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Brian Vad Mathiesen, Aalborg University

Bioeconomy and the role of hydrogen
- Smart Energy Systems

BIOECONOMY AND ITS TRADE-OFFS TOWARDS MEETING THE PARIS AGREEMENT
INSA TOULOUSE NOVEMBER 19, 2019 (REMOTE PRESENTATION)

Innovation Fund Denmark

@BrianVad

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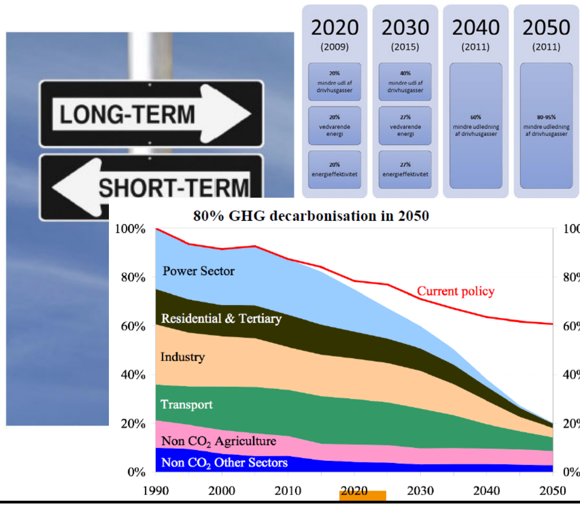
Targets and challenges in Europe

`Long-term target (2011)
- 80-95% reduction of CO emissions in the energy sector

Short term in the energy union (2015)
- Security of supply (el and gas)
- An integrated marked
- Energy efficiency
- Lower CO2 emissions
- Research and innovation
- New directives (RED, EPBD, ED etc.)



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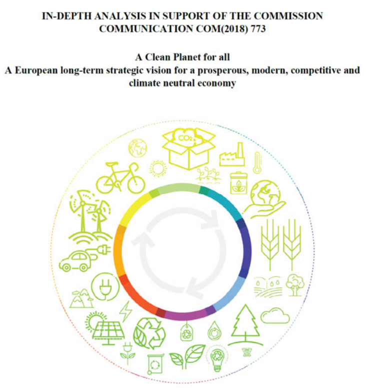
New scenarios: Target of net zero emissions in Europe?



Positives

- A large variety of scenarios
- Two net zero emission scenario
- More details within buildings and industry

Scenario problems

- Very high ambition in all scenarios with regards to energy efficiency in buildings
- No district heating implemented
- Politically driven scenarios for gas
- Claim to make ”optimal systems”

Tool problems

- 5 year time steps
- partial equilibrium modelling system that simulates an energy market
- Investment optimisation (with limits e.g. wind and nuclear)
- No clear distinction between private/business economy and socio-economy.

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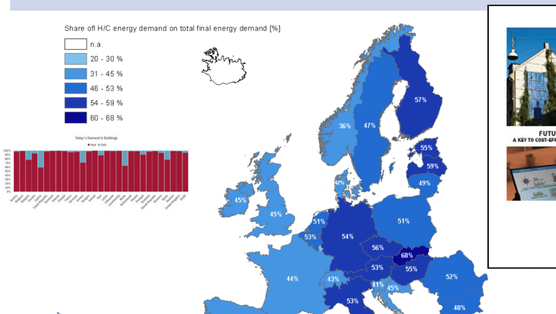
Energy System Challenges and opportunities

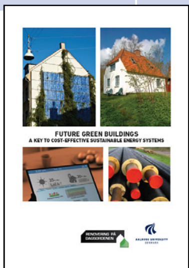
- Electricity demands the smallest of the demands
- Both transport & heating/cooling demands larger
- Electricity grids are much more expensive than thermal grids/gas grids (pr. capacity)
- Energy storages have different costs in different sectors and different scales

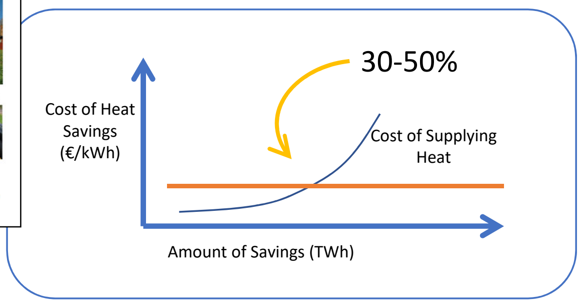
Questions and strategic decisions

- What are the role of the grids in the future
- How can energy storage be used across sectors to transform all demands to renewable energy cost-effectively?
- How important are energy savings in the future and what is the balance between electricity or heat savings compared to renewable energy?



Source: Mapping and analyses of the current and future heating-cooling fuel deployment, DG Energy, 2016





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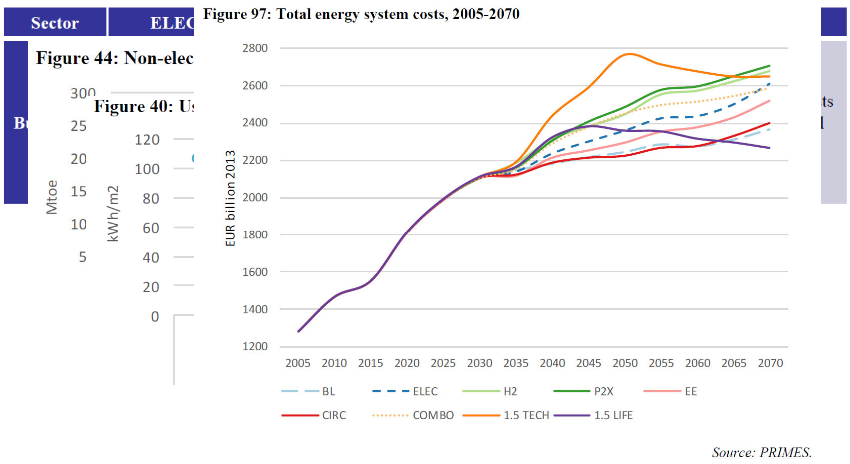
Buildings in the Energy Union in 2050



Highlights

- Gas for heating dominates
- Stagnating district heating
- High ambition on EE in buildings due to tool)
- Higher costs than today

TWh	Total heat demand	Heat demand heat pumps	Total electricity demand
Baseline	2207,1	863,1	1537,3
COMBO	1789,1	883,7	1271,4
1,5 TECH	1620,7	806,2	1127,7
1,5 LIFE	1488,2	712,3	1101,7

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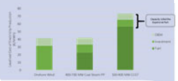
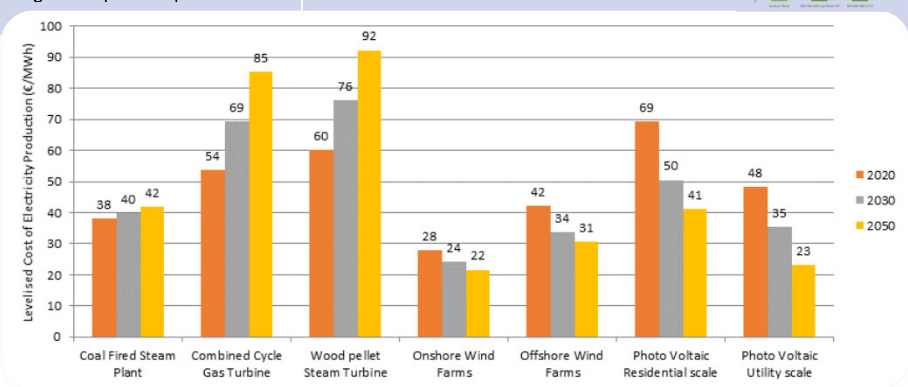
Energy System Challenges and opportunities	Questions and strategic decisions
- Lower and lower Renewable Energy investment costs (Electricity especially) - Batteries are falling in price - Electricity prices are falling (sign of system design failure) and cannot merit investments in new capacity - Power plants for back-up is closing down (lower operation hours)	- How should we use and balance (energy storage) more electricity from renewable energy? - How should we re-design the energy system and how much renewable energy is needed?





Energy PLAN
Advanced energy system analysis computer model

(sources: EnergyPLAN cost database)

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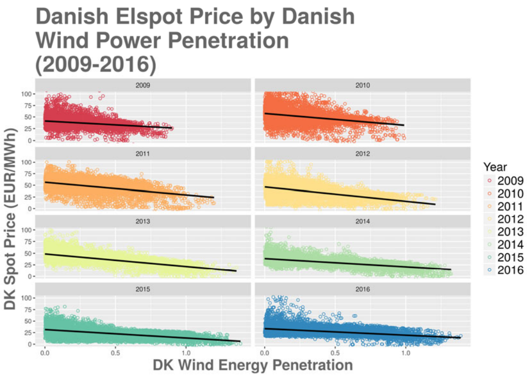

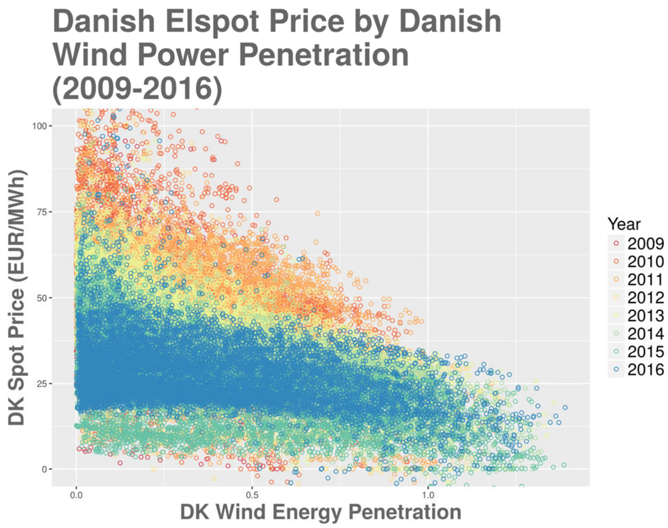

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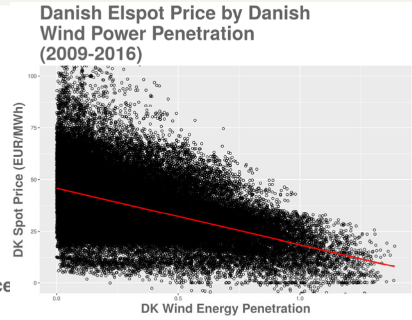

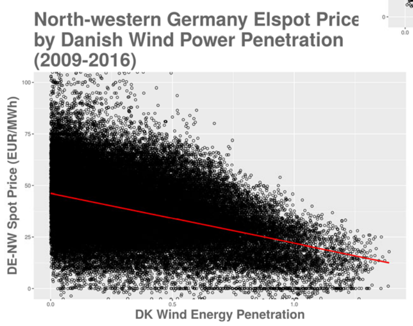

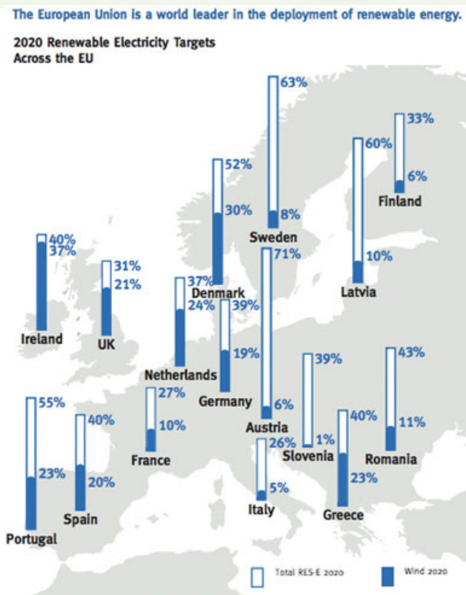

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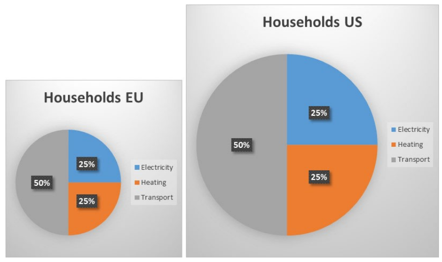
Solutions on the table

1. Interconnectors and trading (infrastructure investments)
2. Flexible electricity demands and smart grids (batteries and single string supply)
3. Integrated efficient Smart Energy Systems



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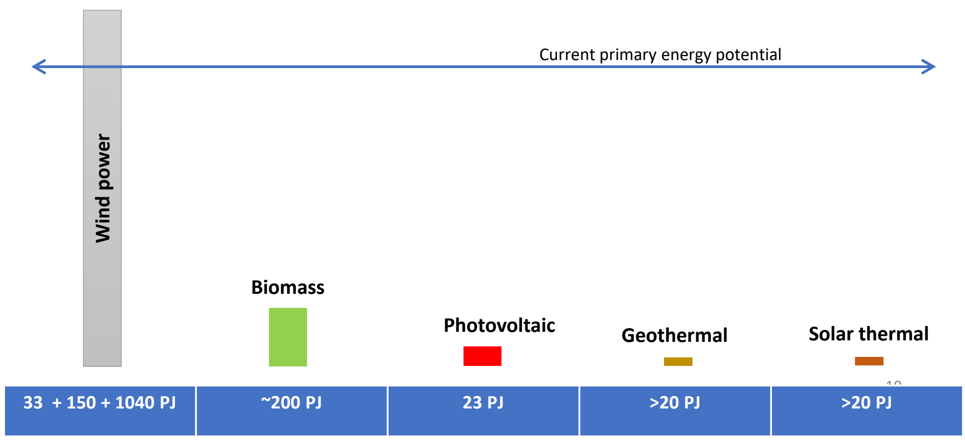
Selected Danish Renewable Energy Potentials



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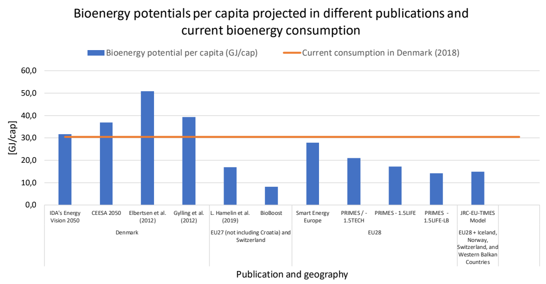
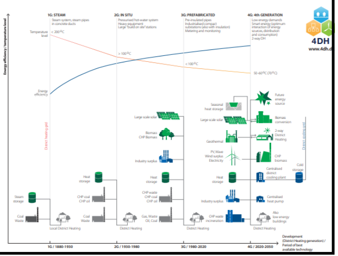
Global and Danish Challenges with in Bioenergy

	Biomass pr. person
Today in Denmark (175 PJ)	30 GJ/capita
Latest EU research (8500 PJ)	17 GJ/capita
EU 2050 scenarios (A Clean Planet for all)	15-21 GJ/capita
IDA 100% RE in DK in 2050 (200 PJ)	30 GJ/capita
Danish Energy Auth. scenarios fra 2014	35-45 GJ/capita



- Biomass consumption beyong the residual potential can have a climate effect
- Danmark has more than the global potential pr. capita
- The current Danish model is not for export within biomass



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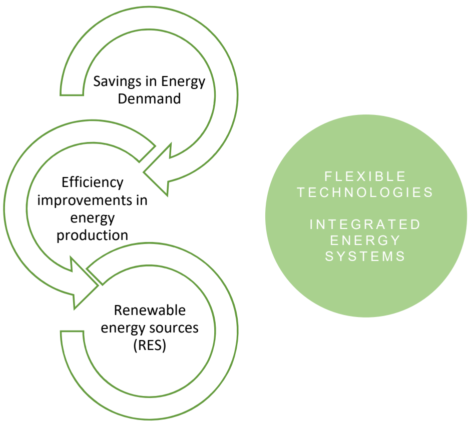
STATE-OF-THE-ART-KNOWLEDGE ON 100% RENEWABLE ENERGY IN 2050



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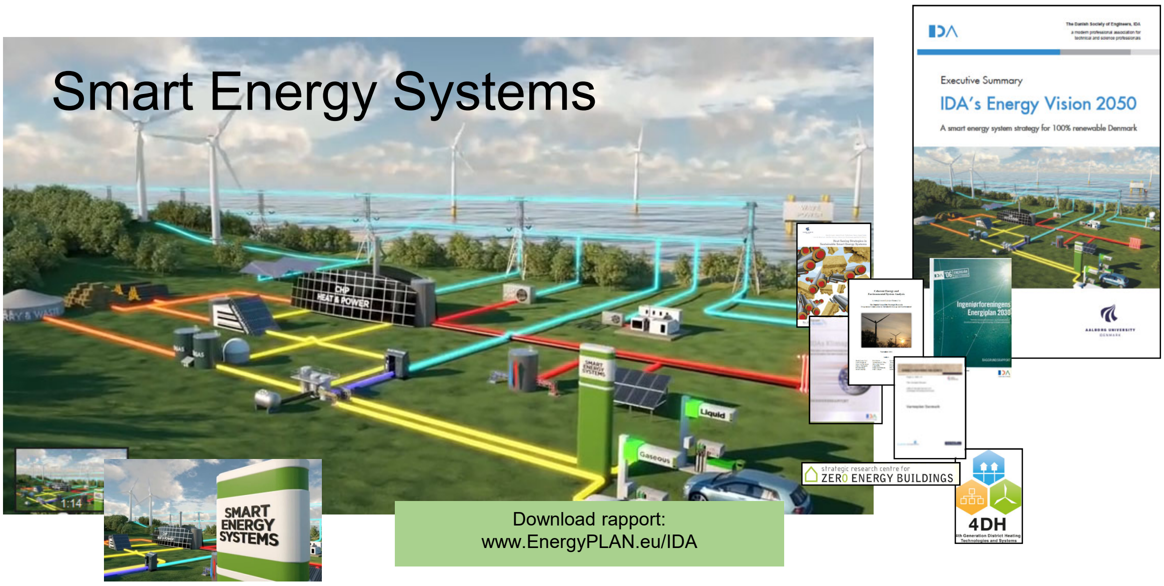

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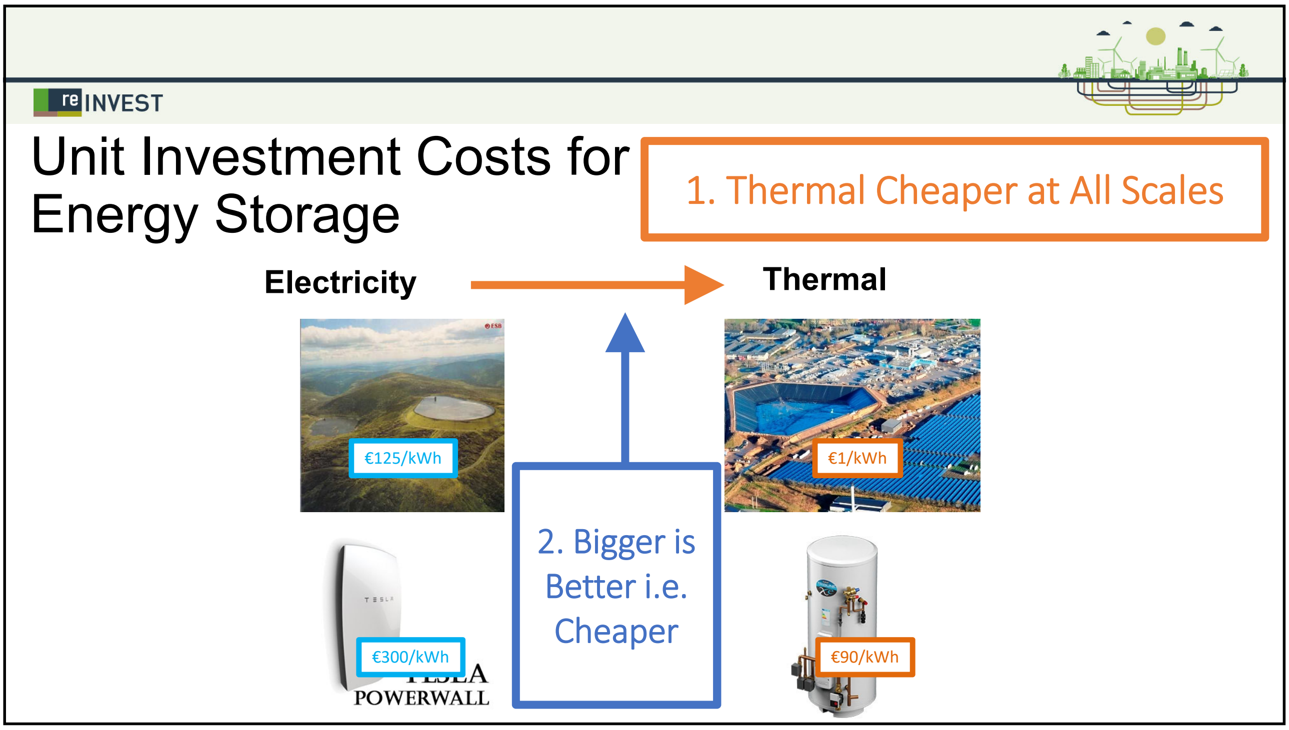
Unit Investment Costs for Energy Storage

1. Thermal Cheaper at All Scales

Electricity → **Thermal**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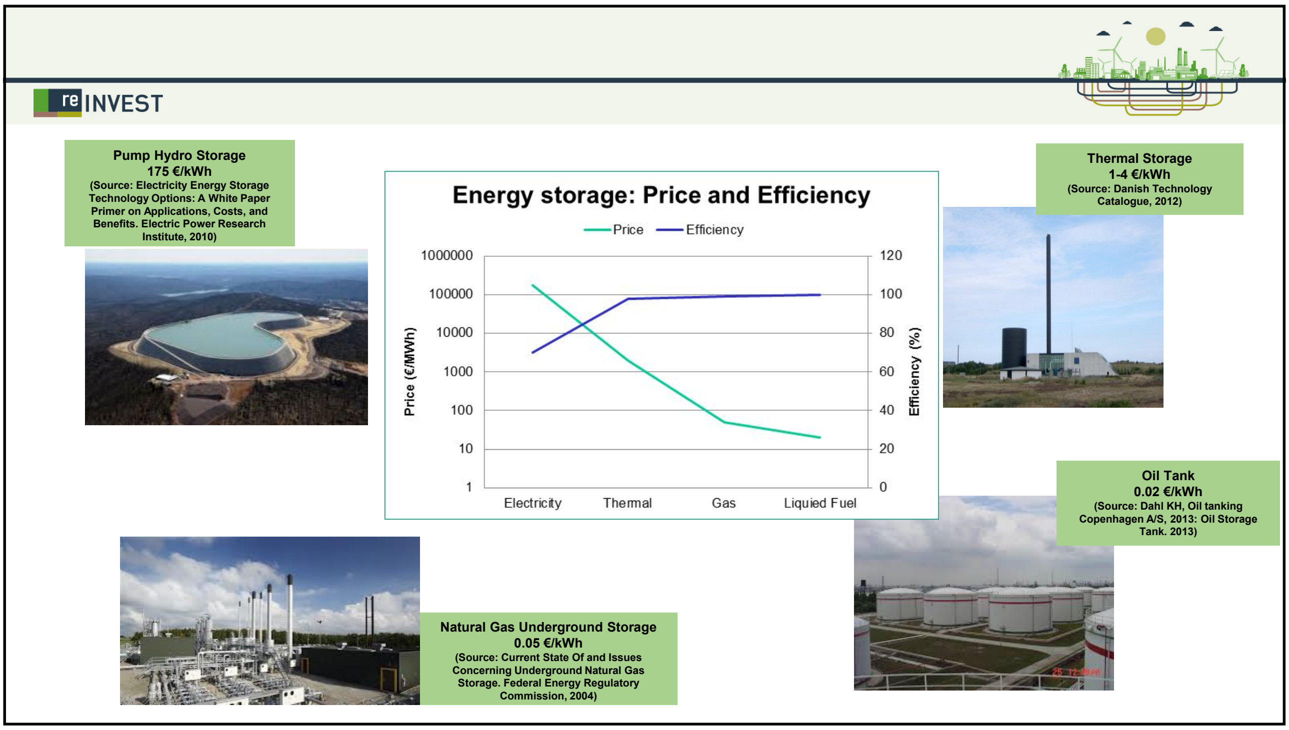
Unit Investment Costs for Energy Storage
1. Thermal Cheaper at All Scales
Electricity
Thermal
€125/kWh
€1/kWh
2. Bigger is Better i.e. Cheaper
€300/kWh
POWERWALL
€90/kWh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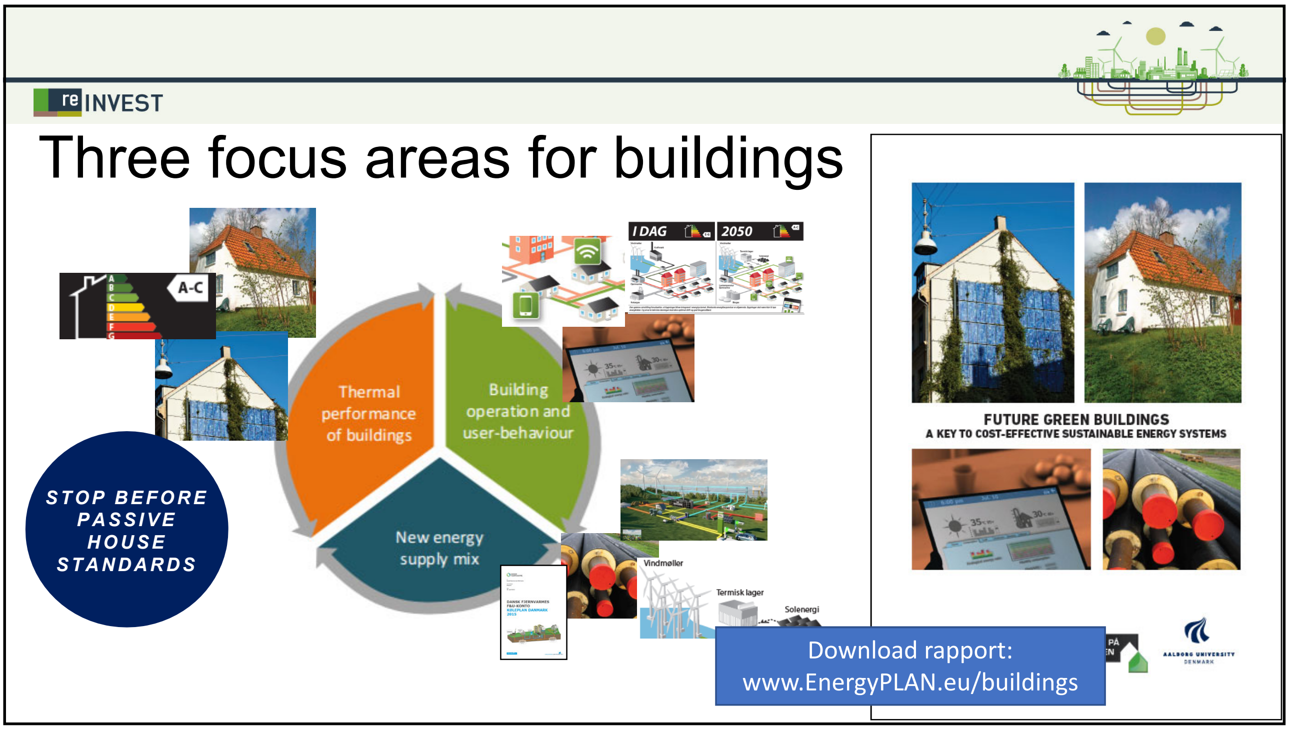
Pump Hydro Storage
175 €/kWh
(Source: Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits. Electric Power Research Institute, 2010)
Energy storage: Price and Efficiency
Price
Efficiency
1000000
100000
10000
1000
100
10
1
Price (€/MWh)
120
100
80
60
40
20
0
Efficiency (%)
Electricity
Thermal
Gas
Liquid Fuel
Thermal Storage
1-4 €/kWh
(Source: Danish Technology Catalogue, 2012)
Oil Tank
0.02 €/kWh
(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)
Natural Gas Underground Storage
0.05 €/kWh
(Source: Current State Of and Issues Concerning Underground Natural Gas Storage. Federal Energy Regulatory Commission, 2004)



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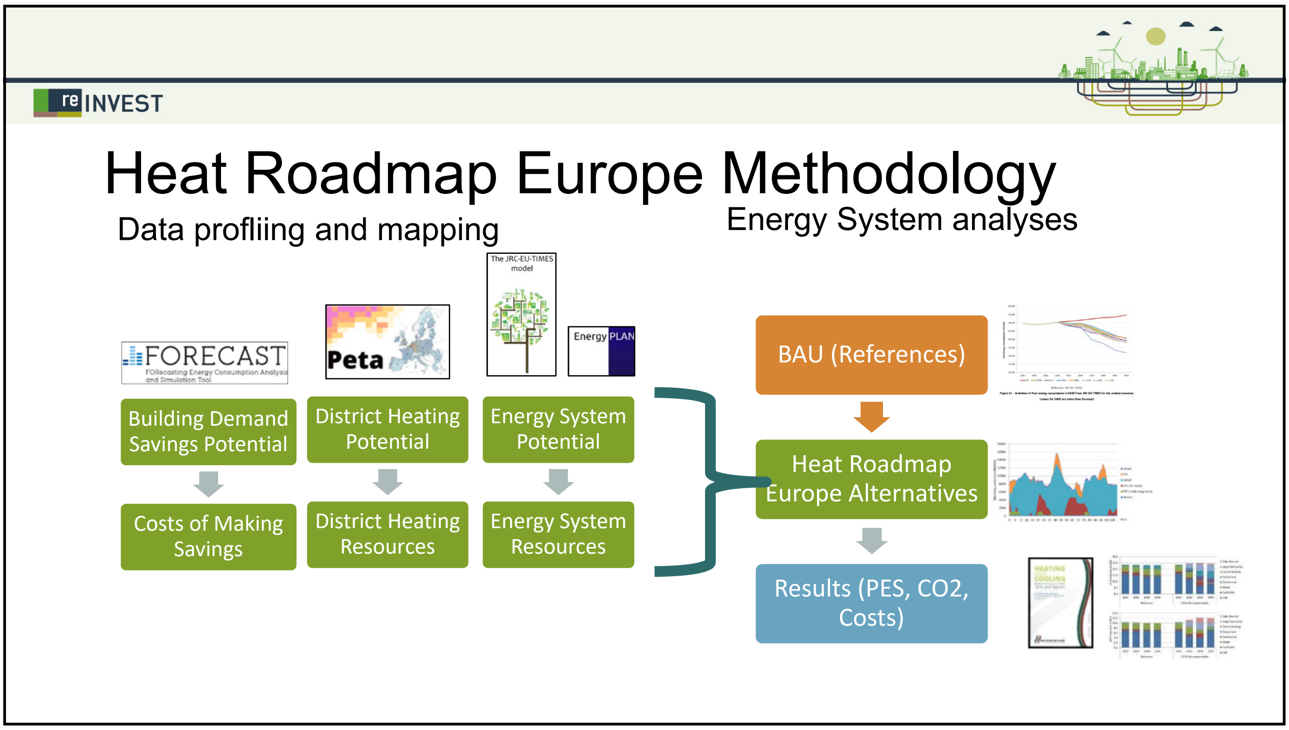
Three focus areas for buildings
A-C
STOP BEFORE PASSIVE HOUSE STANDARDS
Thermal performance of buildings
Building operation and user-behaviour
New energy supply mix
I DAG
2050
Vindmøller
Termisk lager
Solenergi
FUTURE GREEN BUILDINGS
A KEY TO COST-EFFECTIVE SUSTAINABLE ENERGY SYSTEMS
Download rapport:
www.EnergyPLAN.eu/buildings
AALBORG UNIVERSITY DENMARK



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Heat Roadmap Europe Methodology
Data profliing and mapping
Energy System analyses
FORECAST
The JRC-EU-TIMES model
Peta
EnergyPLAN
Building Demand Savings Potential
District Heating Potential
Energy System Potential
Costs of Making Savings
District Heating Resources
Energy System Resources
BAU (References)
Heat Roadmap Europe Alternatives
Results (PES, CO2, Costs)

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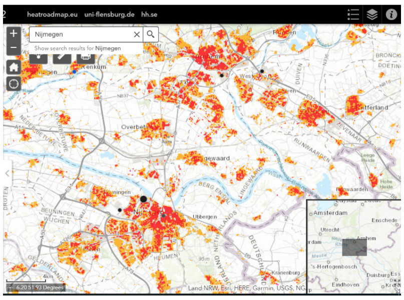
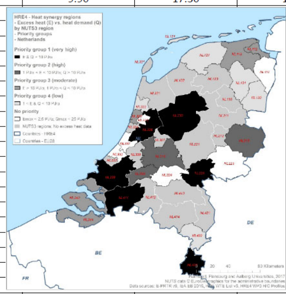
Heat synergies map in PETA4 - Netherlands



- Heat demands: 296 PJ/y
- Excess heat: 560 PJ/y
- District heating share: 6%
- Renewable energy in heating: 3%
- Not a Technical barrier to improve energy efficiency?

NUTS3 Regions	Heat demand [PJ/a]	Excess heat [PJ/a]	Excess heat ratio [-]
NL111	3.83	0.20	0.05
NL112	1.22	11.32	9.28
NL113	9.90	17.30	1.75
NL121			25
NL131			92
NL132			55
NL213			48
NL224			08
NL225			09
NL226			40
NL230			99
NL310			12
NL322			16
NL323			.27
NL325			05
NL326			05
NL332			05
NL337			09
NL339			06
NL33A			39
NL341			.41
NL342			78
NL411	15.57	73.27	4.71
NL422	5.96	8.10	1.36
NL423	15.28	39.67	2.60
Grand Total	**295.84**	**559.23**	**1.89**



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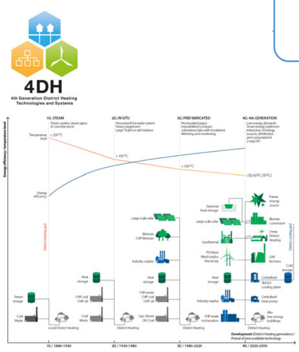
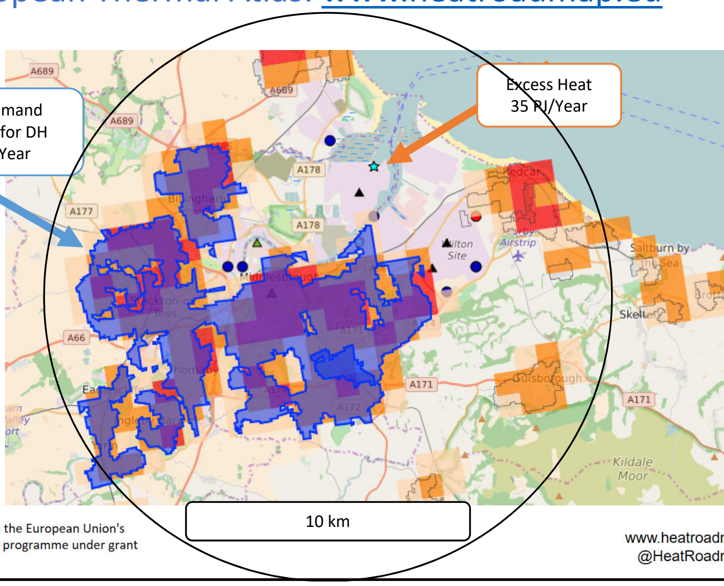
WP2: Pan-European Thermal Atlas: www.heatroadmap.eu

Case Study: Middlesbrough, UK (350,000 People)





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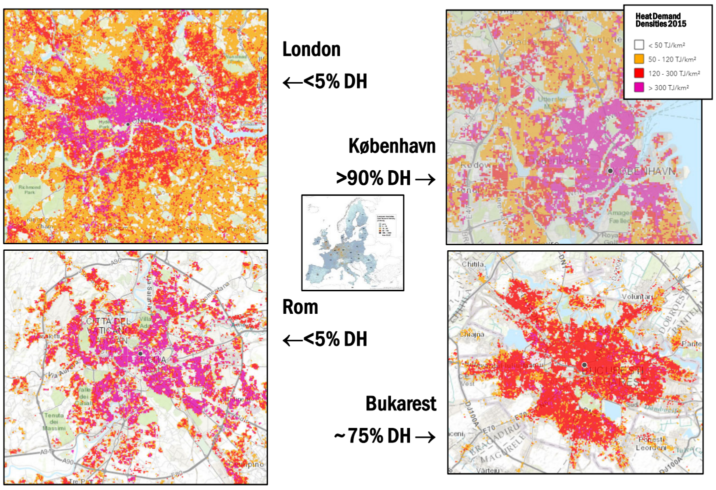
Today's Heat Demand from Peta 4.2 (www.heatroadmap.eu)



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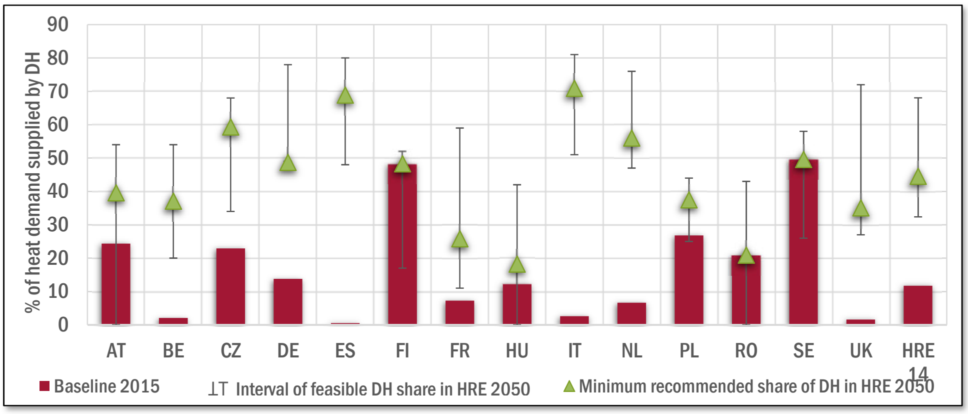
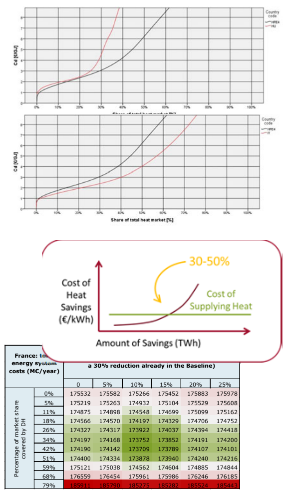
Anbefalede fjernvarmeandele inkl kraftige energibesparelser i boliger i Europa





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Heat pump & district heating shares of heat market

- Building HPs
  - Increase in share from 1% to about half of the heat market mainly in rural areas
- DH supply
  - Increase from 12% to cover the other half of the heat market mainly in urban areas
- Individuel fuel boilers and electric heating for heating should be limited as far as possible
- All natural gas boilers are phased out

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- Decarbonise in line with Paris Agreement
- Technically possible, socio-economically feasible
- Consider local nature of heating and cooling
- Consider the wider energy system

Heat Roadmaps for transitions

Everywhere	Urban areas	Rural areas
Deep energy savings	District energy networks	Mainly heat pumps
Combine savings and supply	High demand density areas	Low demand density areas
~30-50% demand reduction	Supply ~half of energy demand	Remaining ~half of the energy demand

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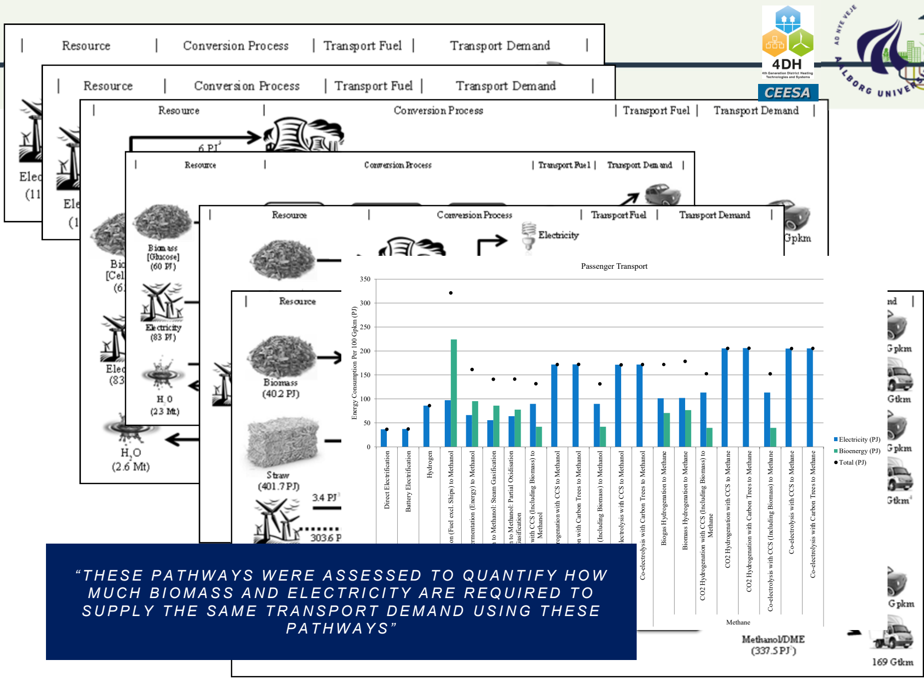

"THESE PATHWAYS WERE ASSESSED TO QUANTIFY HOW MUCH BIOMASS AND ELECTRICITY ARE REQUIRED TO SUPPLY THE SAME TRANSPORT DEMAND USING THESE PATHWAYS"

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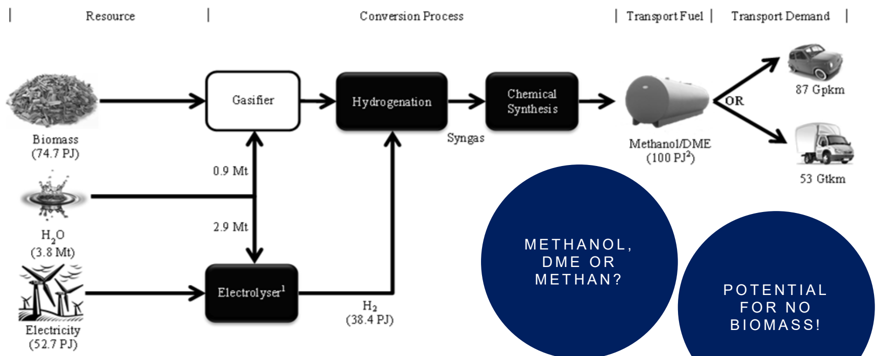
HYDROGENATION OF GASIFIED BIOMASS (FOR HEAVY TRANSPORT)



METHANOL, DME OR METHAN?

POTENTIAL FOR NO BIOMASS!

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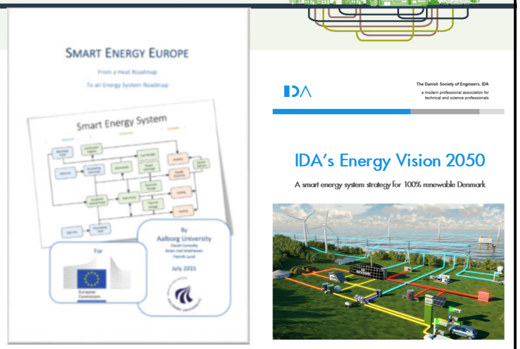
Coherent 2050 analyses

- 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



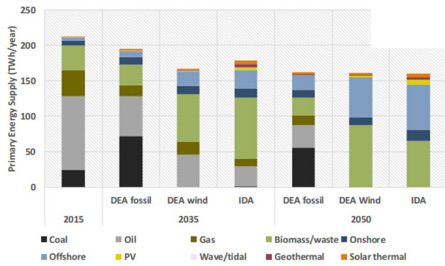


Figure 3: Primary Energy supply in 2035 and 2050 in the IDA Energy Vision, in 2015 and in the DEA scenarios

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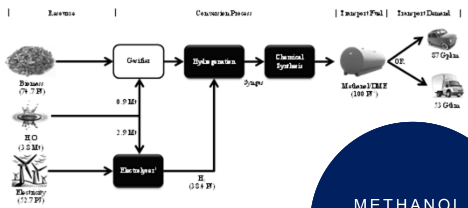
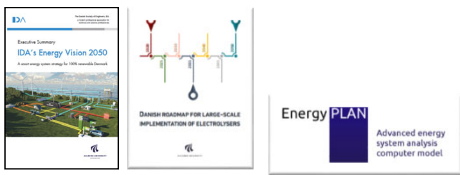
Transport, Renewable energy and biomass

- ✓ Handle transport growth levels on modes (not road)
- ✓ Divert to public transport modes and direct electricity use
- ✓ Indirect use of electricity in vehicles
- ✓ Electrofuels (gas and liquid) in heavy duty transport
- ✓ Math and physics limit use of biodiesel, bioethanol and biogas to niches in transport



METHANOL, DME OR METHANE?



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The gas system

- Phase out the use of natural gas
  - Heat savings, district heating, green gasses
- We need gas grids in the future – but the challenge is more complex than the industry tells us
  - Biogas and gasified biomass for industry and flexible combined heat and power (direct with no hydrogen up-grade)
  - Hydrogen, CO2, synthesis gas for electrofuels and storage
- New gas systems are needed and more research

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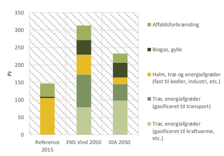
Key uses of biomass in future renewable energy systems

- Limited ressource and not climate nueatral in large amount = efficient use is needed
- Highest value product should win
  - Products, chemistry, medicine
  - Energy purposes is last in line – dependent on type of biomass
- Uses:
  - Biogas and gasified biomass for industry and flexible combined heat and power (direct with no hydrogen up-grade)
  - No or little pure heat production – no baseload and use combined heat and power
  - Electrofuels (gas and liquid with hydrogen upgrade) in heavy duty transport
  - Usage depends on type of biomass



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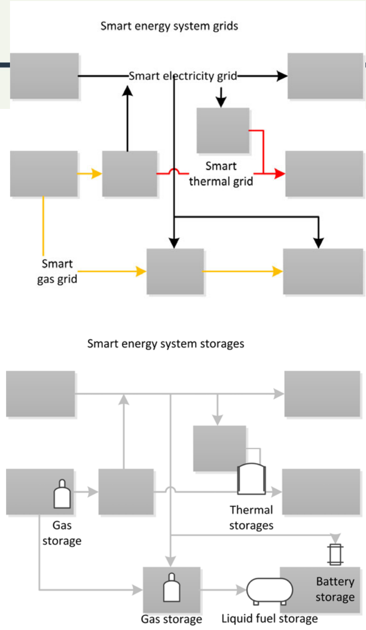
HOW TO USE STORAGES LONG TERM..

- Three crucial grids in Smart Energy Systems
  - Smart electricity grids
  - Smart thermal grids
  - Smart gas grids
- High capacity electrolyses (Power-to-gas)
- More district heating and district cooling
- Large heat pumps with high capacity (Power-to-heat)
- CHP, solar thermal, etc.
- Electricity storage in transport (batteries and electrofuels)
- Production of green gasses and synthetic fuels



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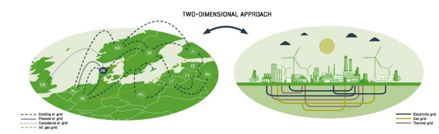

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Energi System Analyse Model

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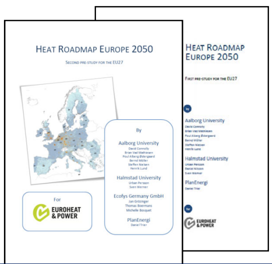
State of Green

4DH
4th Generation District Heating Technologies and Systems

WWW.4DH.DK



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