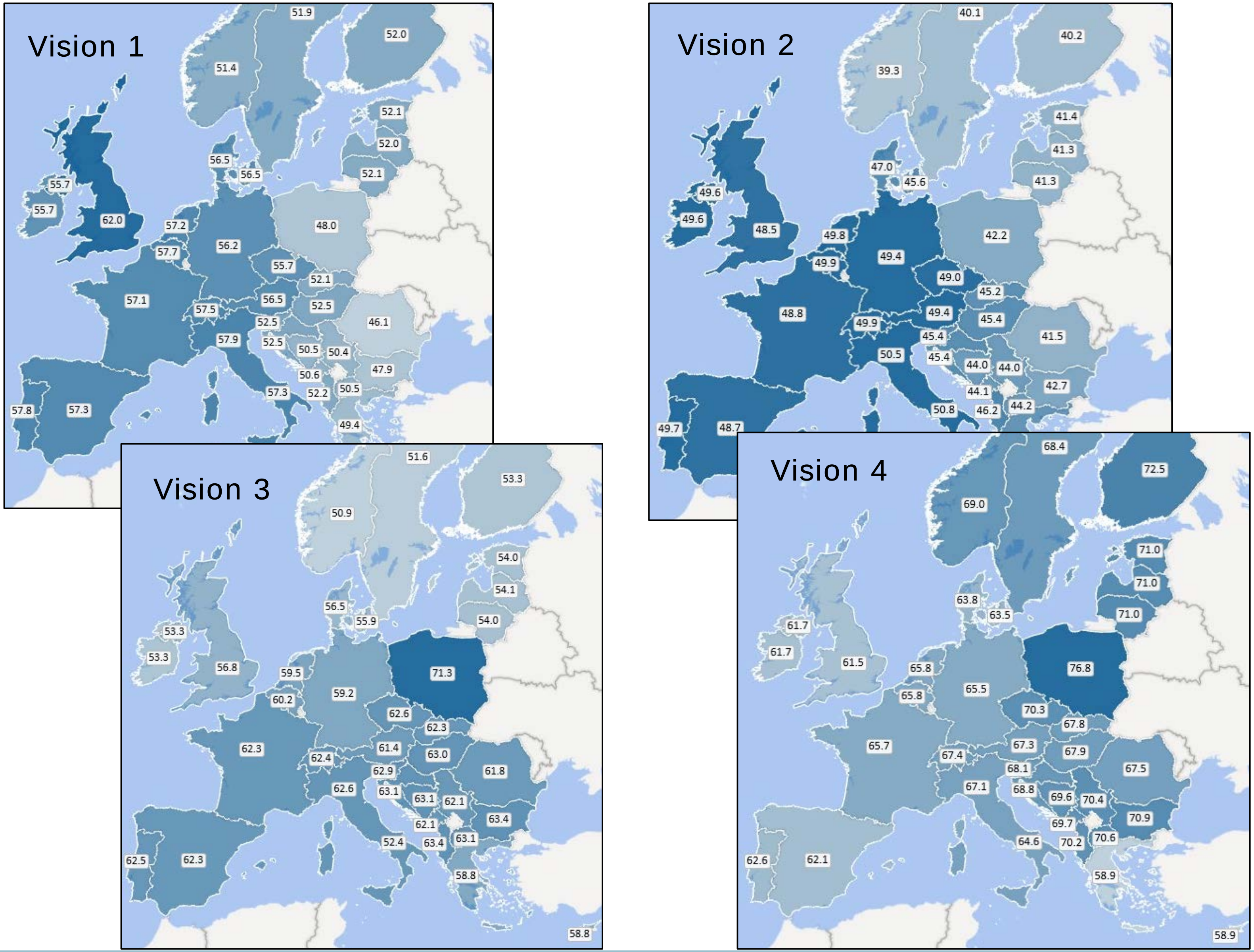
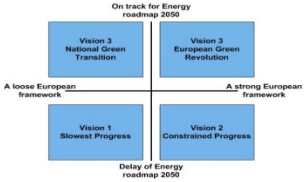


Basis – Time and models

Price setting, load duration and energy conversions

SIFRE *(DK analysis)*

BID (European analysis)



Power balancing, Security of Supply

Simba

FSI

Loadflow, n-1, grid strength

PowerFactory

PowerWorld

Pipeline Studio

Elektro-mechanic fluctuations

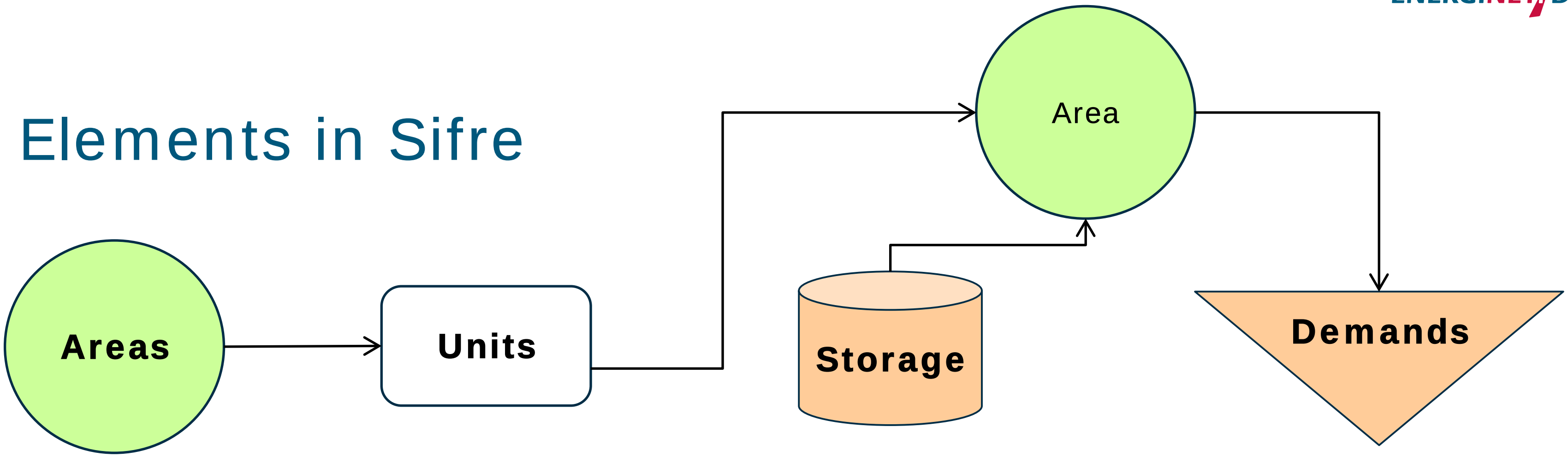
PowerFactory

Electromagnetic transients

PSCAD

μs — ms — min — hours — days — years

Elements in Sifre



Areas
Energy-type and geografic area

Examples:
- Electricity-DK1
- Natural gas area Heat area
- Electricity-NL

Units
Conversion of energy

Examples:
- CHP units
- Boiler
- Heat pump

Storages
Storage of energy

Examples:
- Battery
- Heat accumulator
- Bio-mass storage

Storages
Storage of energy

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- Battery
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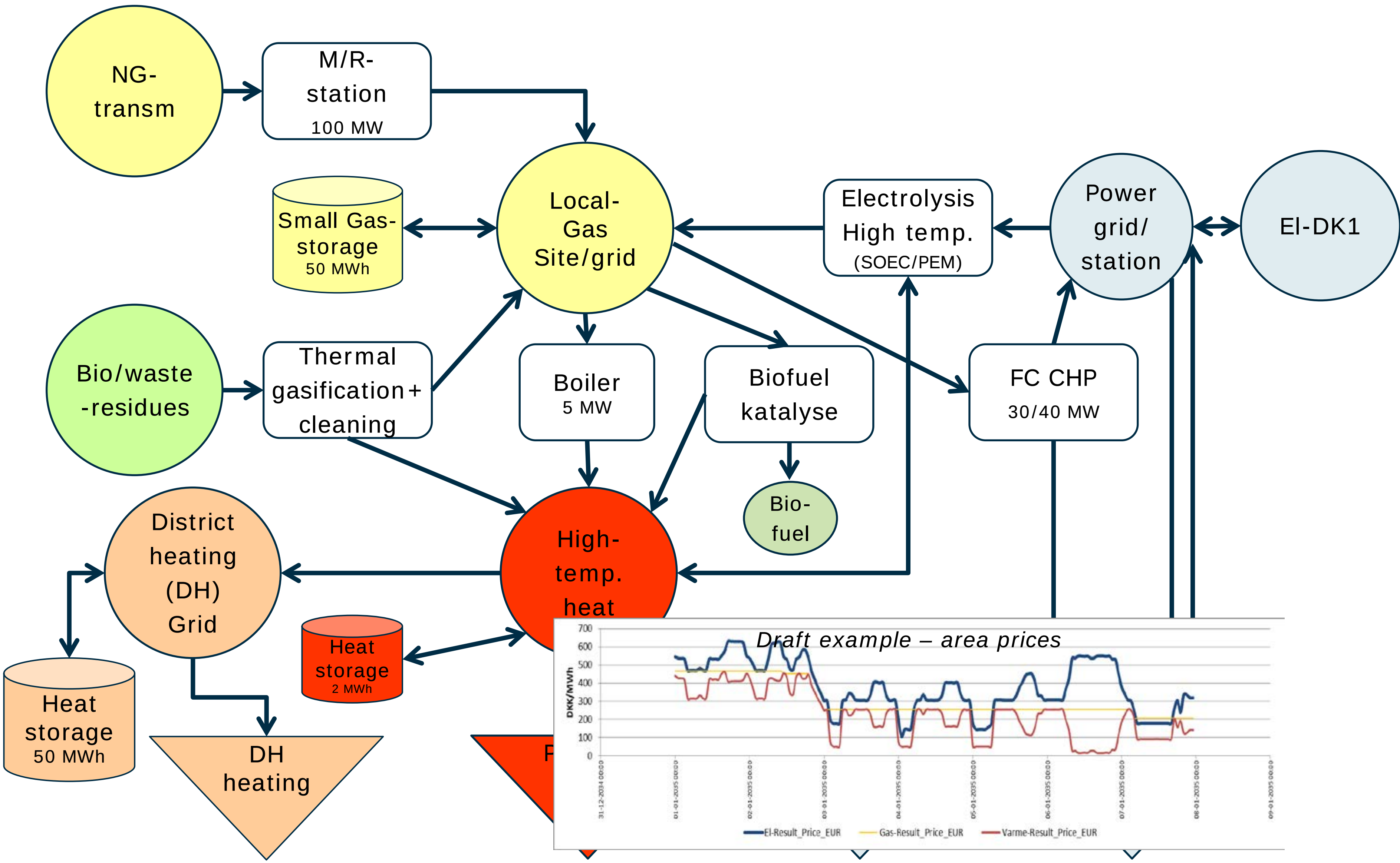
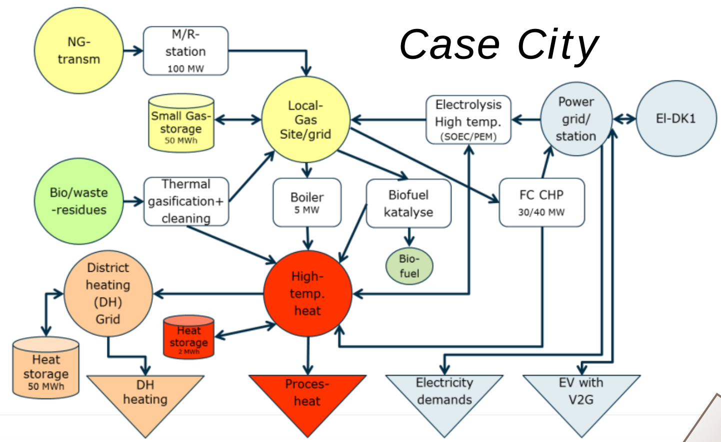
Analysis of local energy system (example)

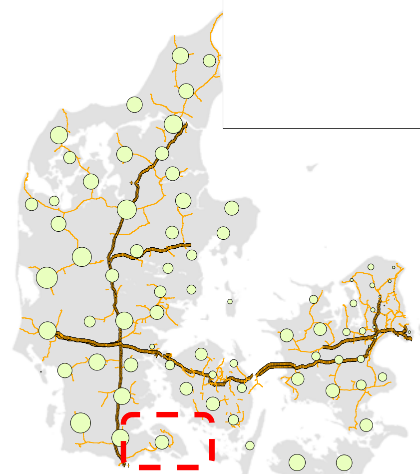


From case ”Cities” to national solutions

Case City

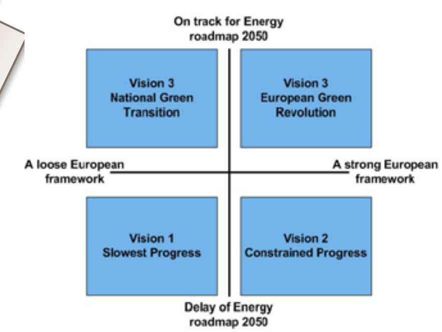


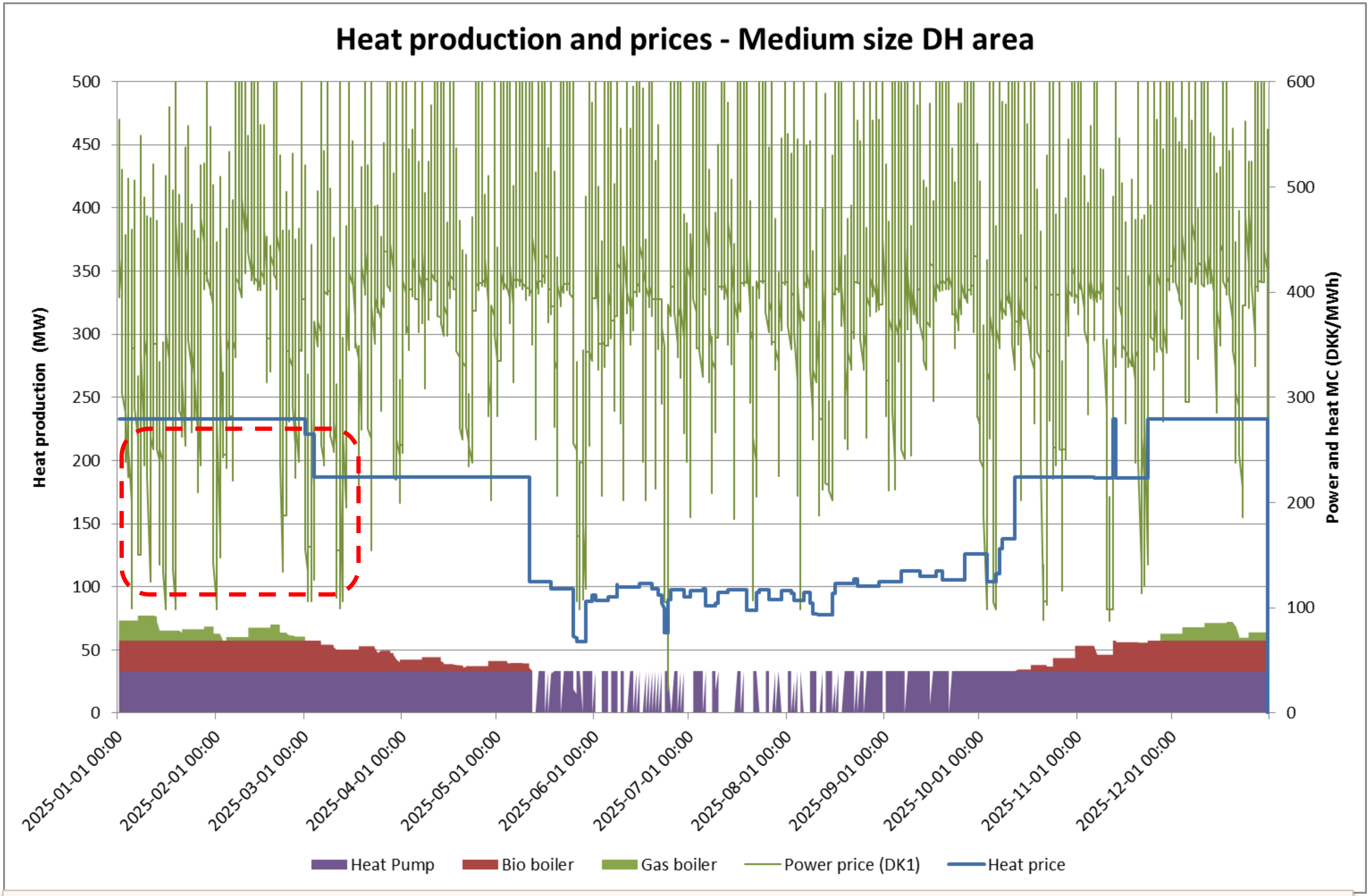
Heat demands
(In Sifre reduced to 40 areas)



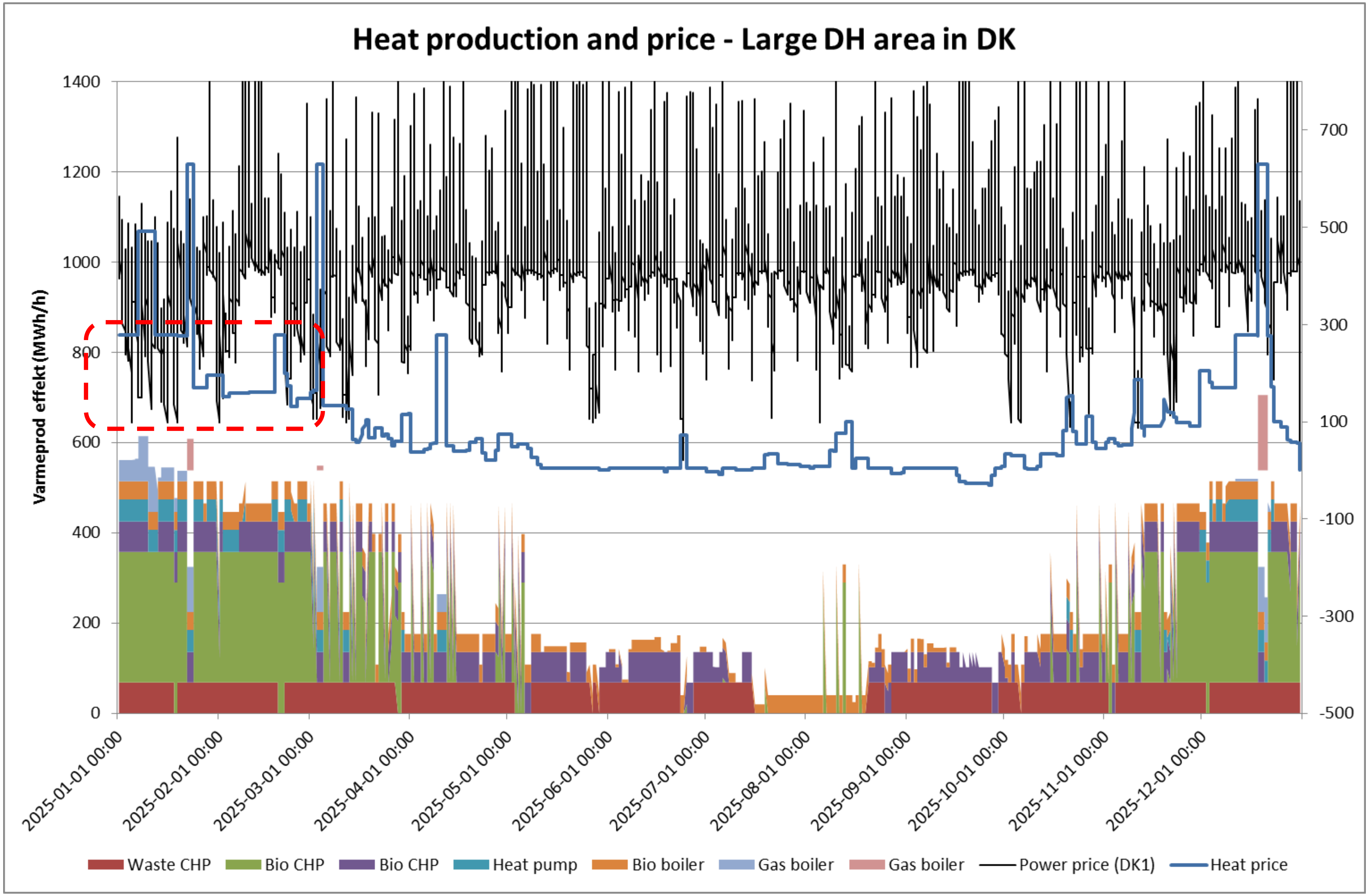
Biogas ressources

Power plant capacity



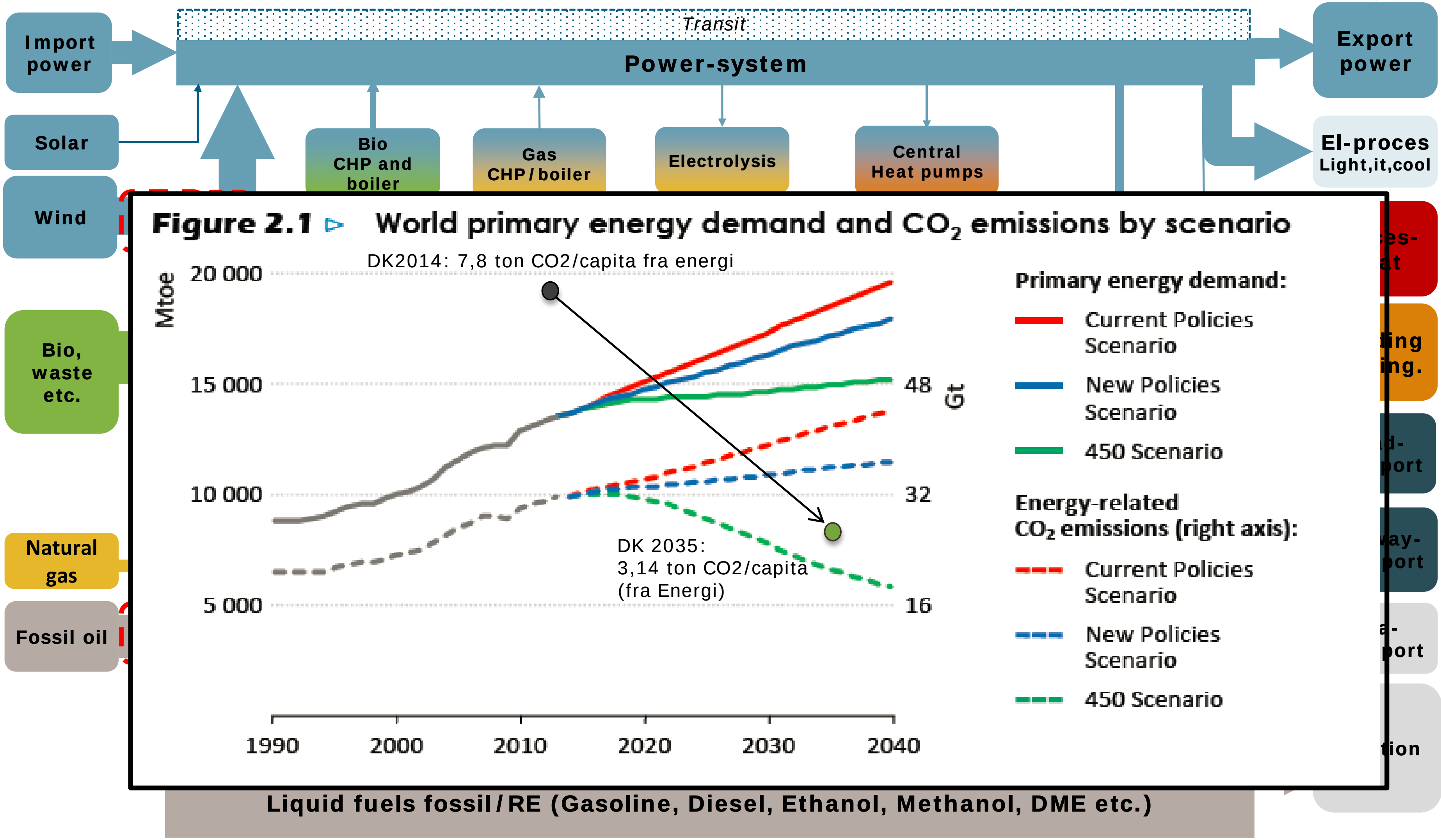


Fluctuating power and heat prices – a need for a price transparent heat and power market to get least cost operation (as found in simulation)



Heat production and price - Large DH area in DK
Varmeprod effekt (MWh/h)
1400
1200
1000
800
600
400
200
0
700
500
300
100
-100
-300
-500
2025-01-01 00:00
2025-02-01 00:00
2025-03-01 00:00
2025-04-01 00:00
2025-05-01 00:00
2025-06-01 00:00
2025-07-01 00:00
2025-08-01 00:00
2025-09-01 00:00
2025-10-01 00:00
2025-11-01 00:00
2025-12-01 00:00
Waste CHP
Bio CHP
Bio CHP
Heat pump
Bio boiler
Gas boiler
Gas boiler
Power price (DK1)
Heat price

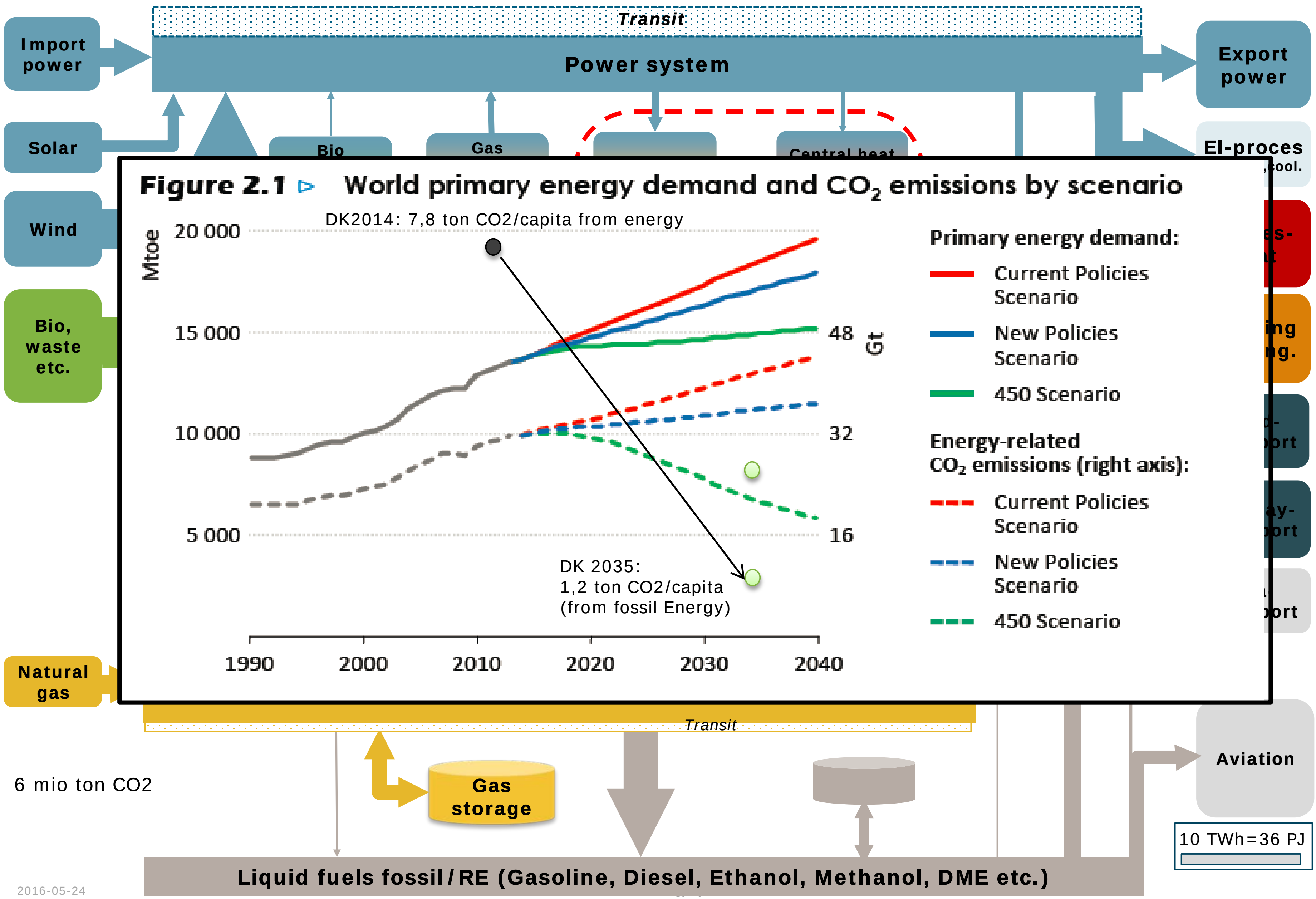
2035 - Reference with fossil free power and heat system



14 mio ton CO2

10 TWh=36 PJ

Feasibility study 2035+ – reduced fossil oil demand



6 mio ton CO2

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R&D focus areas – to in a scenario realising COP21 ambition

Grid and balancing

- Dynamic line rating and new principles for use of power transmission
- System-observation (PMU/WAMS)
- Operation of low inertia power system
- Probalistic forecast of wind/solar
- Ancillery services fro[m] [conv]erterbased production and cons[umption] *(wind,solar,HP,EV,P2G)*

WP3-4-5-6-7

Market and operation

- Direct and indirect control strategies (control, stability, cost)
- TSO/DSO agregat[...] market solutions (incl. tarif)
- Big data and Inte[...]se in market products

WP3-4-5-7

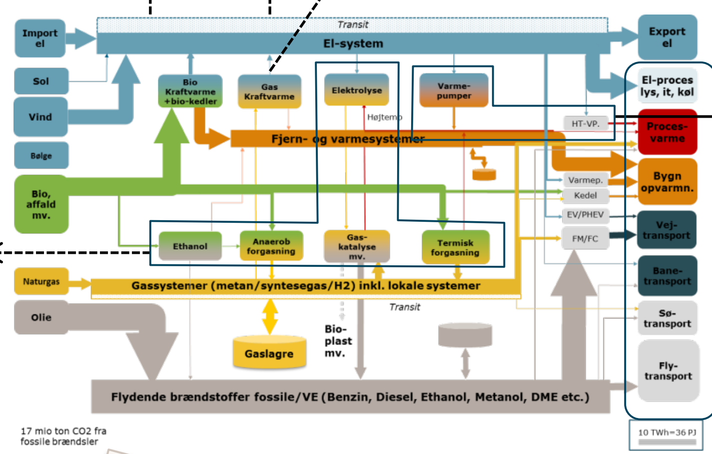
- Low cost [...]er capacity from power units or storage integr[...]s (ETES/CAES mv.)

WP2-6

Energy Plants – Integrated power, fuel, heat

- Conversion of biomass and power [...]
- Integra[...] agriculture and wa[...] systems

WP2-5-6



Power to heat and cooling

- Large heat pumps (inkl. sea-water sourced)
- Proc[ess] heat pumps (he[...])
- Efficent [...] high temp heat
- Market solutions fluctuating heat, power, gas, cooling

WP2-6

Demand response modelling

- Price elasticity, profiles
- Consumper preferences på variable energipriser

WP1

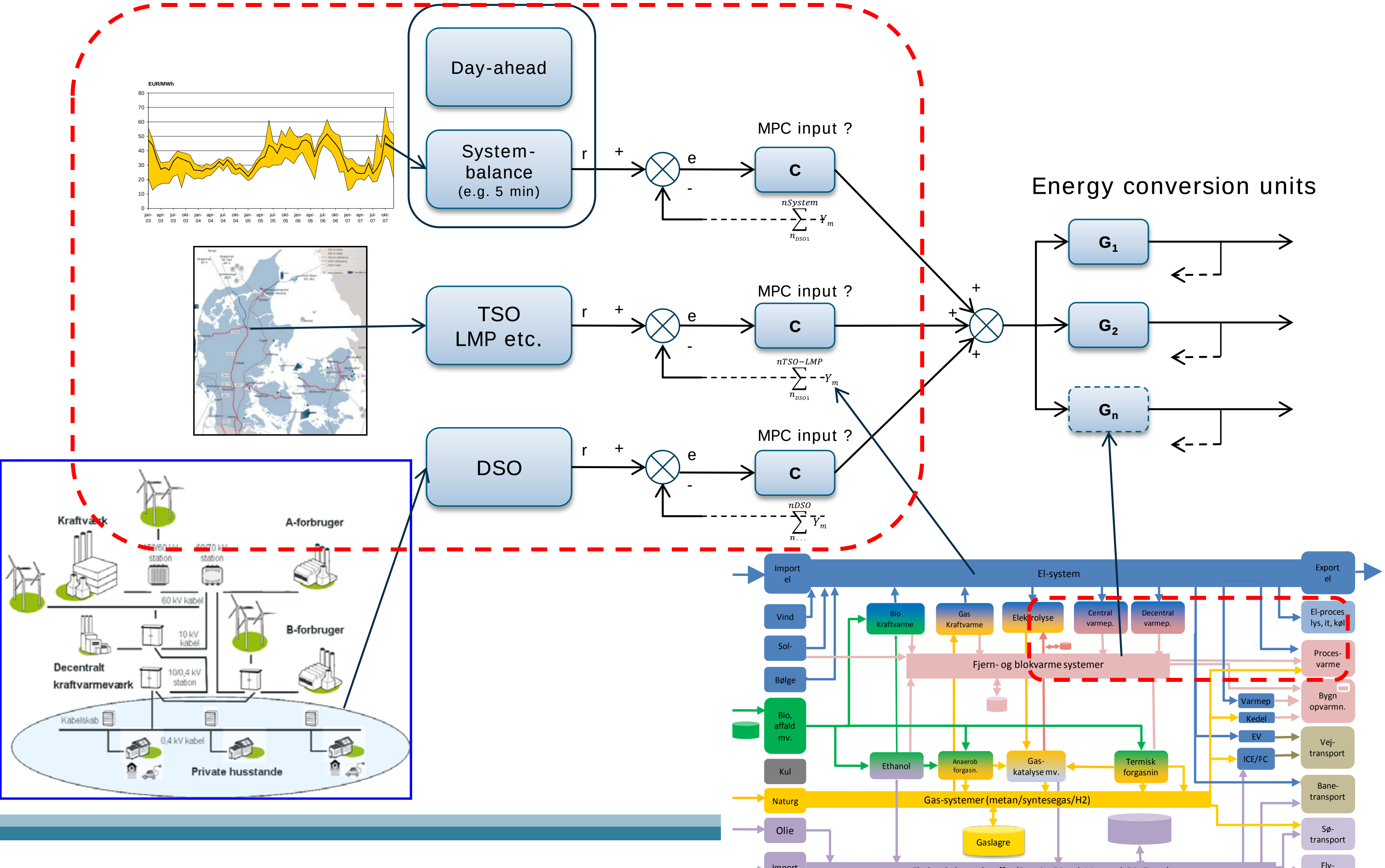
Thank you for attention

Link: www.energinet.dk/energianalyser

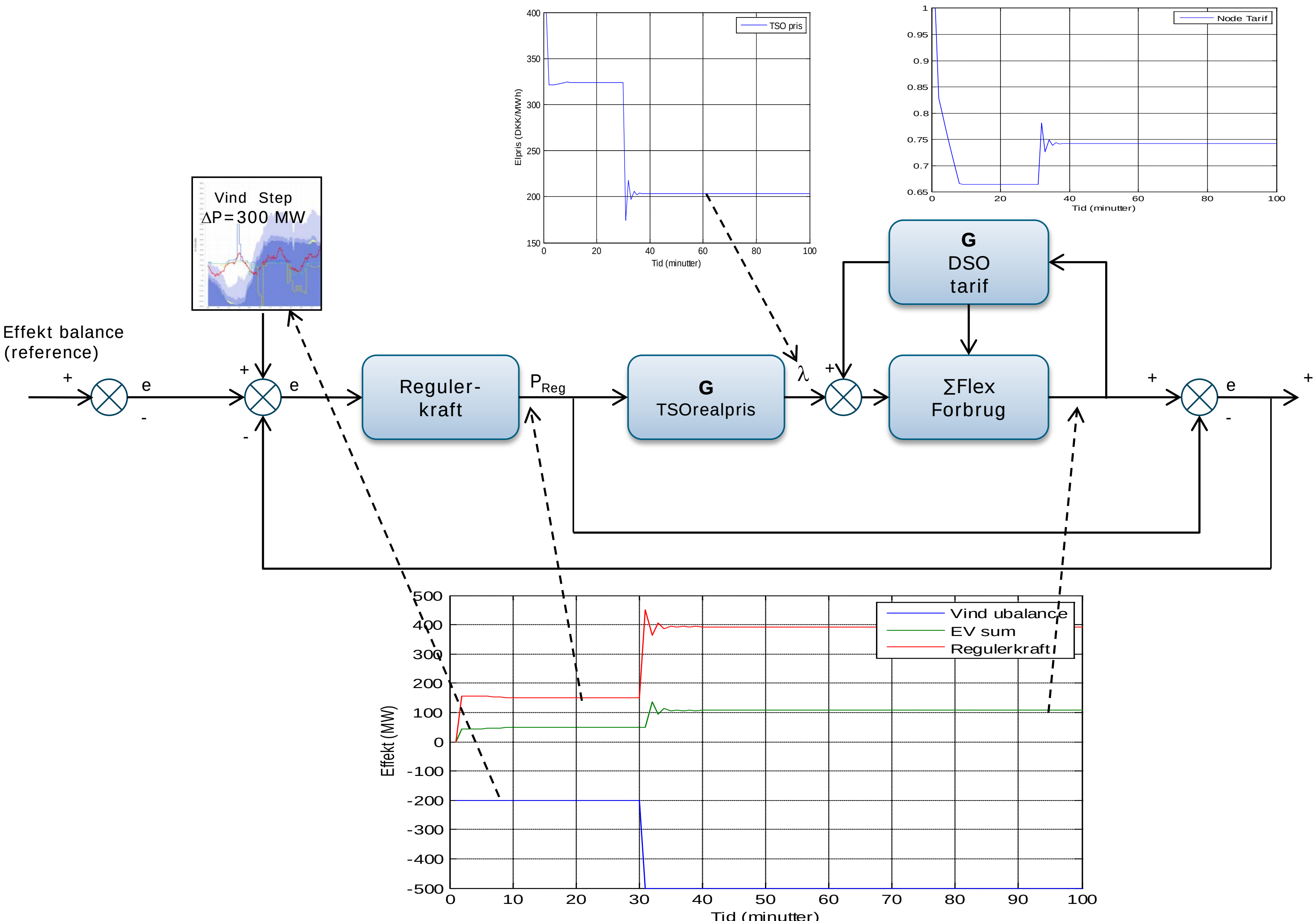
Thank you for attention

Link: www.energinet.dk/energianalyser

Analysis of Energy System dynamics
- including power TSO/DSO (and potentially heat market)



Analyse af system respons (step)



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Energinet.dk working with different scenarios

EU GHG on track
Højt fokus på VE og miljø

- Nationalt focus
- COP21 target (2 degr.)
- Lokale løsninger

- Internationalt
- COP21 mål højt fokus (2 gr)
- Stærkt samarbejde inden for EU
- Fælleseuropæiske løsninger på forsyningssikkerhed, klima og VE

Scenarie 3 | ***Scenarie 4***

Stærkt nationalt fokus ← → **EU stærkt samarbejde**

Scenarie 1 | ***Scenarie 2***

- Nationalt fokus
- Mindre grønt
- Vanskeligt med internationalt samarbejde
- Lokale løsninger

- Mindre grønt
- Stærkt samarbejde inden for EU
- Fælleseuropæiske løsninger på forsyningssikkerhed og udfordringer for energisektoren

EU GHG not on track
Lavt fokus på VE og miljø

Integration of local and national gas-system

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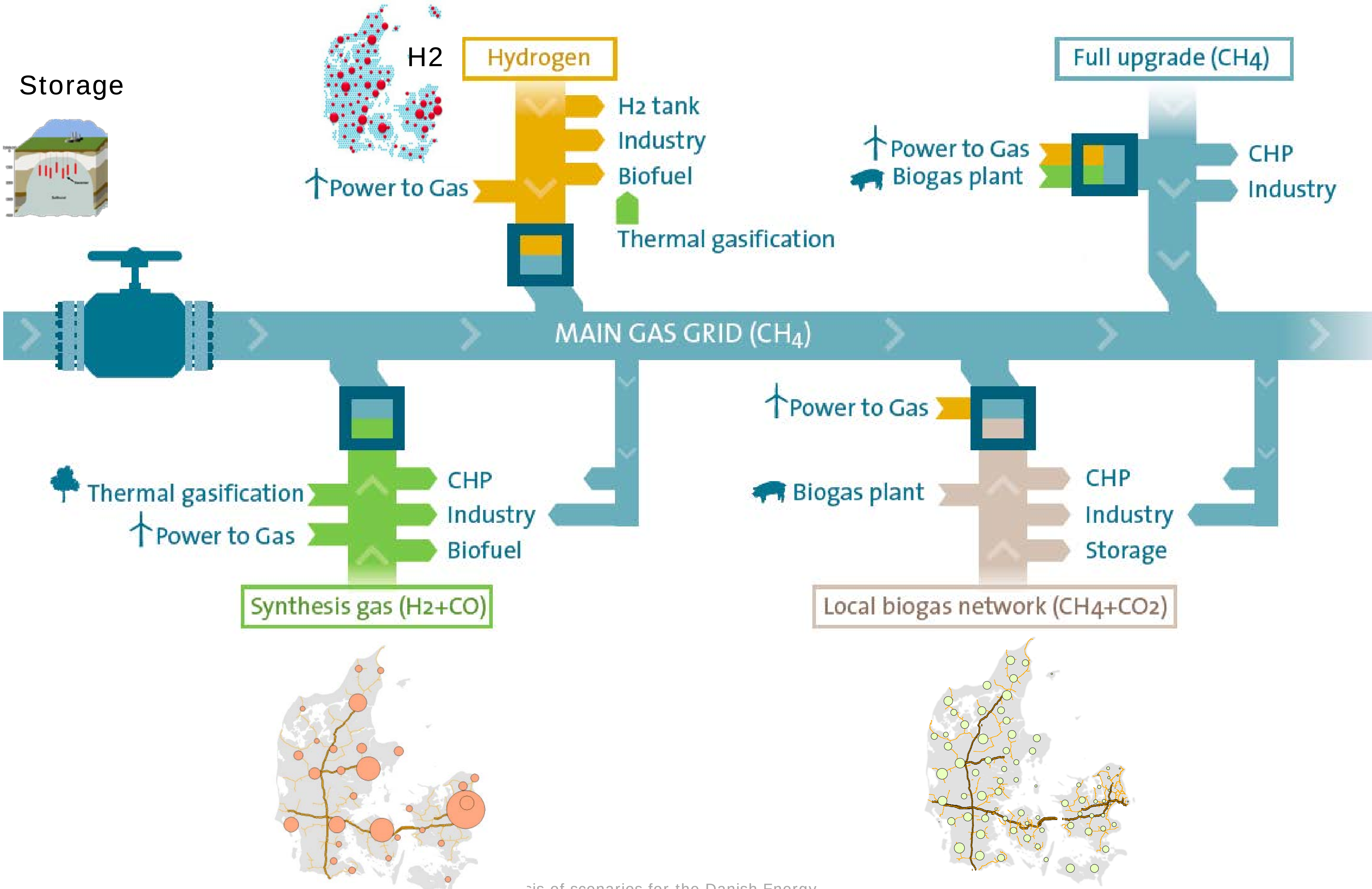
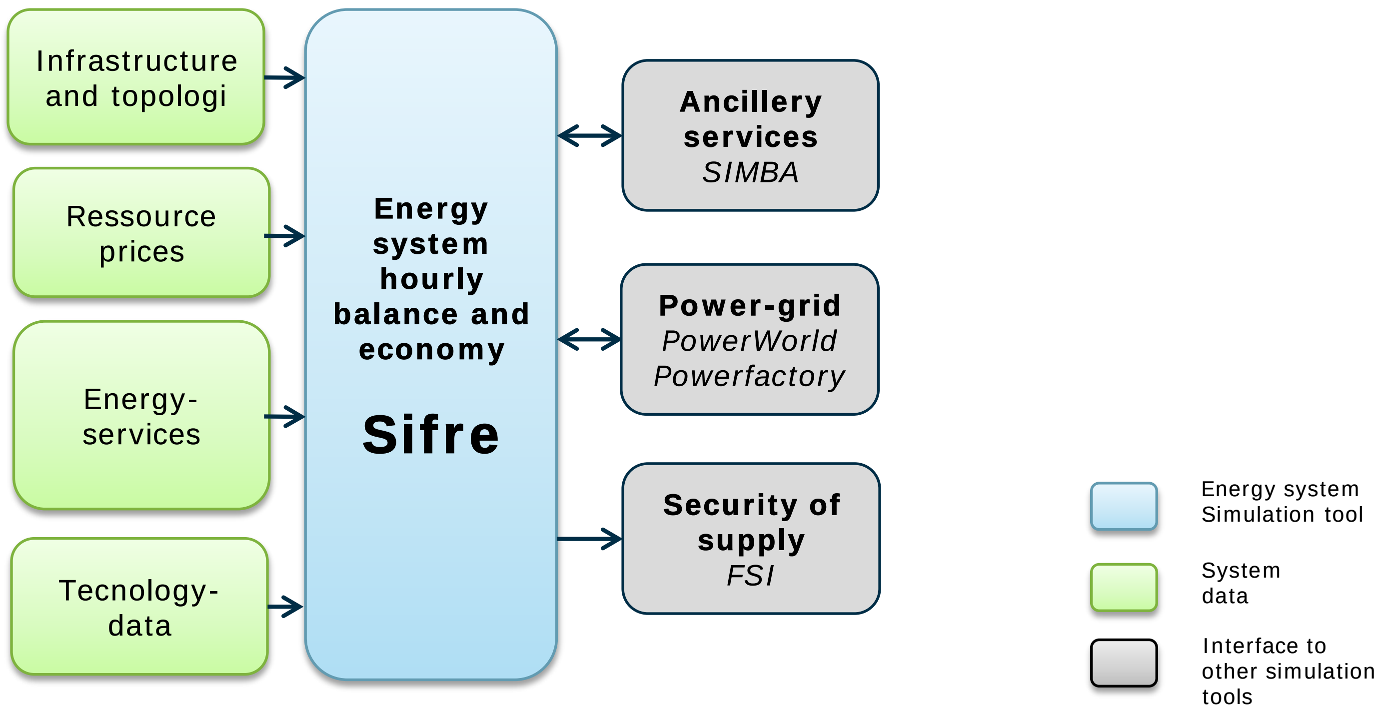


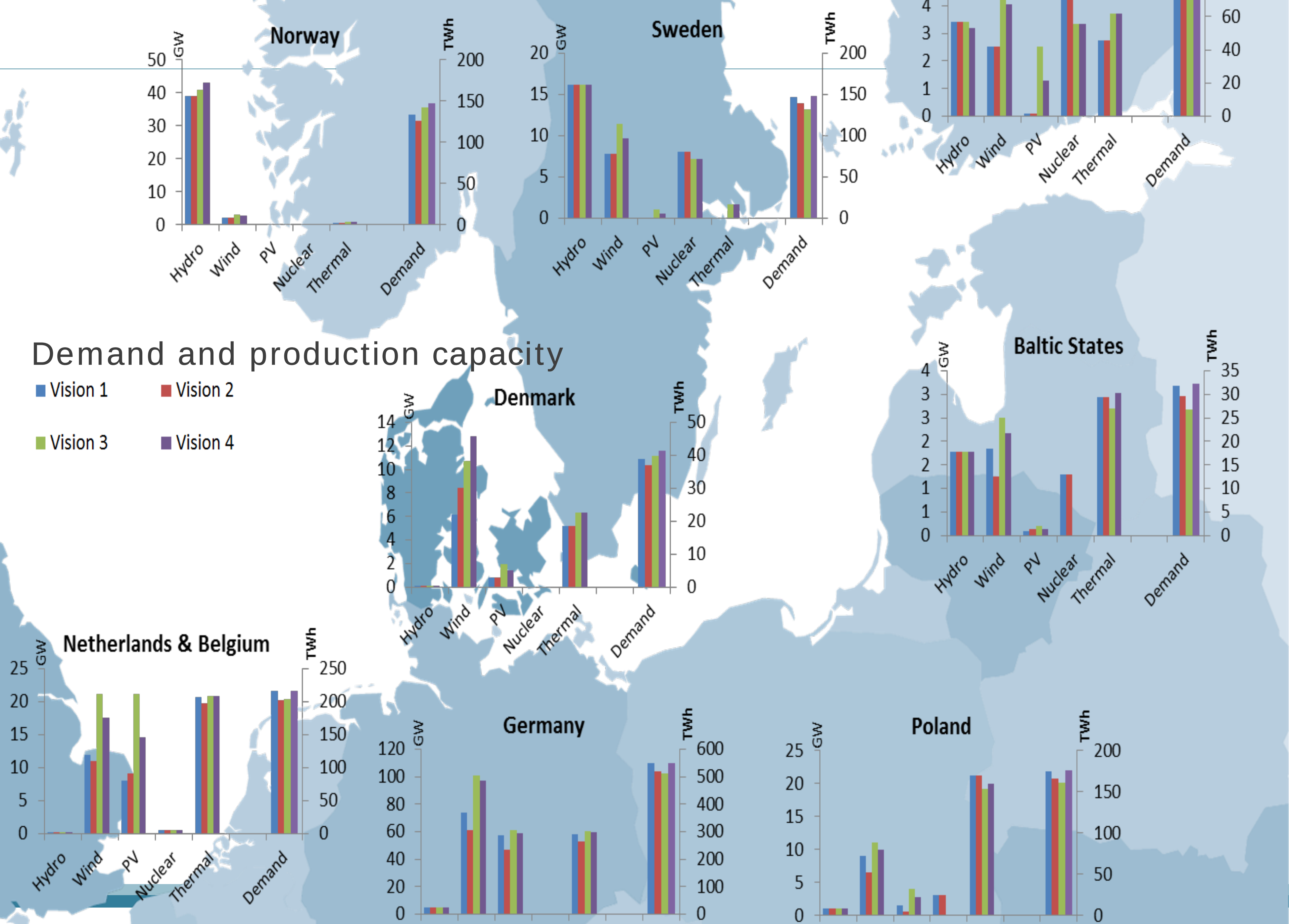
Sifre – integration with other analysis tools



Sifre to be used as ”central” energy system analysis tool at ENDK

SIFRE = SImulating **F**lexible **R**enewable **E**nergy sources

Demand and production capacity



Sifre – Input/Output

Input

Energy system

Production unit,
Fuels,
Demands,
Connections,
...

Method

Simulation

Front end (C#)
Gurobi solver
(least cost solution)
Data stored in MS-SQL

Output

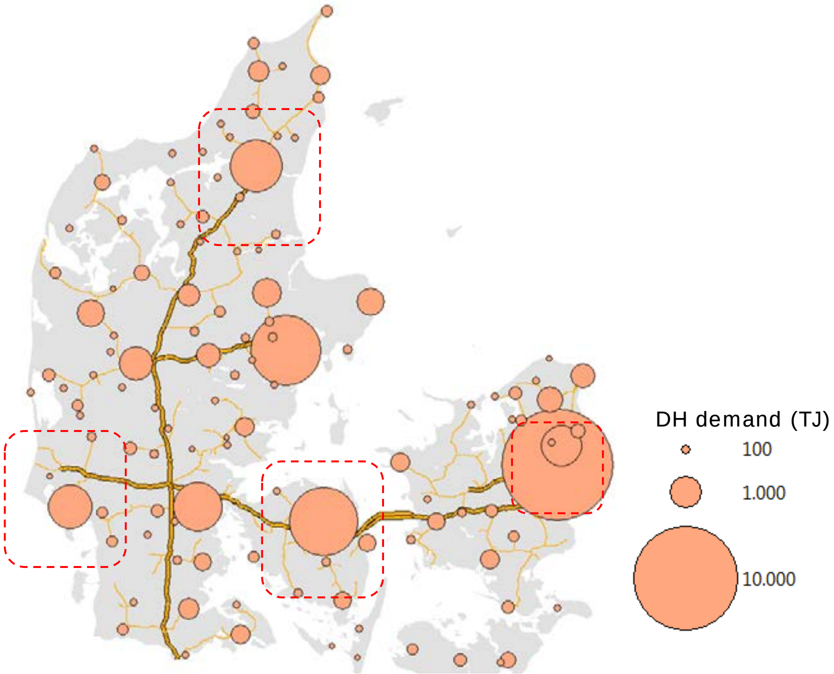
Energy system analysed

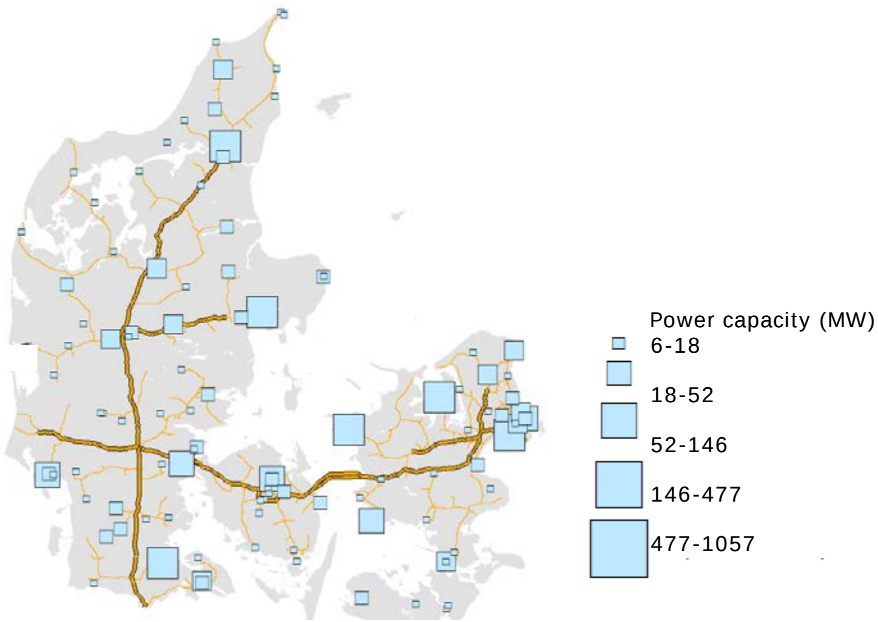
Energy prices,
Production profiles
Flexible demands
Transmission
Storage use
Export,
Import,
...

The Danish system modelled in Sifre

40 Sifre heating areas representing all heating areas in DK

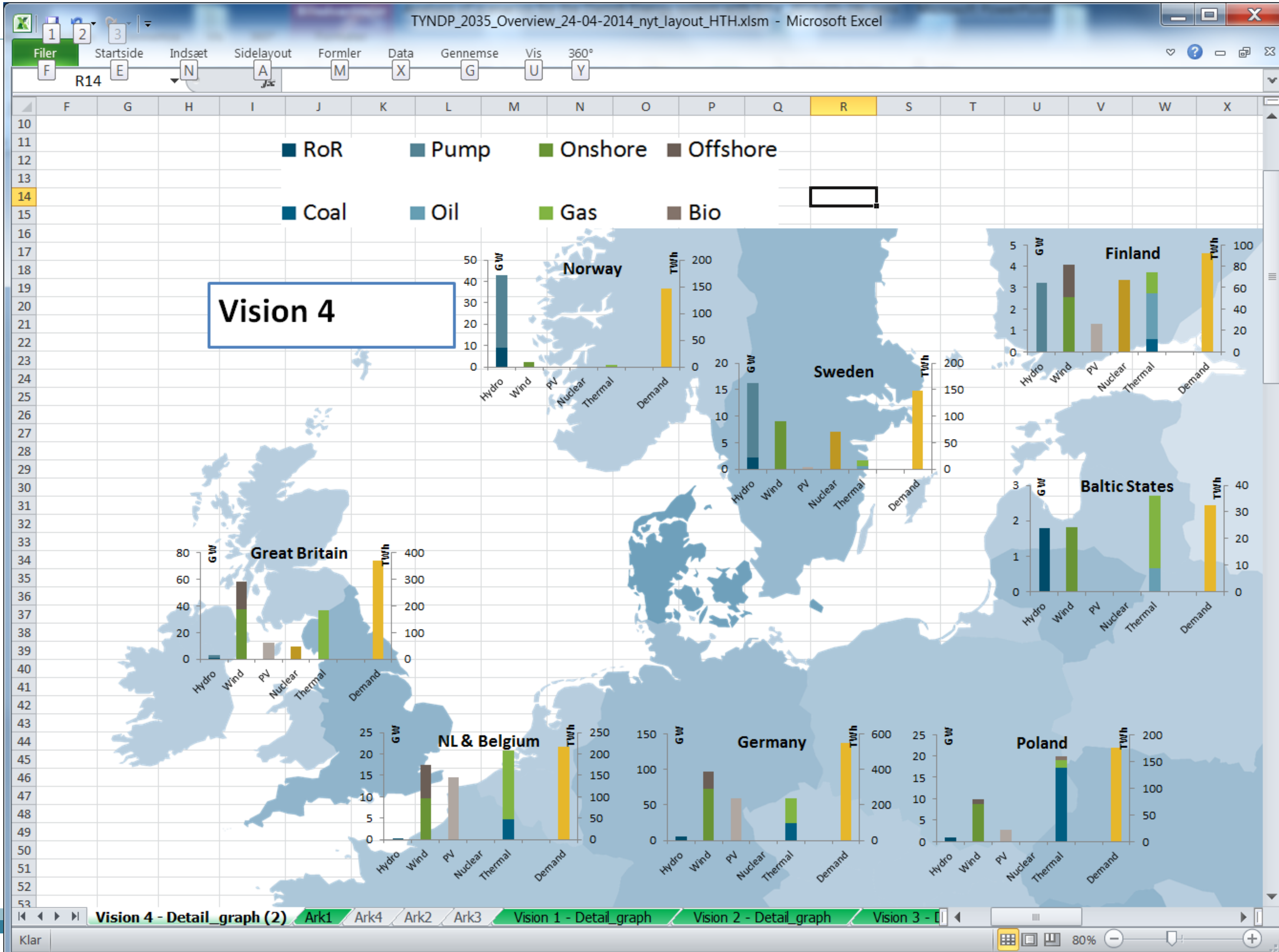
2 electricity system areas
1 gas system area => 1 pr. MR station





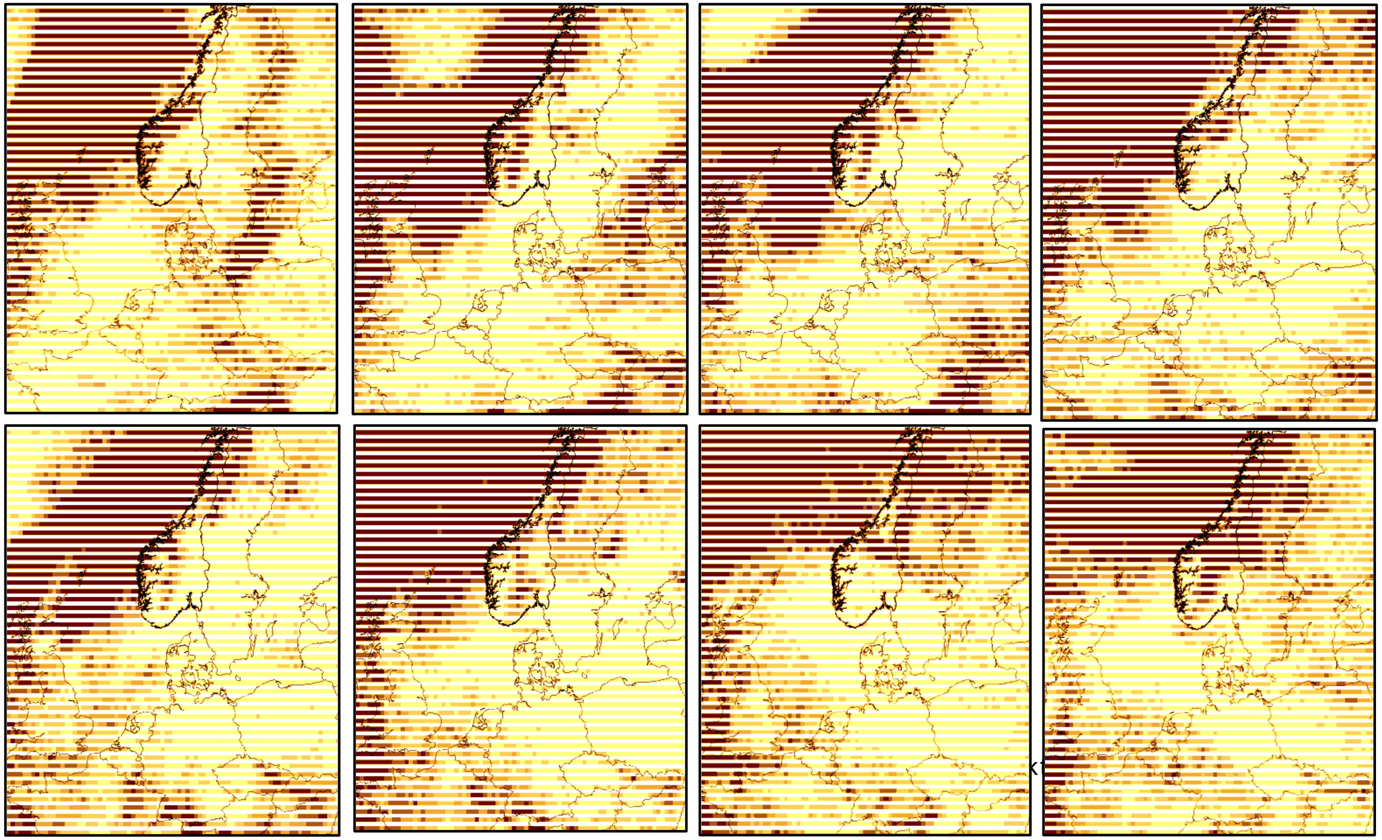
District heating areas (DH) and yearly demand

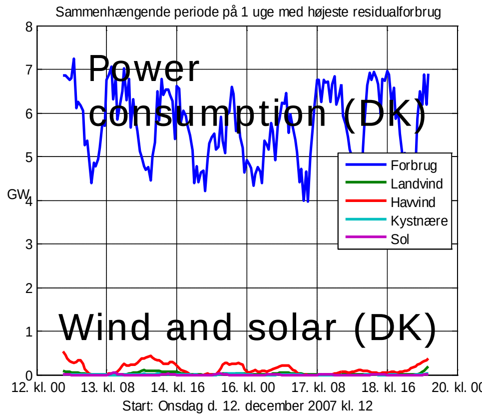
Conversion units 2016 (power plants)


TYNDP_2035_Overview_24-04-2014_nyt_layout_HTH.xlsm - Microsoft Excel
Filer
Startside
Indsæt
Sidelayout
Formler
Data
Gennemse
Vis
360°
R14
RoR
Pump
Onshore
Offshore
Coal
Oil
Gas
Bio
Vision 4
Norway
Sweden
Finland
Baltic States
Great Britain
NL & Belgium
Germany
Poland
GW
TWh
Hydro
Wind
PV
Nuclear
Thermal
Demand
Vision 4 - Detail_graph (2)
Ark1
Ark4
Ark2
Ark3
Vision 1 - Detail_graph
Vision 2 - Detail_graph
Klar
80%

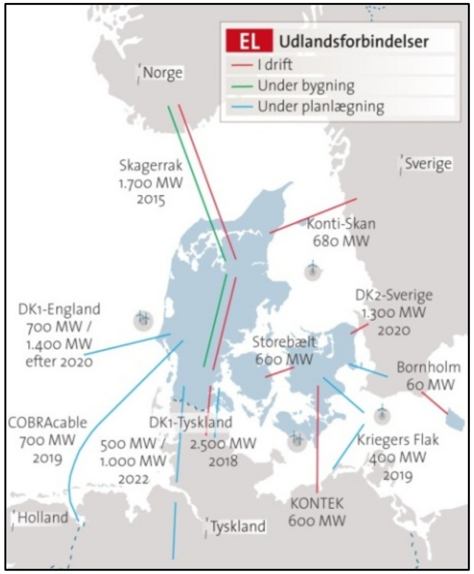
Windpower in North sea region in a week with ”Worst case i DK”

From 12/12 kl. 24.00 and 7 days ahead





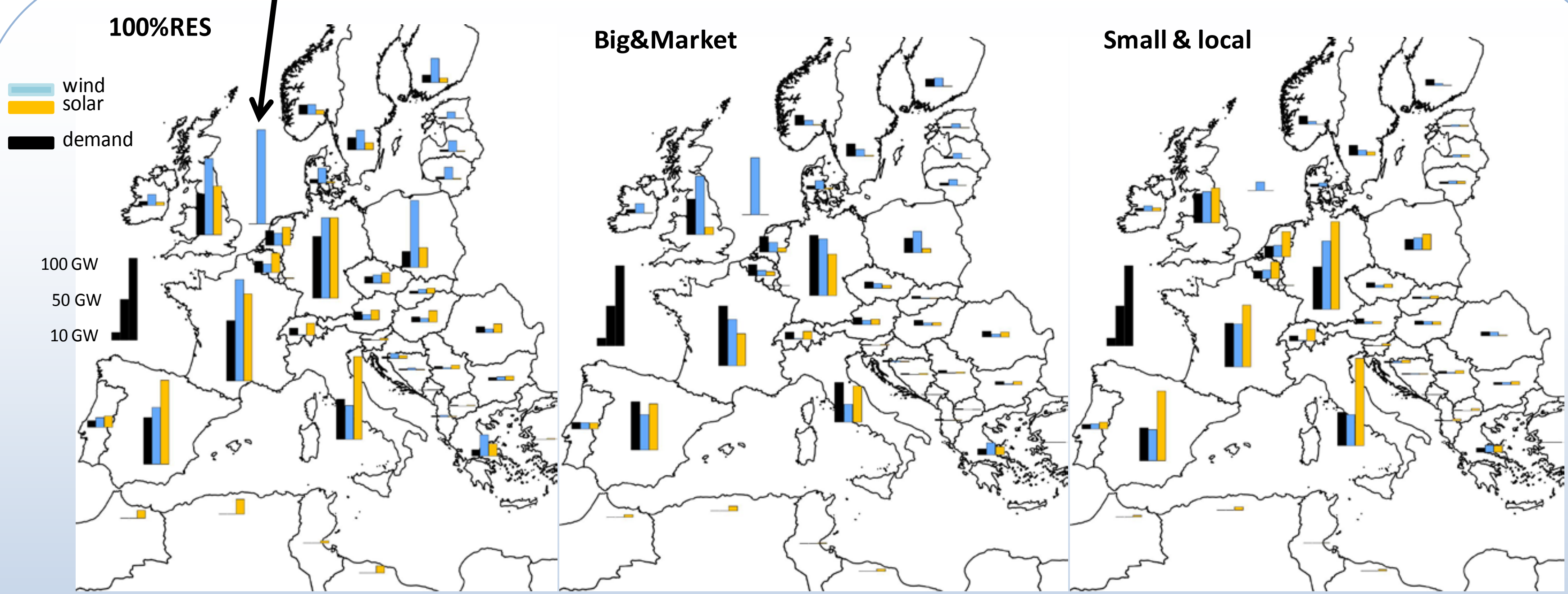
	0 - 0,14
	0,14 - 0,33
	0,33 - 0,55
	0,55 - 0,81
	0,81 - 1



- *Essential to use the geographical spread of windpower*

Wind and solar in European eHighway scenarios towards 2050

Obs: More than 100 GW wind-power in North Sea region!
A need for transmission grid to integrate RE in Europe



The figure shows the average demand for three scenarios in 2050, in comparison to the installed RES capacities (solar and wind). With significant amount of renewables, the RES generation capacities exceed the average demand. As a result, during period of high RES generation, it is necessary either to export, either to store, or to curtail the generation.

Source: Final draft eHighway scenarios