SIFRE and perspectives for city and national planning

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DTU Lyngby

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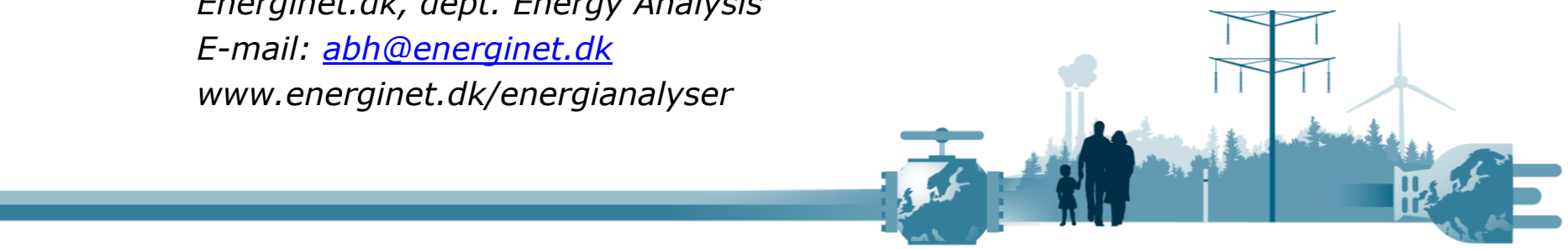


Disposition

1. Methodology in simulation of energy system at ENDK
   - the role for Sifre (**SI**mulating **F**lexible **R**enewable **E**nergy sources)
2. Simulated Scenarios for DK – from today to 2035 and 2050
3. R&D&D focus areas – further investigated by Cities simulation
   - *Controlling and market in the energy system!*
   - *Power system – Enhanced use of infrastructure and international capacity*
   - *Fuels and gas –chemical system integration*
   - *Thermal integration in Cities*
4. From Cities simulation and R&D&D back to system planning

Methodology in simulation of energy systems – the role for Sifre

*Sifre: **SI**mulating **F**lexible **R**enewable **E**nergy sources*

System analysis and simulation a central part of the proces

Framework conditions

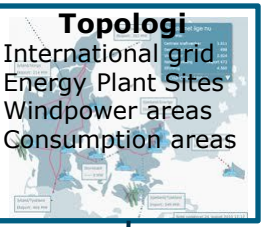
Political framework conditions
RE/CO2//Bio etc.
Security of supply
CCS, shale gas etc.

External conditions
Ressource prices
Power prices int.
CO2 market

Energy services demand
Cathegories
Time-profiles
Elasticity

Strategic choices - marketbased

Topologi
International grid
Energy Plant Sites
Windpower areas
Consumption areas



Energisystem-elements
Infrastrukture
Conversion units
System control

System Concepts

Energy system and concept analysis

SIMULATION (Sifre to substitute Sivael)

- *Energy balances and power flow*
- *Socio-economic analysis*
- *Security of supply*

Key findings

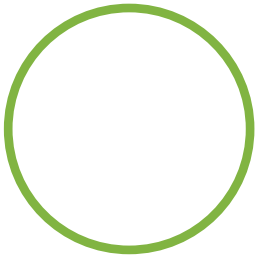
Result of analysed concepts

RDD strategy

Research, Development and demonstration

System-planning

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

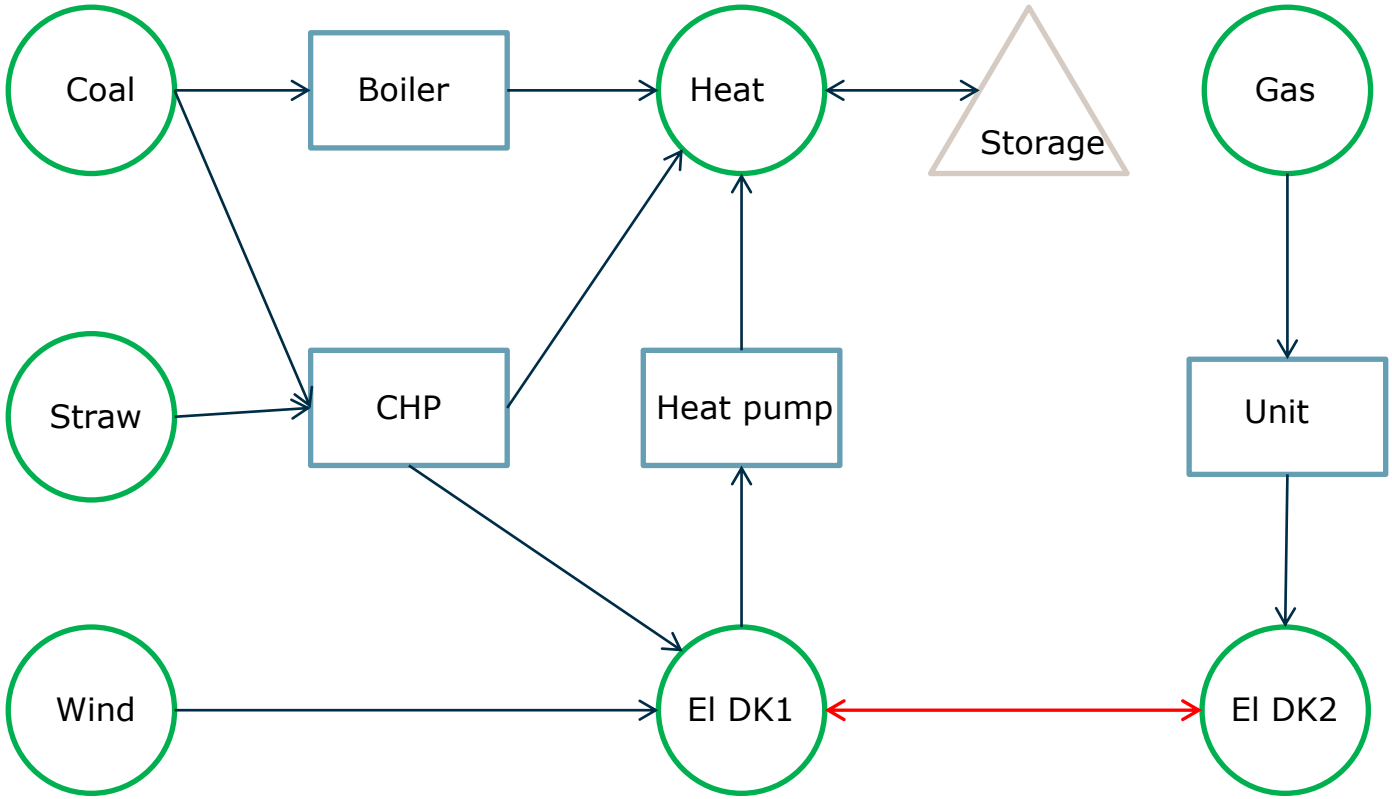
Storages

Storage of energy

Examples:

- Battery
- Heat accumulator
- Bio-mass storage

Example on an energy system analysed in Sifre



Sifre – Input/Output

Input

Energy system

Production unit,
Fuels,
Demands,
Connections,
…

Method

Simulation

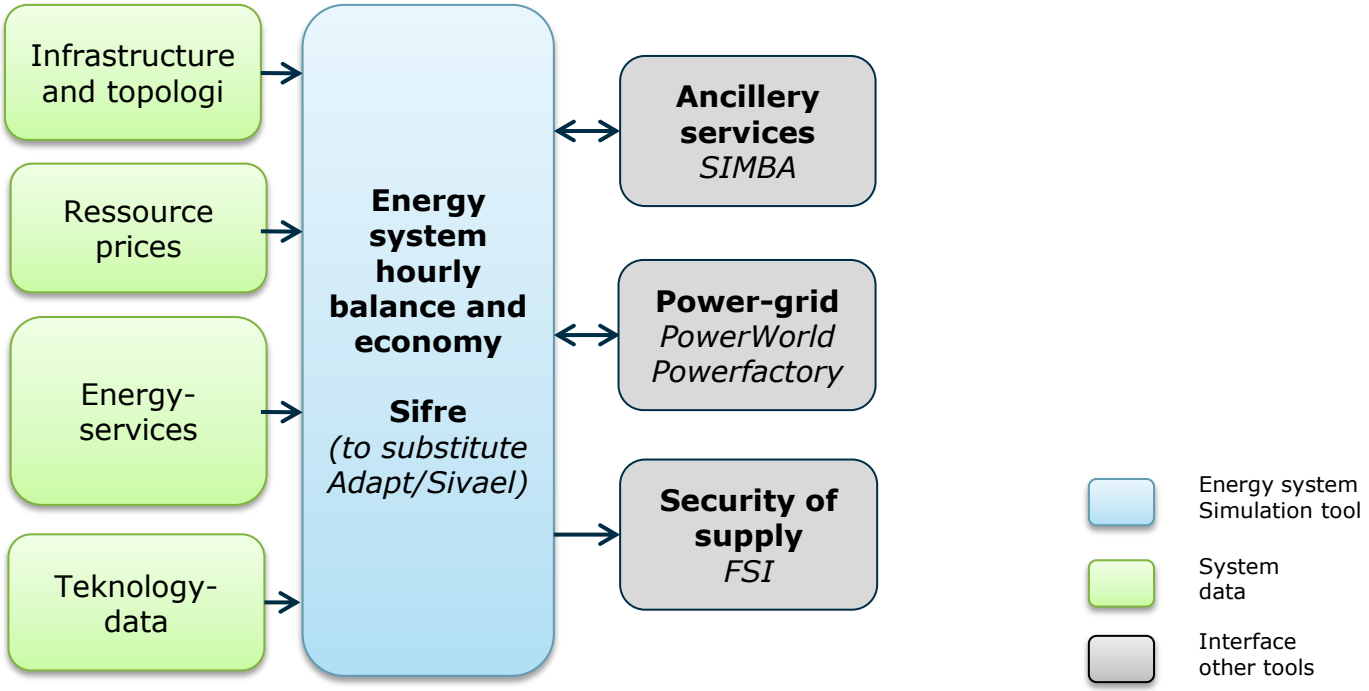
Front end (C#)
Gurobi solver
(least cost solution)
Data stored in MS-SQL

Output

Energy system analysed

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

Sifre – integration with other analysis tools

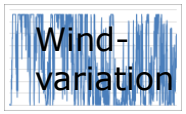


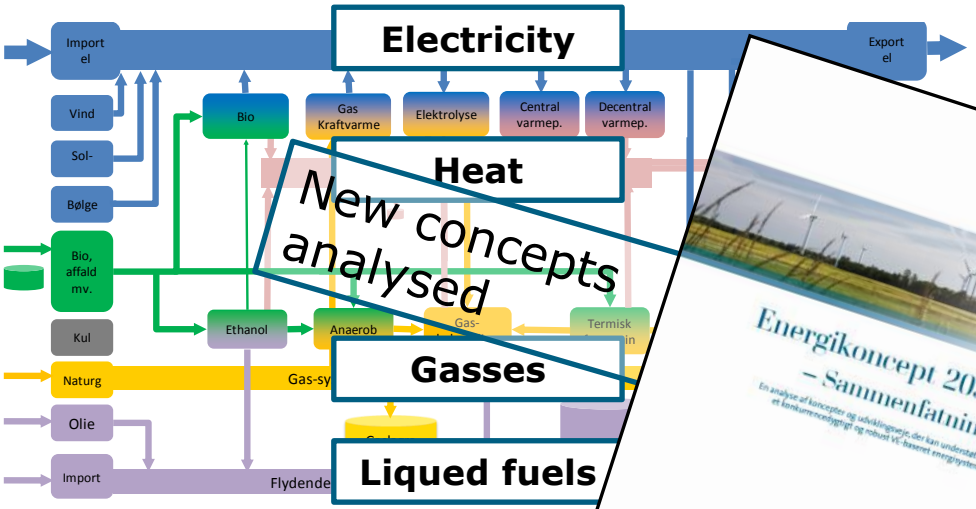
Sifre to be used as "central" energy system analysis tool at ENDK

Energy system performance evaluated by simulation

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

- Wind
- Solar
- Biomass
- Natural gas
- Fossil oil
- Coal
- Etc…





- …ilding
- …eating
- Proces-heat
- Cooling
- Light, IT etc.
- Transport

Sustainable ressources

Integrated energy system
Robust, flexible and efficient

Minimised, low and stable costs

Total performance for system evaluated.

System property to "**damp**" step on ressource prices *(low β-faktors)*

Price inkl. hedging = *Price excl. hedging + Price hedging*
= *Price exc. hedging + β_n x (Ressource price hedging– Ressource price excl. hedging)*

New concepts simulated in the energy system

Elements **Concepts**

Element 1:

Element 2:

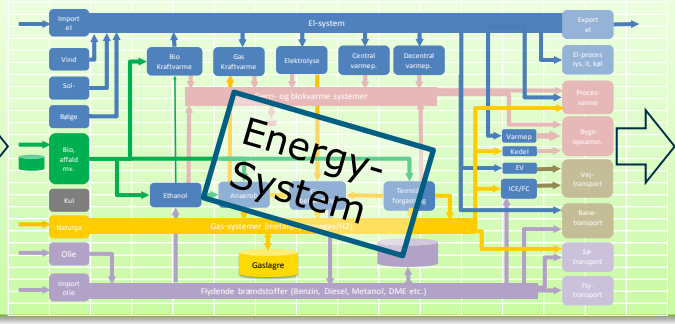
Element 3:

Concept x:

Concept:
"A solution based on a cluster of elements"

Research.–Dev.–Demo.

-Energy ressources
-Frame conditions



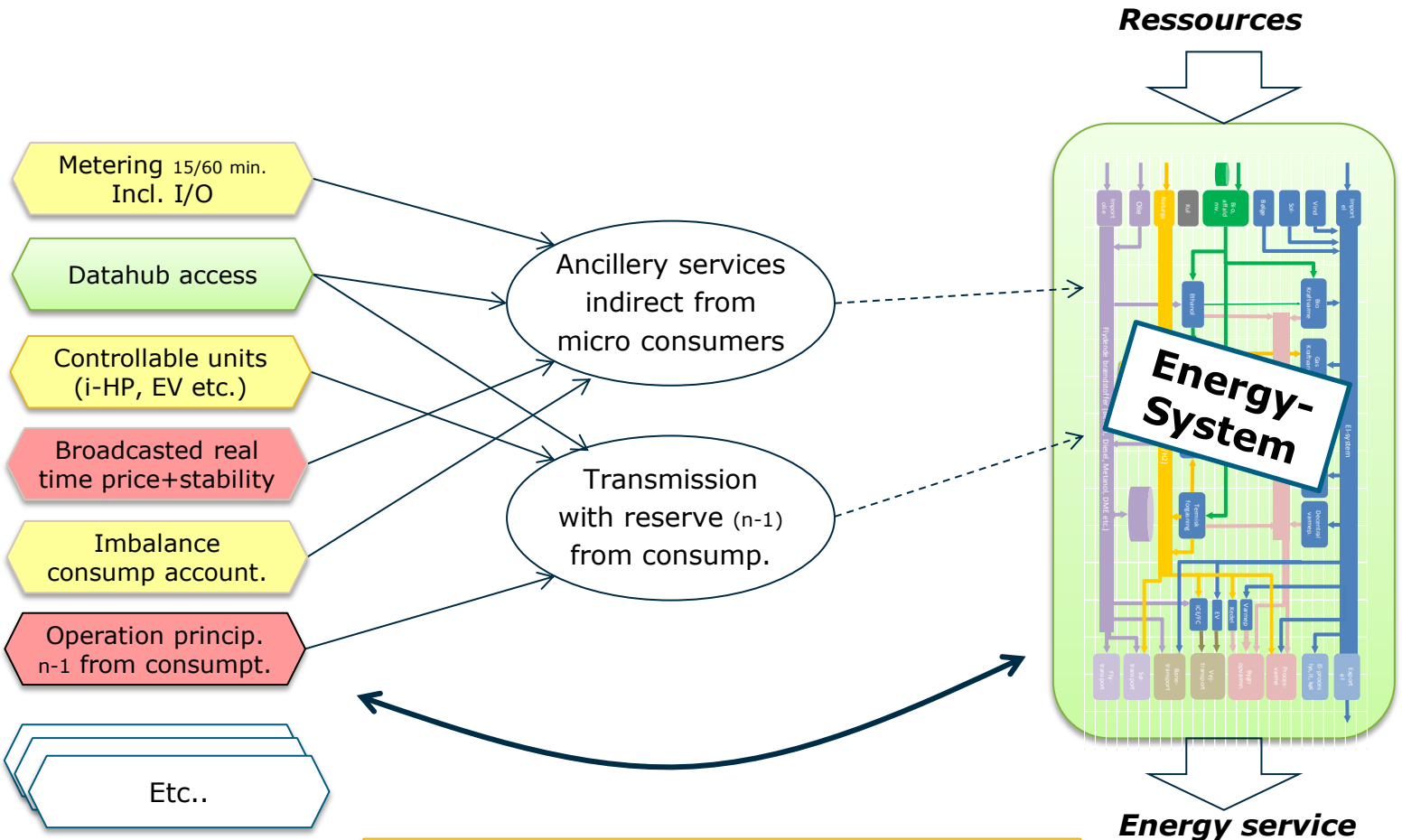
Energy services
-Cost efficient
-Security of supply

It is simulated how concepts impacts on energysystem "performance"

Example: Element -> Concept -> System

Elements

Example concepts



Simulation of potential if element is developed and implemented

Research.–Dev.–Demo.

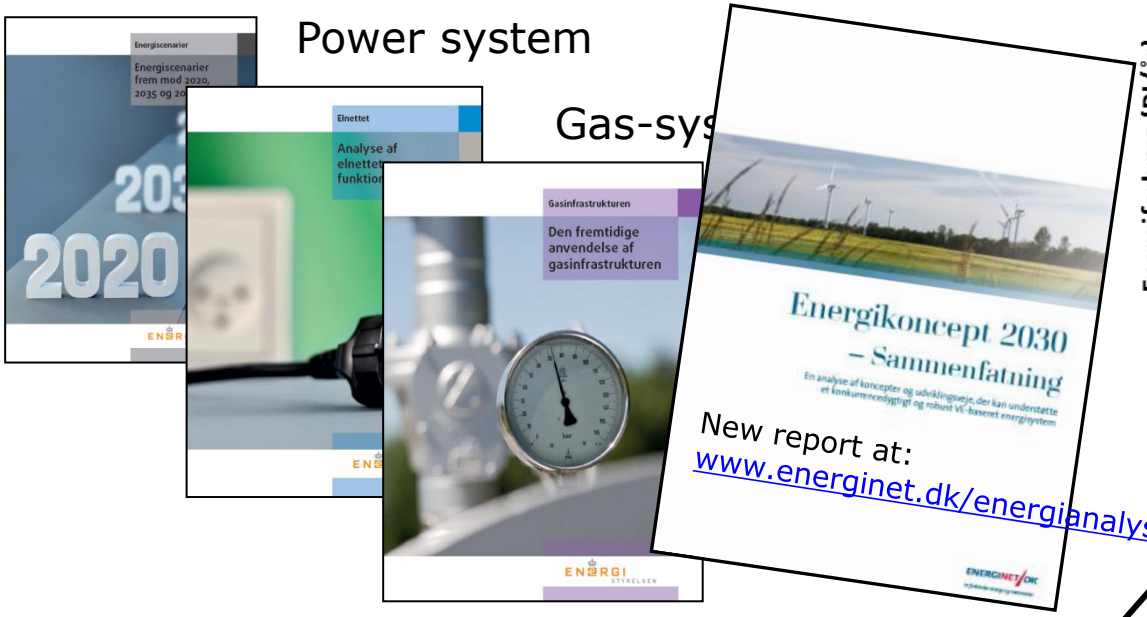
Simulated scenarios for DK (national/international level)

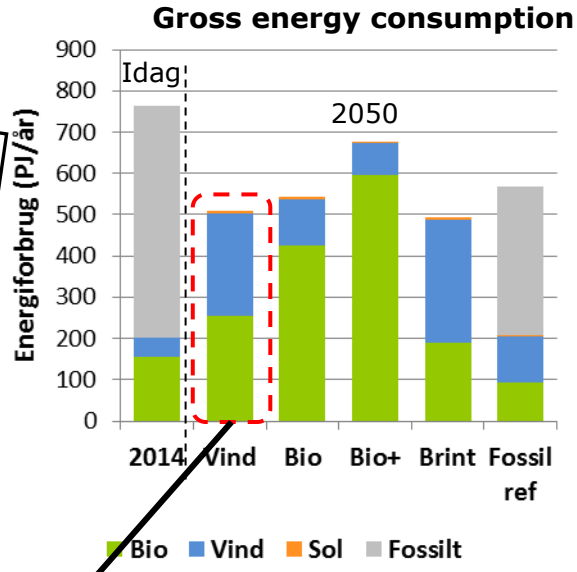
Scenario basis – ENS and ENDK

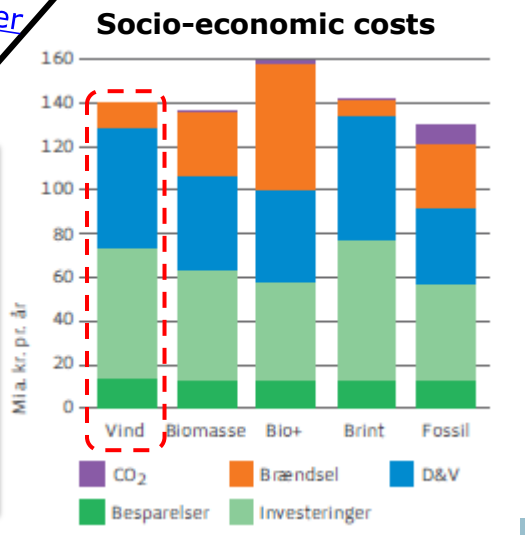
Scenarios

Power system

Gas-sys







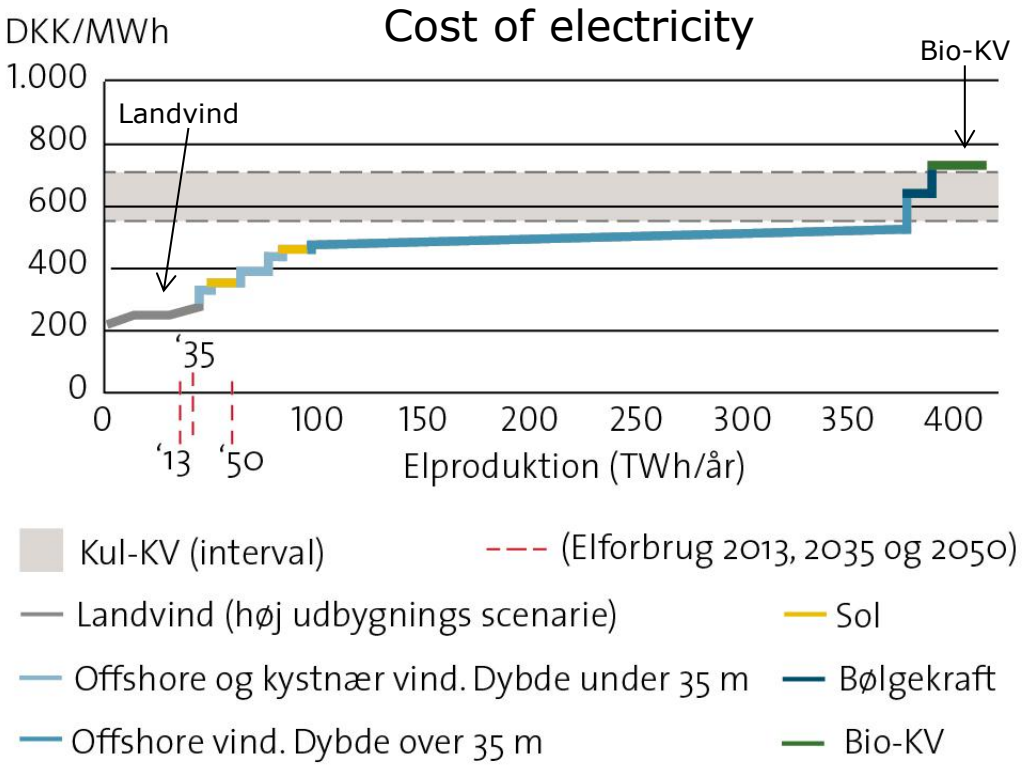
Wind-scenario – study 2014:
High security of energy, 8% more expensive than fossil reference in 2050

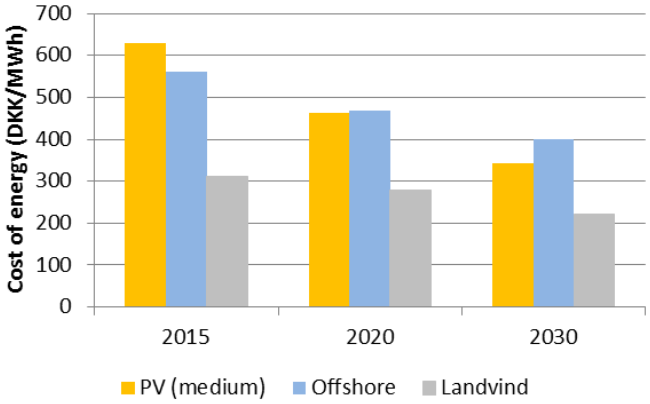
Especially peak-power capacity, reinforcement of power infrastructure, balancing of power and production of RE-fuels are more expensive in the basis wind scenario

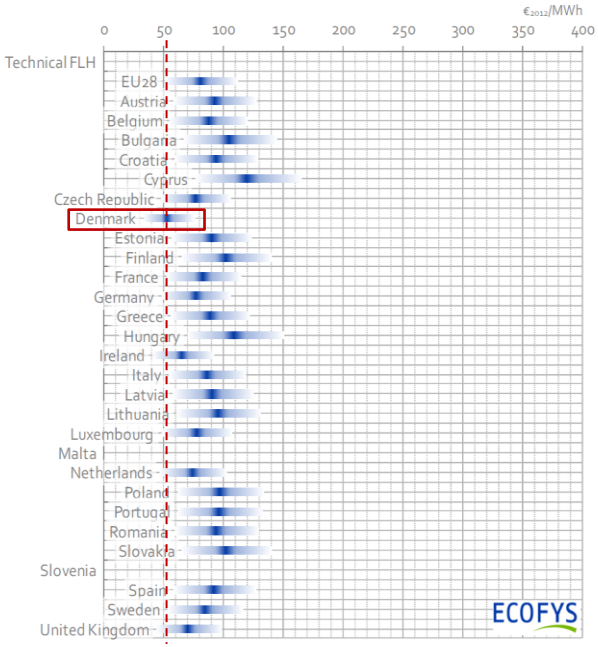
A need for R&D&D to investigate cost-cutting concepts

RE-electricity ressources DK

(potential and socio-economic cost of energy 2030 excl. integration)





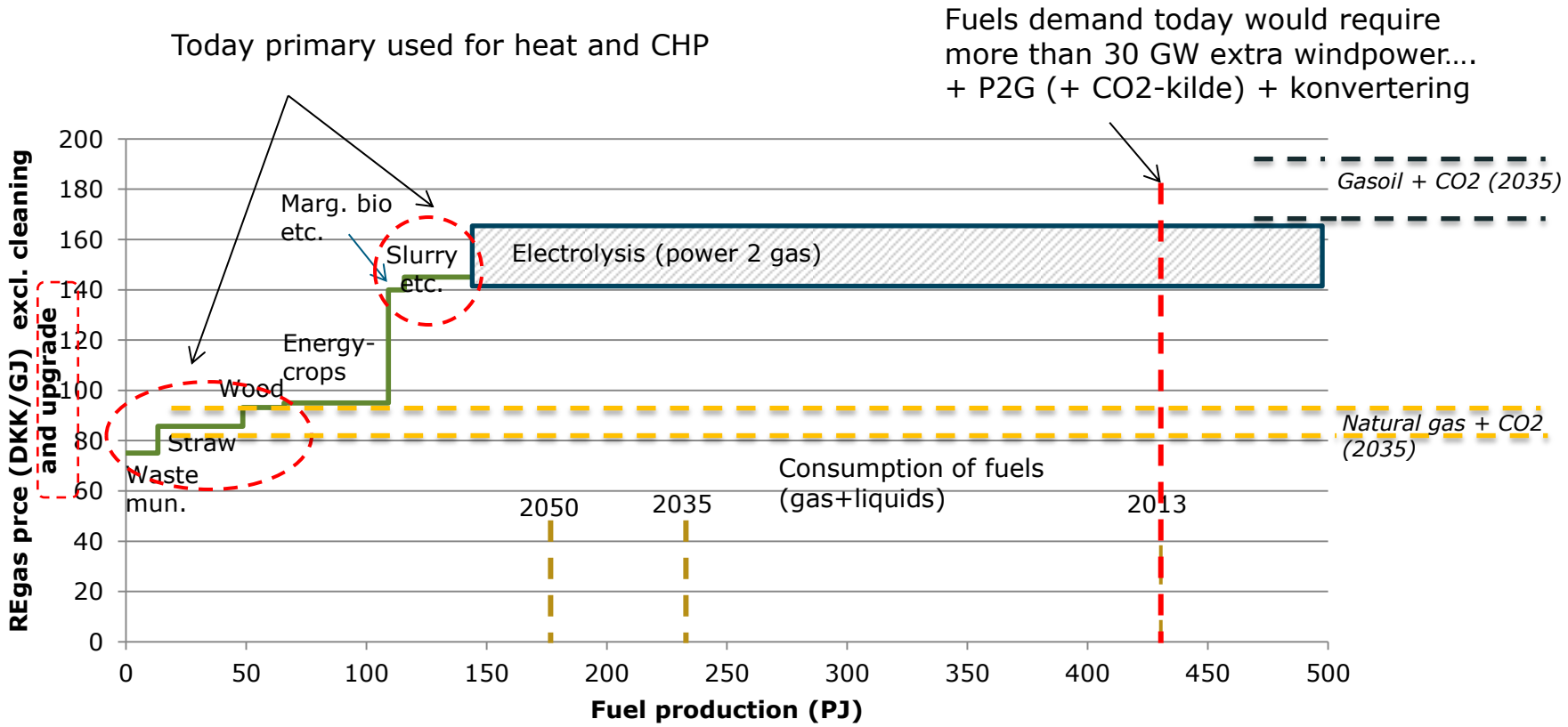


Beregnet ved 4% diskontering og teknologidata-katalog 2014/2015
For sol er ikke vist barmarks anlæg.

Potentiale til at gøre vindkraft konkurrencedygtigt med fossil elproduktion
Landvind i DK er i særlig grad en omkostningseffektiv VE-ressource

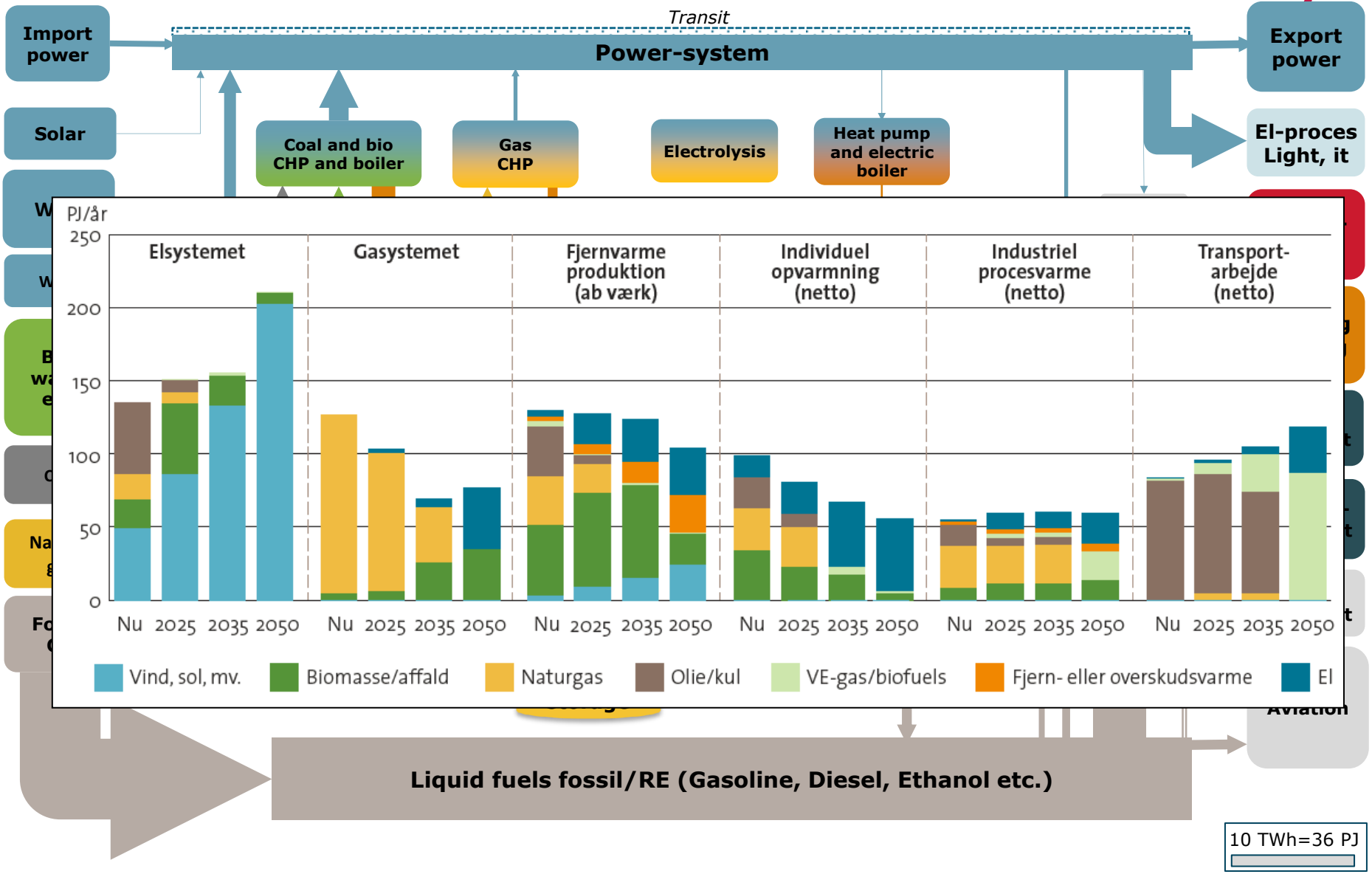
Ressources and cost for fuels

(2030 if all biomass is allocated to fuels)

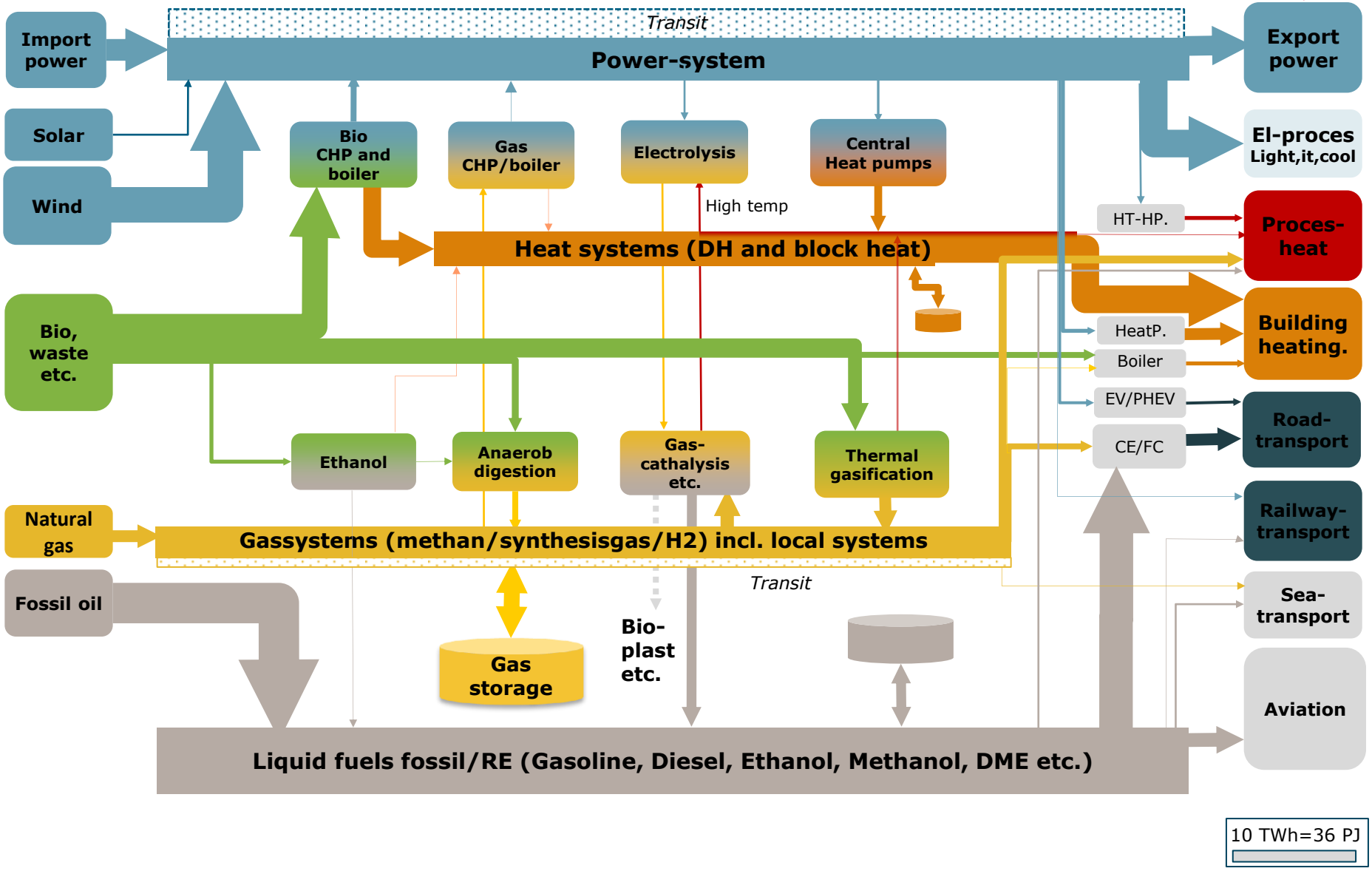


A significant demand for fuels – biomass is essential for producing high amount of fuels

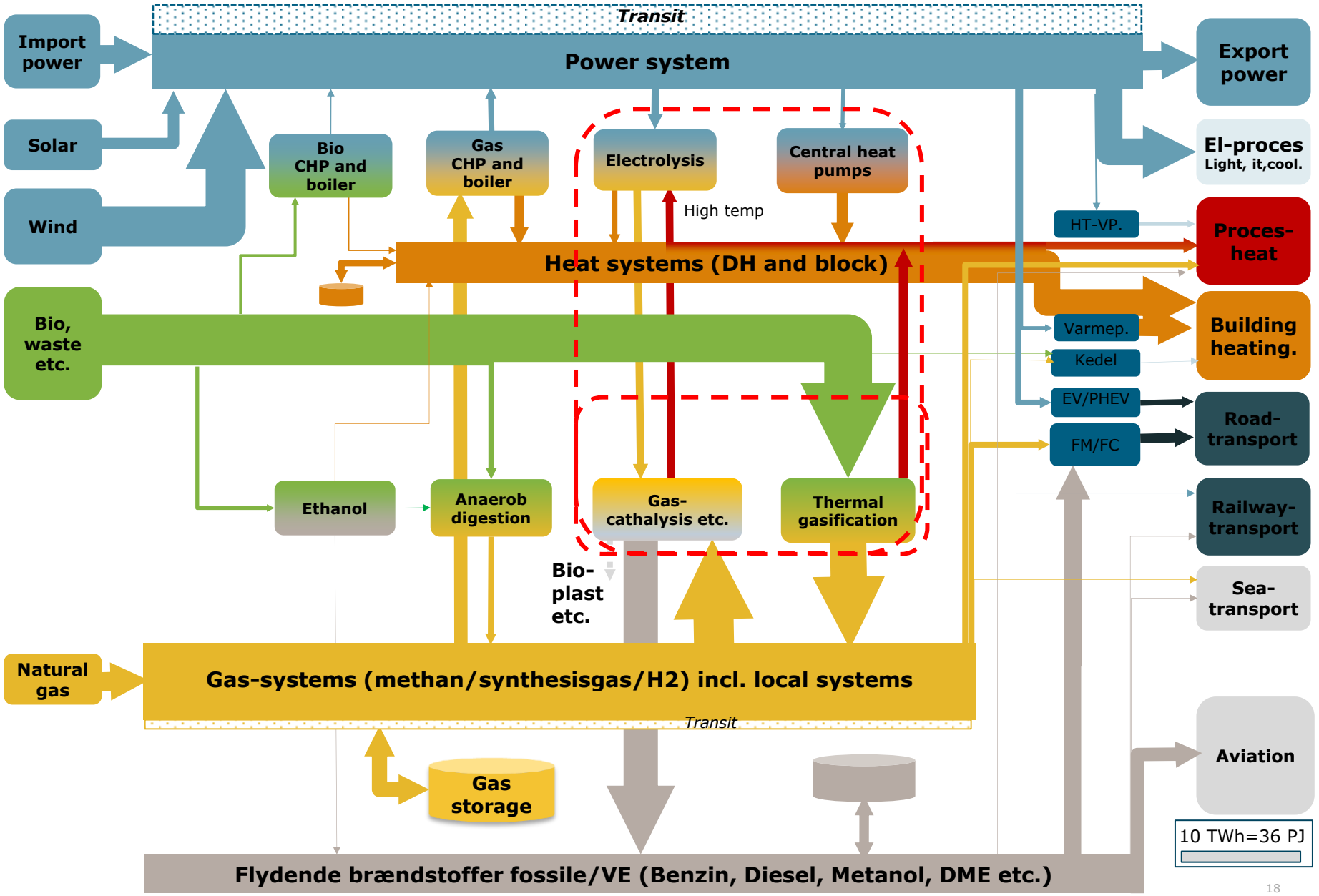
2014


Transit
Import power
Power-system
Export power
Solar
Coal and bio CHP and boiler
Gas CHP
Electrolysis
Heat pump and electric boiler
El-proces Light, it
PJ/år
250
200
150
100
50
0
Elsystemet
Gasystemet
Fjernvarme produktion (ab værk)
Individuel opvarmning (netto)
Industriel procesvarme (netto)
Transport-arbejde (netto)
Nu 2025 2035 2050
Vind, sol, mv.
Biomasse/affald
Naturgas
Olie/kul
VE-gas/biofuels
Fjern- eller overskudsvarme
El
Liquid fuels fossil/RE (Gasoline, Diesel, Ethanol etc.)
10 TWh=36 PJ

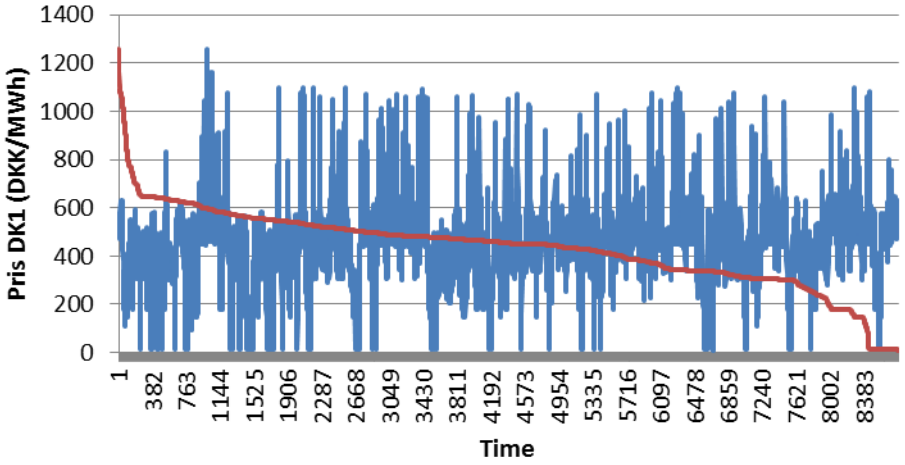
2035 - Reference with fossil free power and heat system



Feasibility study 2035 – reduced fossil oil demand

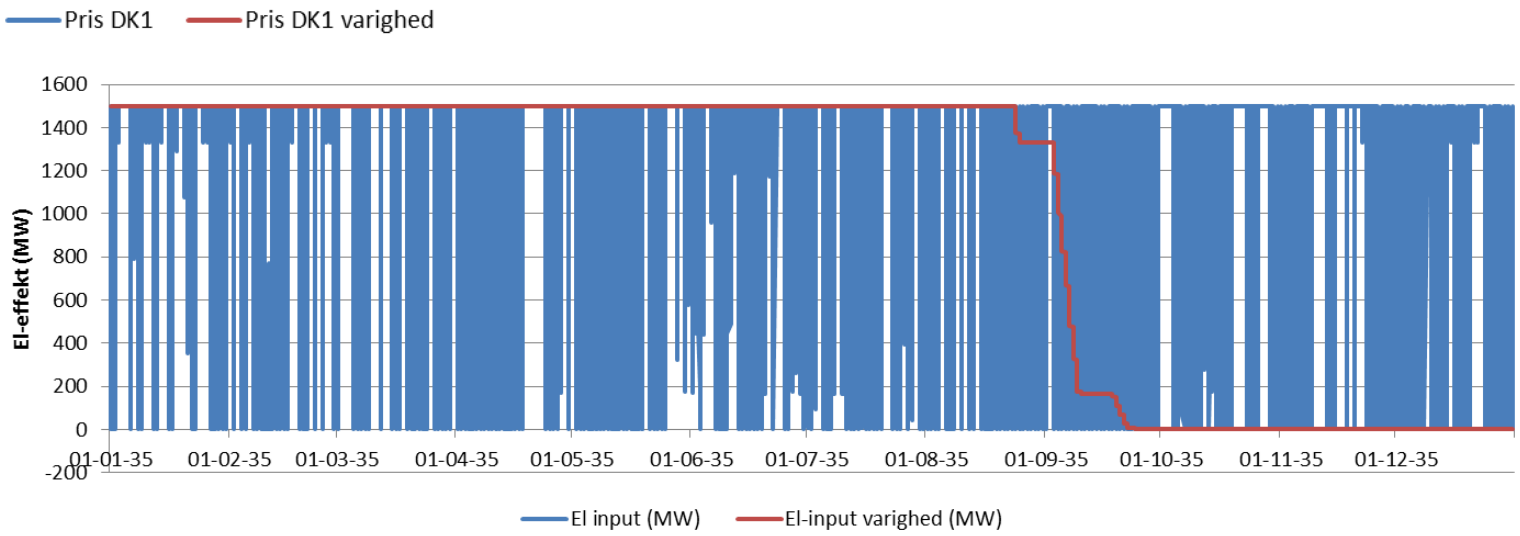


System-analyse af elektrolyse – case 2035

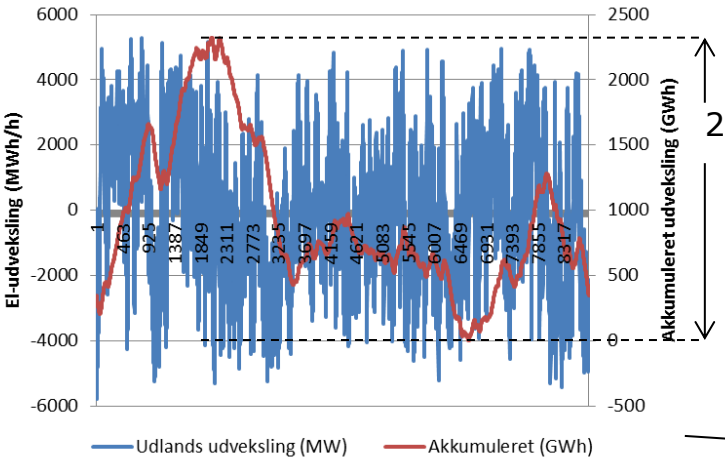


Case: 12 GW vind + 7,5 GW sol

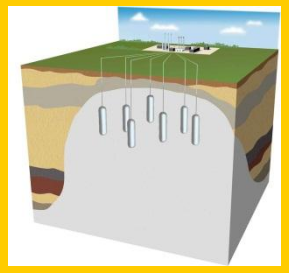
Case SOEC fuldt markedsmoden
- Efficiency (LHV): 0,8
- Capex: 4,5 mioDKK/MW
- 407 DKK/MWh/5990 årstimer

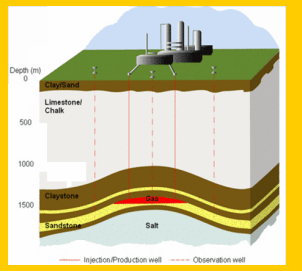


Lagerkapacitet i energisystemet – Scenarie 2035



Gaslagre (11 TWh metan-gas)
vist som el input ved Power-to-gas





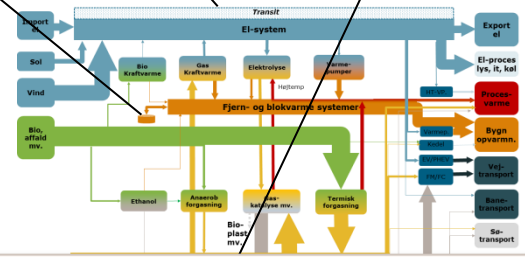
Udlandsforbindelser årlig akkumuleret case 2035 (2,3 TWh)

Fjernvarme med ekstra sæsonlagre

Fjernvarme m. lager

Individuel varmep.

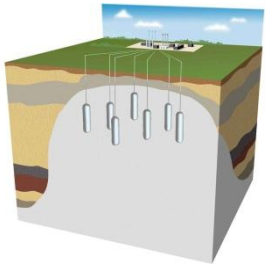
El- og plugin hybrid case 2035



Lagerkapacitet fra elbiler og varmepumper er vigtig til korttidsbalancering men har minimal betydning for lagring af større energimængder fra fluktuerende vindkraft

Simulation of the Cities and local areas - analysing new concepts in the system

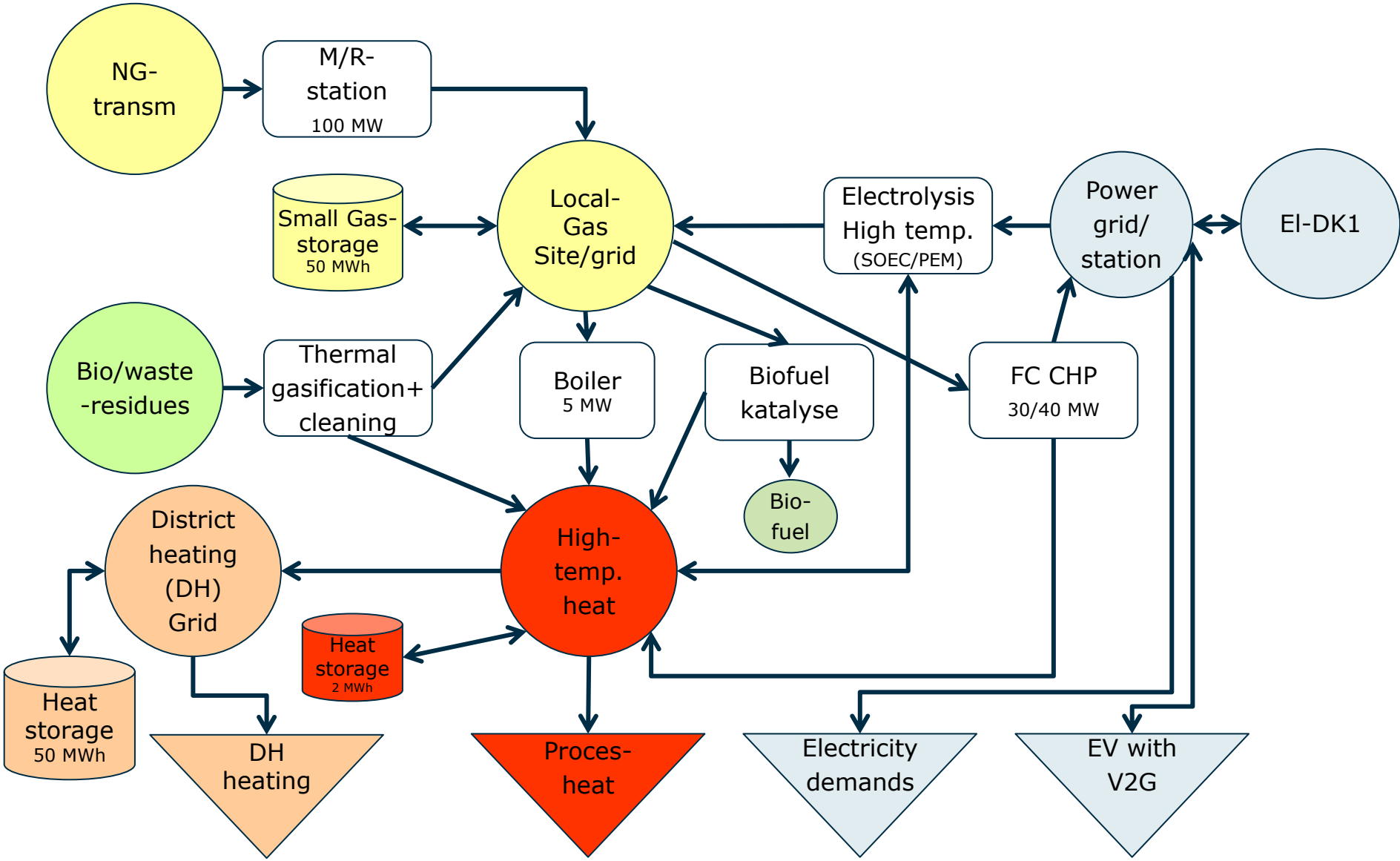
Integration of local and national gas-system



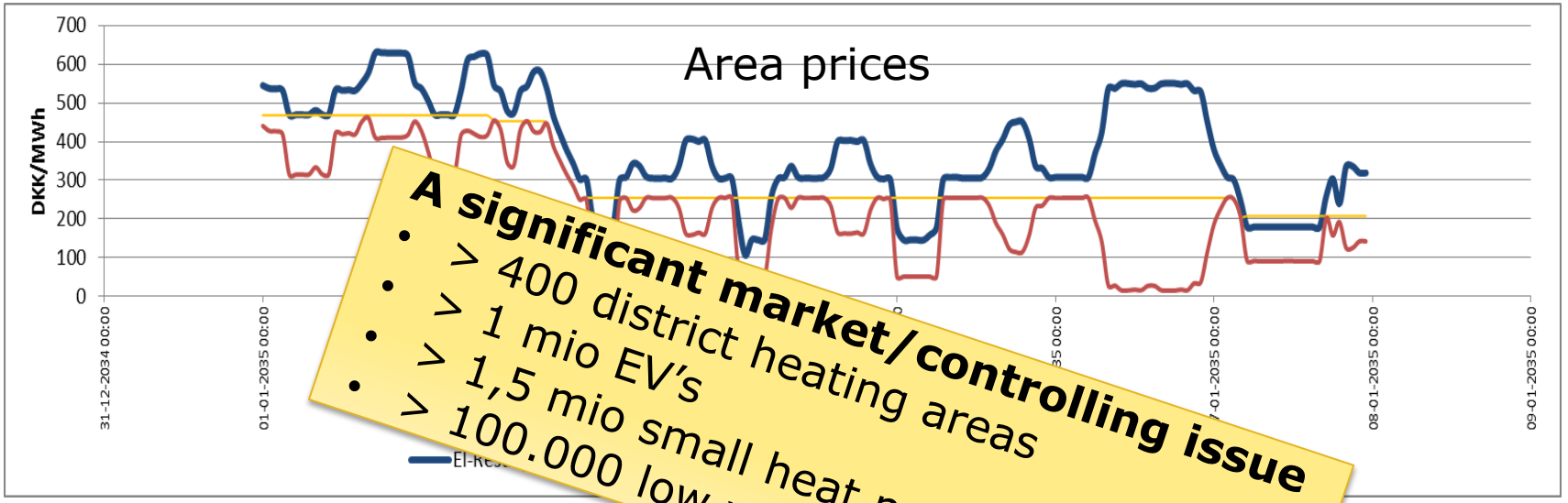
Hydrogen
H2 tank
Industri
Biofuel
Power to Gas
Termisk forgasning
Fuld opgradering (CH4)
Power to Gas
Biogasanlæg
Kraftvarme
Industri
OVERORDNEDE GASNET
Termisk forgasning
Power to Gas
Kraftvarme
Industri
Biofuel
Syntesegas (H2+CO)
Power to Gas
Biogasanlæg
Kraftvarme
Industri
Lager
Lokalt biogasnet (CH4+CO2)
Energinet.dk

New types of RE gasses to be integrated – essential to handle sub-nets with other gas-specification

Analysis of local energy system

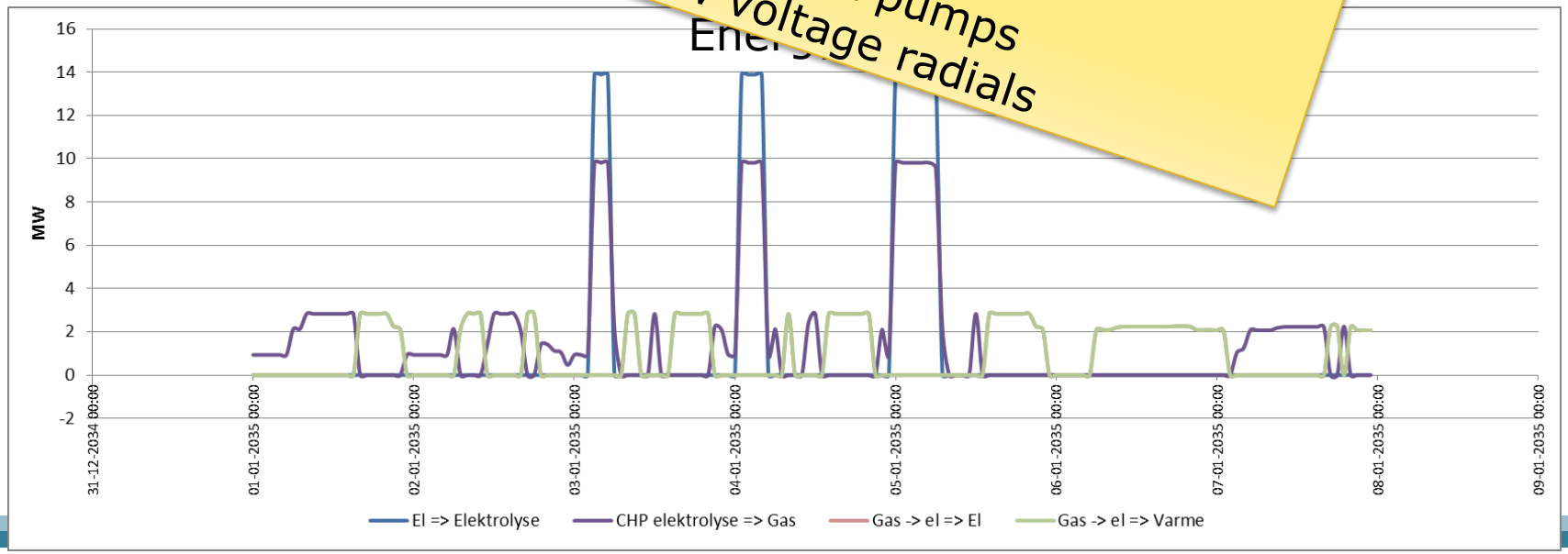


Simulation – draft example

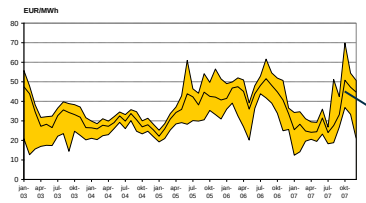


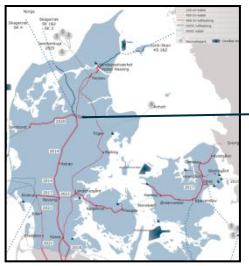
A significant market/controlling issue

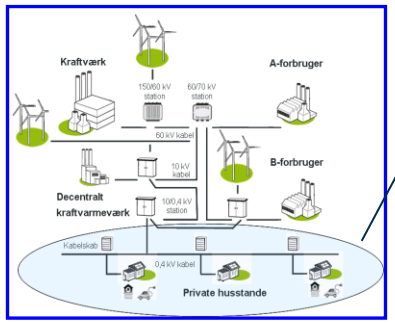
- > 400 district heating areas
- > 1 mio EV's
- > 1,5 mio small heat pumps
- > 100.000 low voltage radials



Analysis of Energy System dynamics







Day-ahead

System-balance (e.g. 5 min)

TSO LMP etc.

DSO

r + e -

MPC input ?

C

$n_{DSO1}^{nSystem} \sum -Y_m$

$n_{DSO1}^{nTSO-LMP} \sum Y_m$

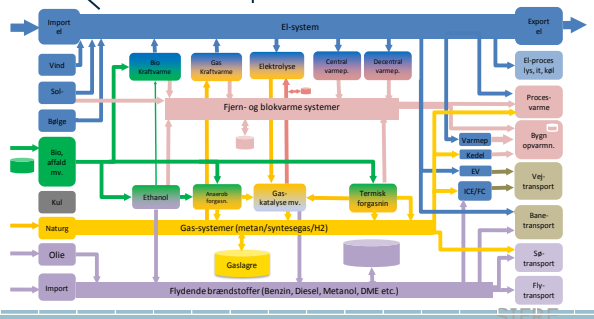
$n_{DSO1}^{nDSO} \sum Y_m$

Energy conversion units

G_1

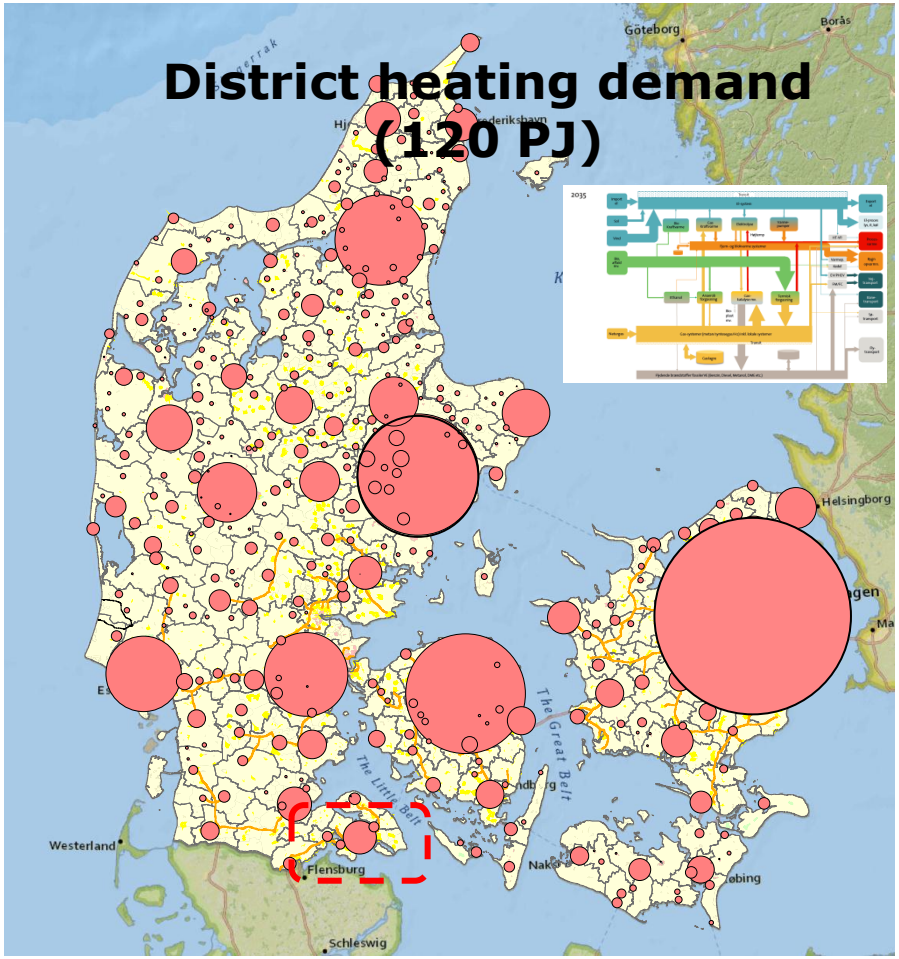
G_2

G_n



From local and Cities concept analysis back to national/international level?

Scaling the R&D&D solutions to DK - Demand for heat is essential



Proces heating demand (60-65 PJ)

	Sum	Type 1	Type 2 (høj temp)
I alt (proces og rumv.	72737	41941	10715
-heraf industri	66423	41647	10715
-heraf handel/service	6314	294	0
Landbrug	7961	5840	183
Gartneri	2622	2172	0
Råstof-indvinding	2876	2375	164
Slagterier	2022	1207	471
Fiskeindustri	1120	963	0
Mejerier	3592	2769	0
Bageri	1458	1212	0
Foderfremst.	1215	1160	0
Sukker	2842	2455	0
Øvrig fødevare	1730	1235	201
Drikkevarer	1397	1153	0
Tekstil	300	232	0
Træ	3023	2041	93
Papir	1909	1602	0
Enzymer og gødning	749	505	59
Basiskemikalier	563	442	0
Maling og sæbe	3176	2778	0
Medicin	1287	1039	0
Cement	9116	5782	3329
Teglsten mv	1322	375	935
Asfalt og tagpap	1360	1317	0
Øvrig beton/tegl	2446	1512	472
Metalvarer	1574	402	330
Andre maskiner	1233	228	58
Møbler	1785	283	0

Summing up..

1. Simulation of energy system
   Sifre will used as a central simulation tool at ENDK – and integrated with system specific tools in the power and gas system
2. Simulated Scenarios for DK – from today to 2035 and 2050
   Acceptable system balances and socio economy is found by national simulation – taking into account that technology and concept challenges are solved!

3. Identified challenges – input for R&D&D
   - Controlling and market in the energy system!
   - Power system – Enhanced use of infrastructure and international capacity
   - Fuels and gas – integration of RE-gasses at national and local levels
   - Thermal integration is essential for a good energy efficiency and economy
4. Scaling the R&D&D knowledge to national/international planning
   - The simulated analysis at Demo and research scale could be used for increased knowledge at national – or even international strategic system planning

Thank you for attention

Link: www.energinet.dk/energianalyser