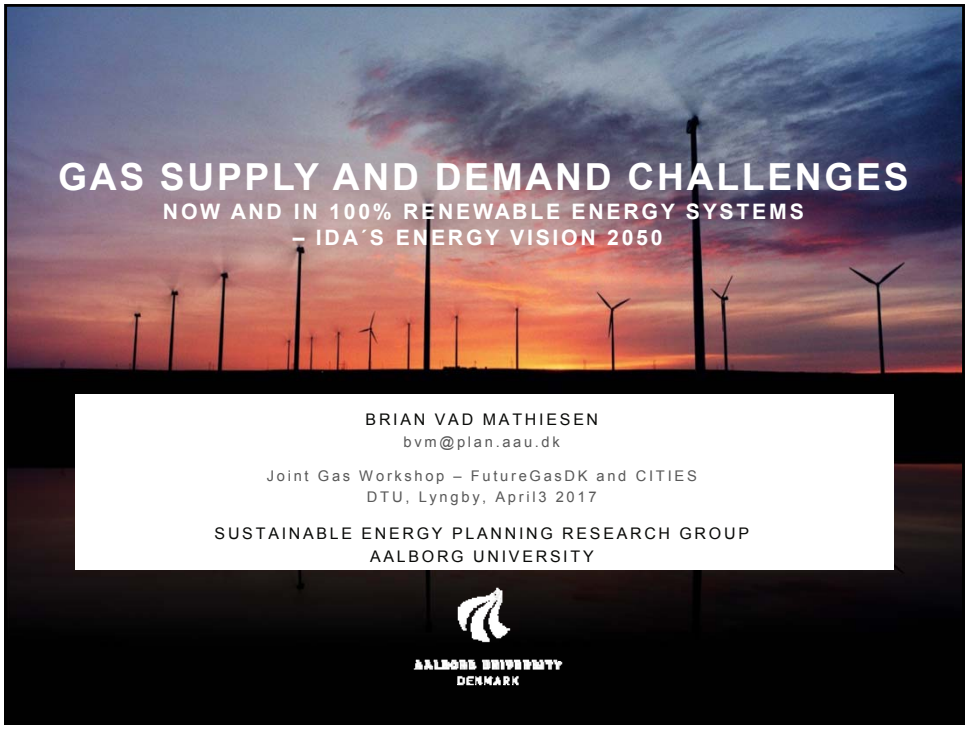
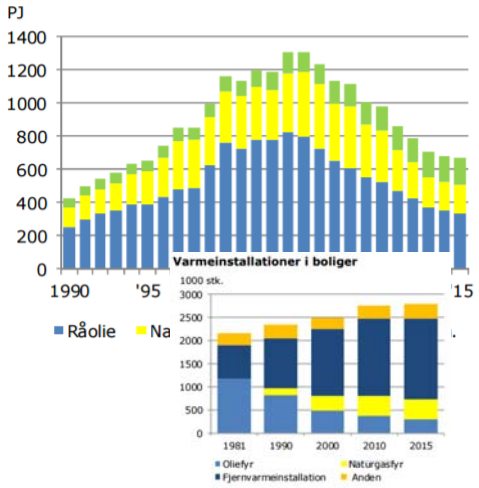
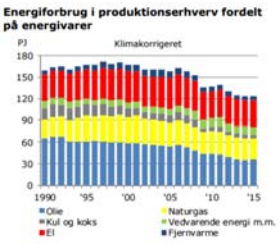


Current gas consumption

Primær energiproduktion



Total 133 PJ
- 24 PJ in Households
- 14+20 PJ in Power/heat
- ~30 PJ in Industry
- ~7 PJ in Services
- + losses



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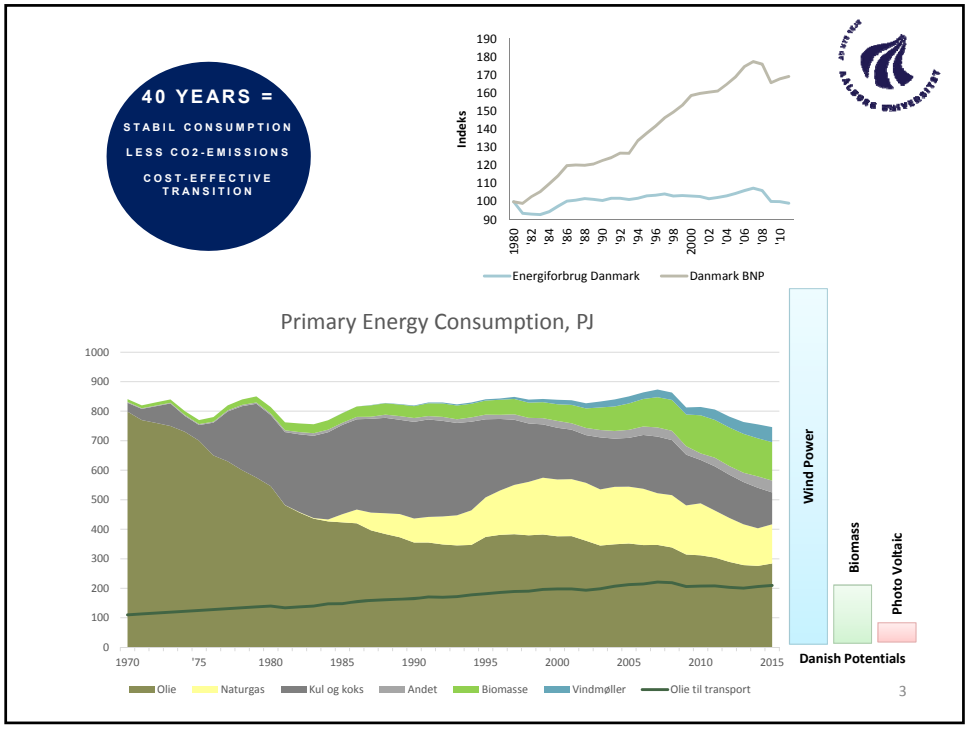
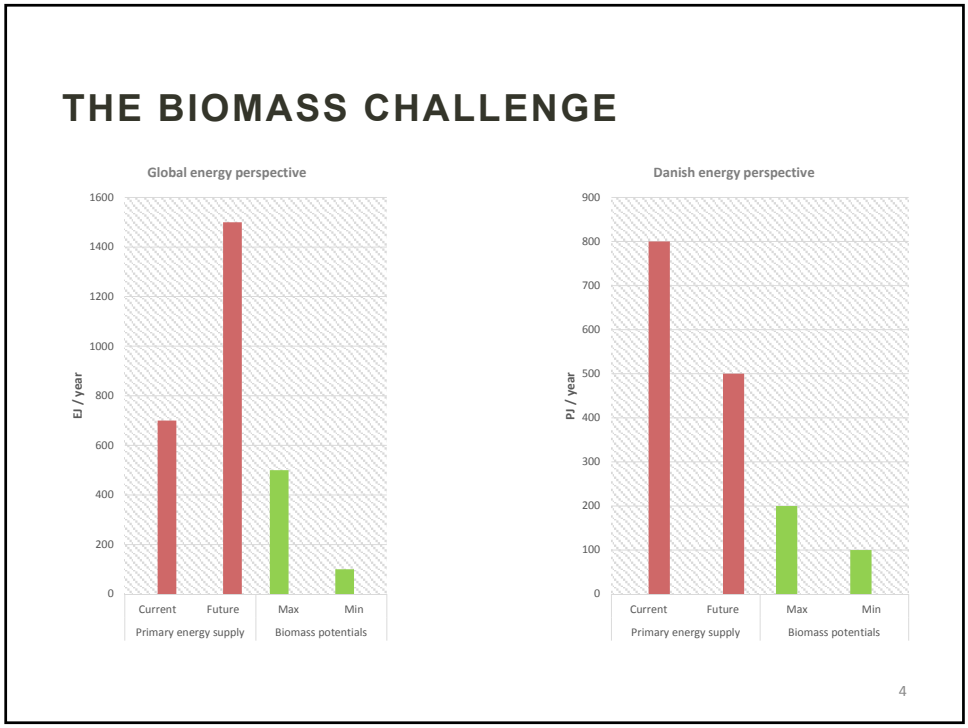
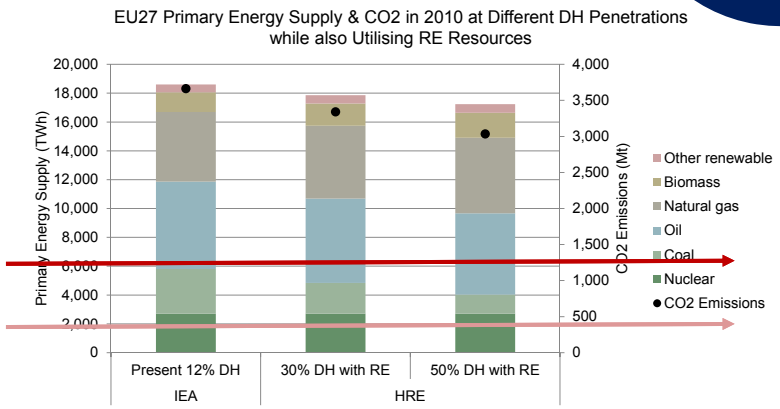

40 YEARS =
STABIL CONSUMPTION
LESS CO2-EMISSIONS
COST-EFFECTIVE TRANSITION
Indeks
Energiforbrug Danmark
Danmark BNP
Primary Energy Consumption, PJ
Olie
Naturgas
Kul og koks
Andet
Biomasse
Vindmøller
Olie til transport
Wind Power
Biomass
Photo Voltaic
Danish Potentials
3


THE BIOMASS CHALLENGE
Global energy perspective
EJ / year
Current
Future
Max
Min
Primary energy supply
Biomass potentials
Danish energy perspective
PJ / year
4

THE BIOMASS CHALLENGE

EU Residual biomass potential:
Less than 7 EJ

EU Energy Crops:
Less than 15 EJ



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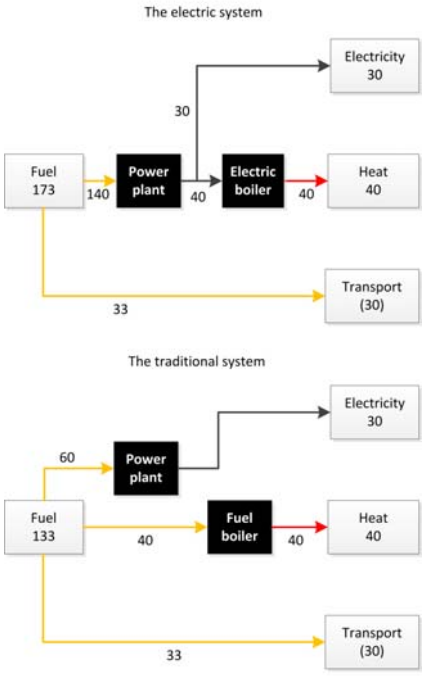


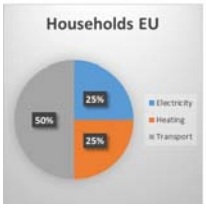
What are the challenges?

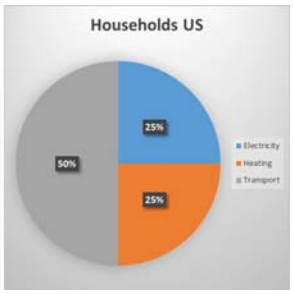
- We want to decrease the use of fossil fuels but:
  1. *The current system is extremely flexible…*
  2. *We cannot replace these with biomass only…*
  3. *We need to use intermittent renewable ressources!*
- We can increase wind power but..
  - *There is a limit with the current energy system design*
  - *….There is a need for a new system design*

6

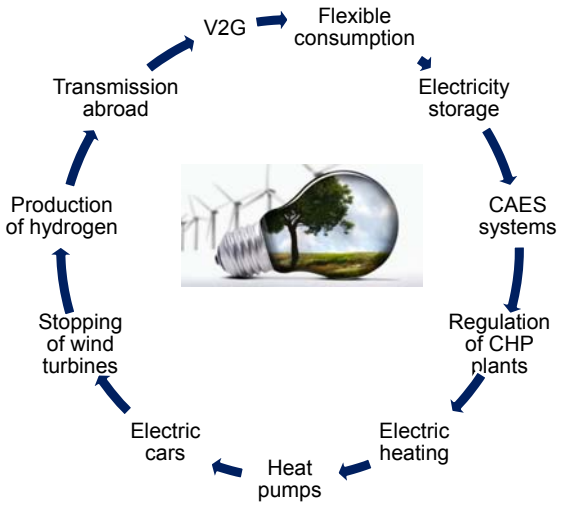
Solutions on the table

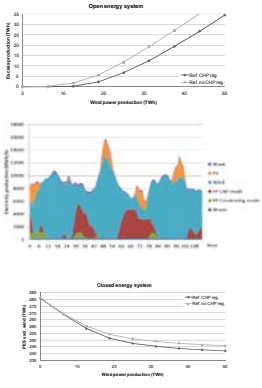
1. Interconnectors and trading
2. Flexible electricity demands and smart grids
3. Integrated efficient Smart Energy Systems



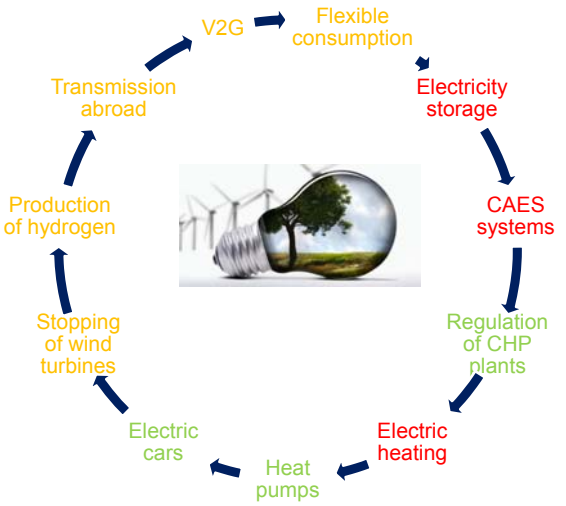


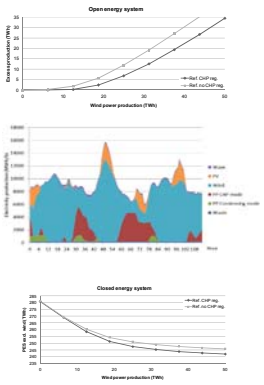
OPTIONS FOR SYSTEM INTEGRATION





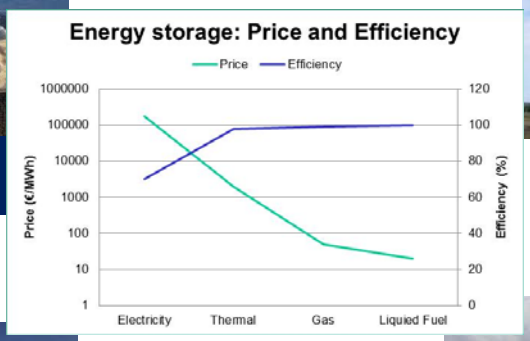
OPTIONS FOR SYSTEM INTEGRATION





ENERGY STORAGE

PUMP HYDRO STORAGE
175 €/KWH

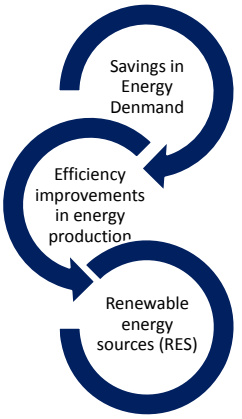


THERMAL STORAGE
1-4 €/KWH

NATURAL GAS UNDERGROUND STORAGE
0.05 €/KWH

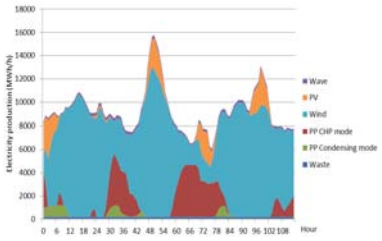
OIL TANK
0.02 €/KWH

RENEWABLE ENERGY STRATEGIES FOR SUSTAINABLE DEVELOPMENT

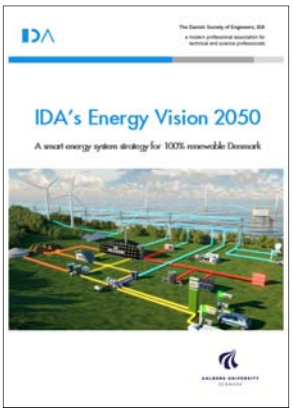


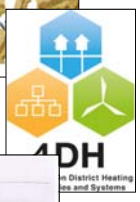
FLEXIBLE TECHNOLOGIES

INTEGRATED ENERGY SYSTEMS



IDA's Energy Vision 2050

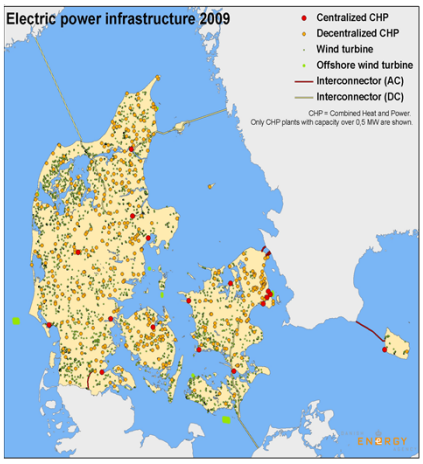




strategic research centre for ZERO ENERGY BUILDINGS

Savings are essential

- Electricity savings (25%)
- Heat savings (42%) (From 132 kWh/m2 to about ca. 80 kWh/m2 in 2050)
- Savings in industry
- Transport growth but modal shift to more efficient transport Technologies.

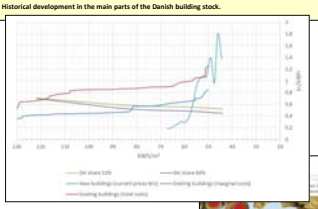


Buildings in 100% renewable energy systems

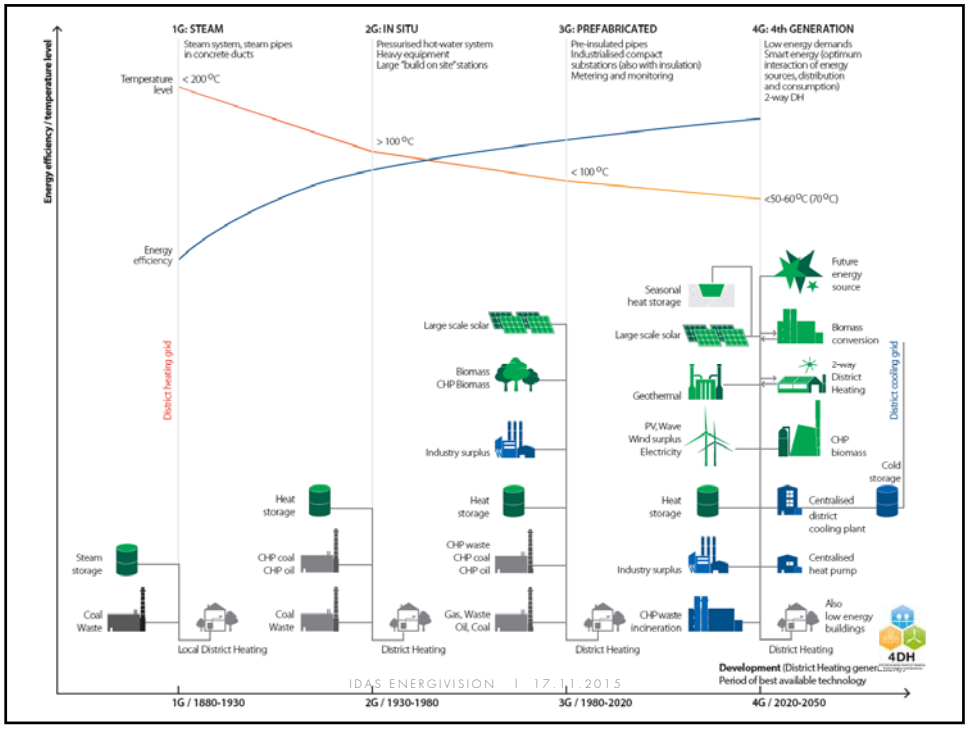
- Ambitious heat savings essential (also in operational phase)
- Heat savings together with renovations.
- Buildings (new and old) should be seen as part of the system and not be optimised on-site or as a local group.
- District heating to be expanded to cover 66%.
- Focus on shift to lower temperature sources.
- Ground-source heat pumps should primarily be used outside district heating areas (supplemented with solar thermal & biomass)
- Implement district cooling where possible,

Year (primo)	1970	1980	1990	2000	2010
Total heated area (Million m²)	185.1	246.7	278.0	298.3	331.7
Total heat demand (TWh/year)	27163	34155	36793	38466	40327
Specific demand (kWh/m²)	147	138	132	129	122
10-year growth factor		1.33	1.13	1.07	1.11

Table 3: Historical development in the main parts of the Danish building stock.



strategisk forskningscenter for ENERGINEUTRALT BYGGERI

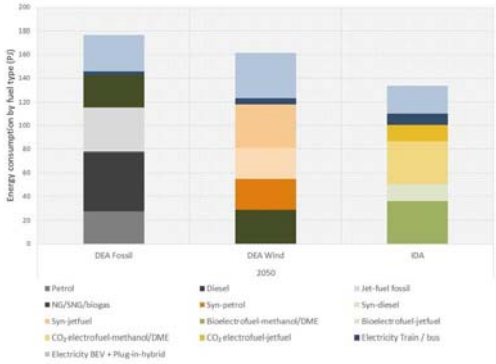


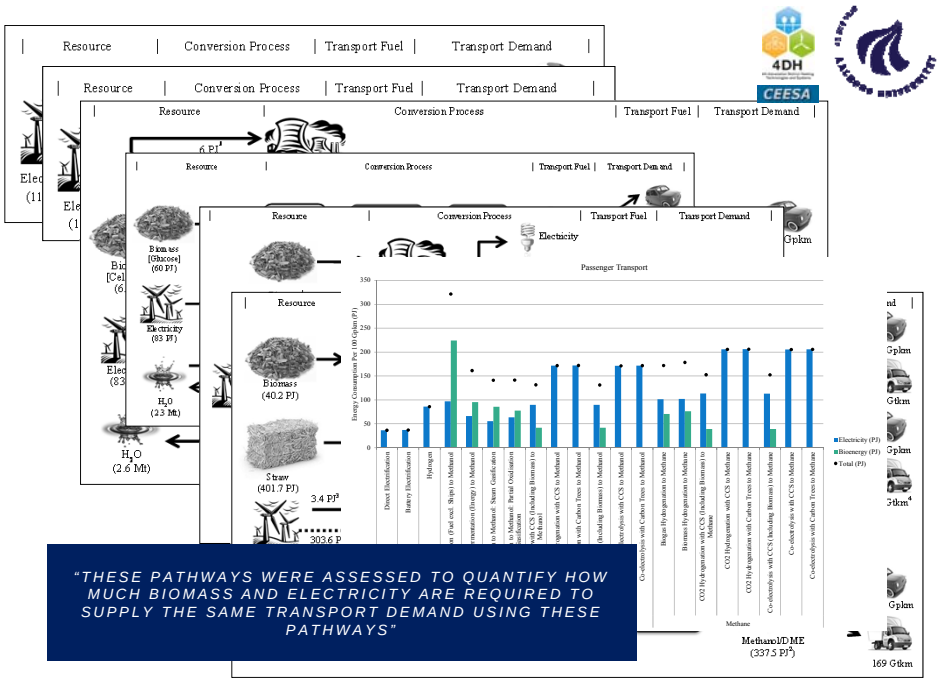
Industry

- Growth in demands (40%)
- Priority:
    1. Savings
    2. More district heating and district cooling for industry
    3. Replace fossil fuels with electricity consumption
    4. Replace fossil fuels with solid biomass
    5. Replace fossil fuels with biogas
    6. Replace fossil fuels with green gas (synthetic fuels)
- Larger use of low temperature sources for district heating in nearby heat networks.

Transport

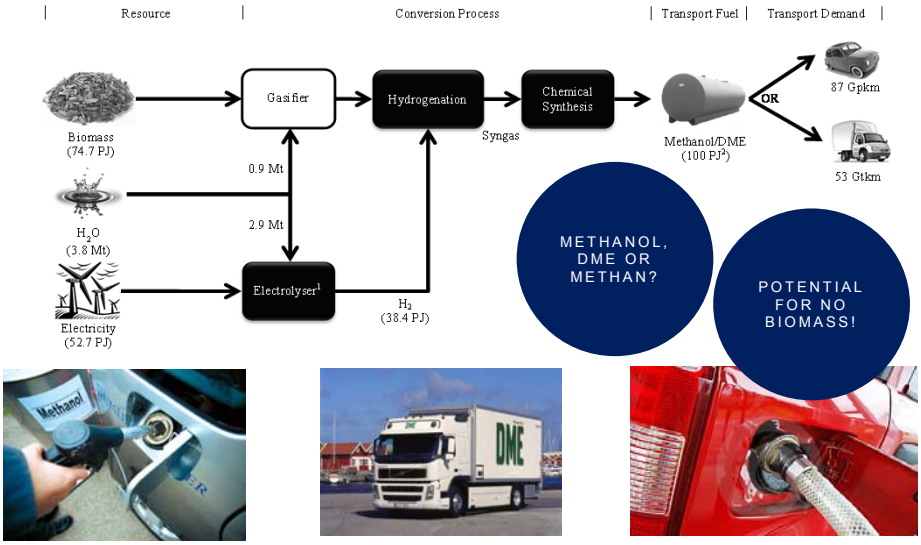
- More public transport and direct use of electricity
- Personal transport in electric vehicles and plug-in electric vehicles
- Heavy transport on electrofuels. The key to sustainable biomass consumption.





"THESE PATHWAYS WERE ASSESSED TO QUANTIFY HOW MUCH BIOMASS AND ELECTRICITY ARE REQUIRED TO SUPPLY THE SAME TRANSPORT DEMAND USING THESE PATHWAYS"

HYDROGENATION OF GASIFIED BIOMASS
(FOR HEAVY TRANSPORT)



Wind, solar, PV and wave power

- 5.000 MW Onshore Wind, 14.000 MW Offshore Wind
- 5.000 MW PV, 300 MW bølgekraft (Plan B: More wind or PV)

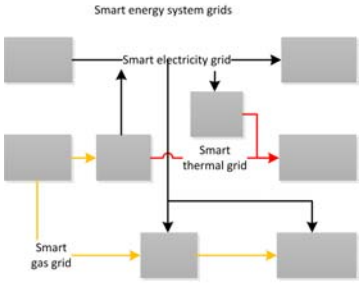
- 2,3 TWh large solar thermal (0,3 TWh today)
- 2,2 TWh individual solar thermal (0,1 TWh today)
- 4,6 TWh geothermal

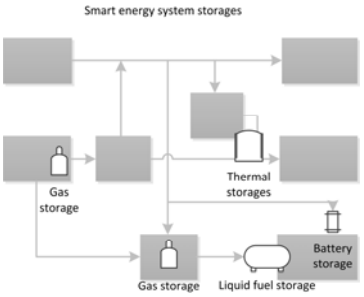
SMART ENERGY SYSTEMS
- ARE CRUCIAL IN 100% RENEWABLE ENERGY SYSTEMS

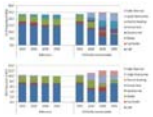
A cross-sectoral and coherent energy system solution

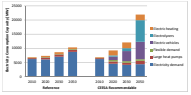
- **Smart Electricity Grids** to connect flexible electricity demands such as heat pumps and electric vehicles to the intermittent renewable resources such as wind and solar power.
- **Smart Thermal Grids** (District Heating and Cooling) to connect the electricity and heating sectors. This enables thermal storage to be utilised for creating additional flexibility and heat losses in the energy system to be recycled.
- **Smart Gas Grids** to connect the electricity, heating, and transport sectors. This enables gas storage to be utilised for creating additional flexibility. If the gas is refined to a liquid fuel, then liquid fuel storages can also be utilised.

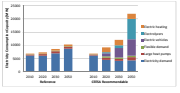
GRIDS AND STORAGES IN SMART ENERGY SYSTEMS







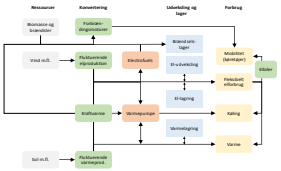




22

IDA's Energy Vision 2050 - Intelligent use of storage

- Electrolyses with high capacity (P2G)
- District heating systems
- Heat pumps with high capacity– large and small (Power-to-heat)
- Electricity for transport
  - Direct in trains and electric vehicles
  - In electrofuels for heavy duty vehicles

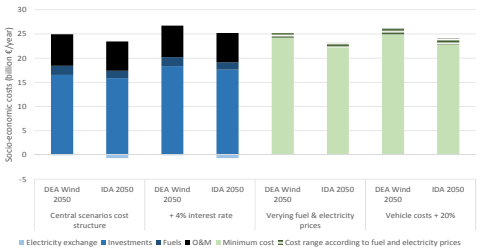


Gas challenges and solutions strategies

- Phase out Natural gas (from 133PJ - 37 TWh/year)
  - Savings
  - District heating
  - Electrification
  - Bioenergy
- Future gas grids are complex, local, national and adapted to future needs (not current)
- Use of existing gas storages is complex but needed
- Use of biogas and gasified bioenergy for industry and CHP (mainly direct w no hydrogenation)
- CO2 from bioenergy can be used for fuels in transport (store wind power in gaseous/liquied fuels)
- Storage in liquid and gaseous fuels

Robust economy and efficient use of biomass

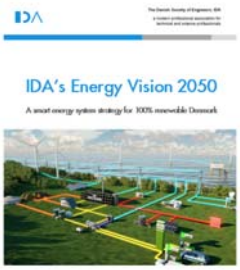
- 3 FUEL PRICE LEVELS
- 10 ELECTRICITY PRICE LEVELS (15-150 €/MWH)
- 60 CENTRAL SENSITIVITY ANALYSIS
- MORE THAN 400 SIMULATIONS OF THE ENTIRE SYSTEM – HOUR-BY-HOUR 8784



Main conclusions

- 100% is possible technically and feasible
- Future need to focus on transmission between the sectors instead of only between countries
- A flexible system is robust with regards to costs and biomass consumption. It uses storages intelligently
- It provides more jobs and lower health costs than fossil fuel systems

WWW.SMARTENERGYSYSTEMS.EU



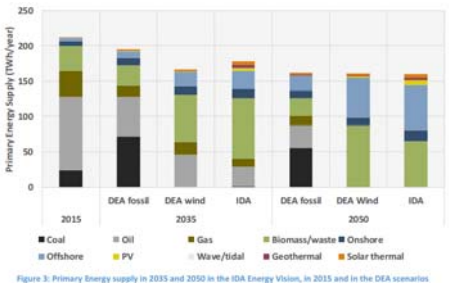


Figure 3: Primary Energy supply in 2035 and 2050 in the IDA Energy Vision, in 2015 and in the DEA scenarios