

The logo for RE-INVEST features the letters 're' in white on a dark blue background, with a green square to its left. Below this, the word 'INVEST' is written in large, dark blue, sans-serif capital letters. The bottom of the logo is divided into a brownish-red section on the left and a yellowish-green section on the right.

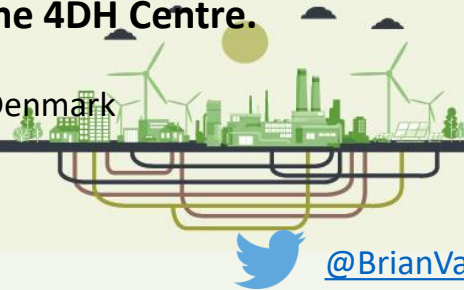
re INVEST

Smart Energy Systems or electrification - Infrastructures and paths to 100% Renewable energy

– studies from the projects RE-INVEST, Heat Roadmap Europe, the 4DH Centre.

Brian Vad Mathiesen; Friday 23 February 2018

Eufores – Renewable Energy Workshop; Location: Parliament, Copenhagen, Denmark



Innovation Fund Denmark



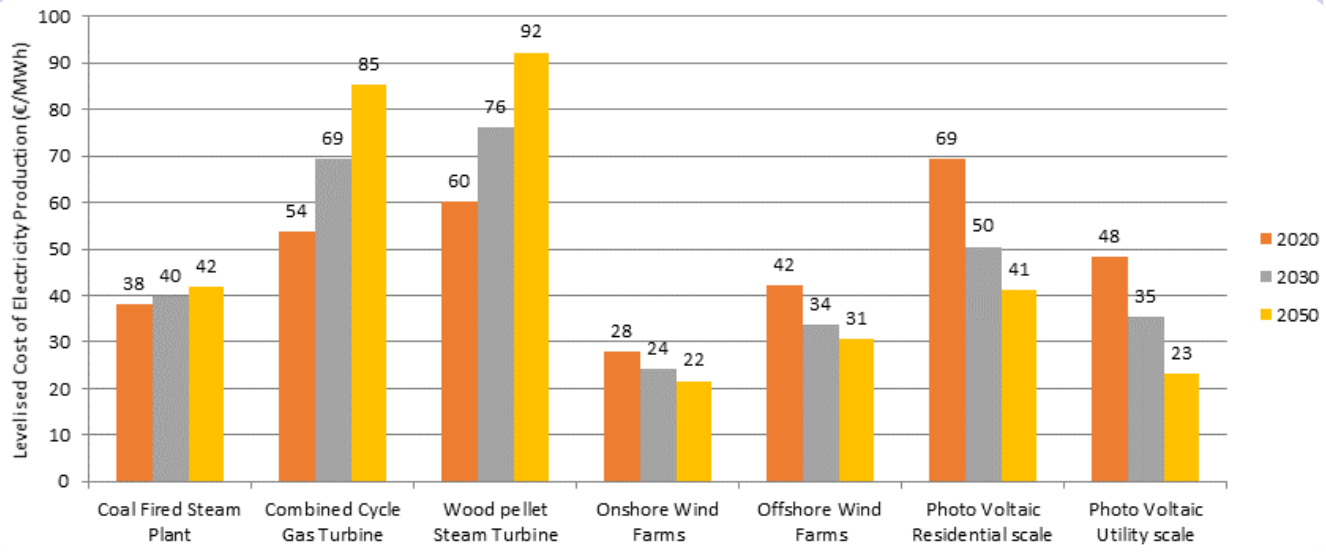
[@BrianVad](https://twitter.com/BrianVad)



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)

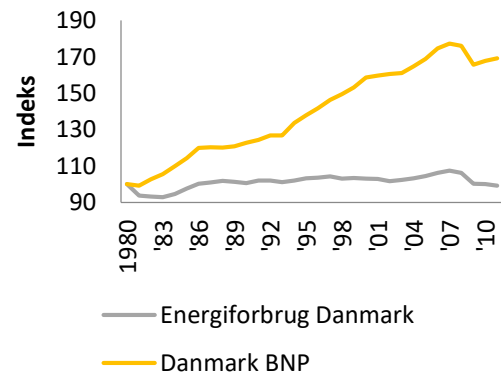
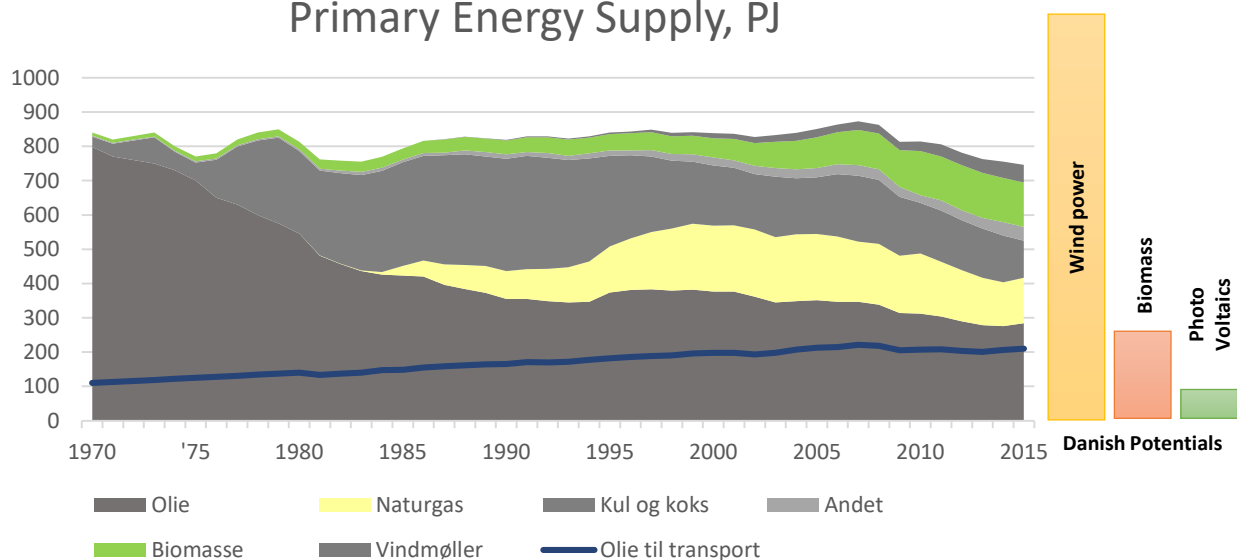
- How should we use and balance (energy storage) more electricity from renewable energy?
- How should we re-design the energy system and how much renewable energy is needed?



(sources: EnergyPLAN cost database)

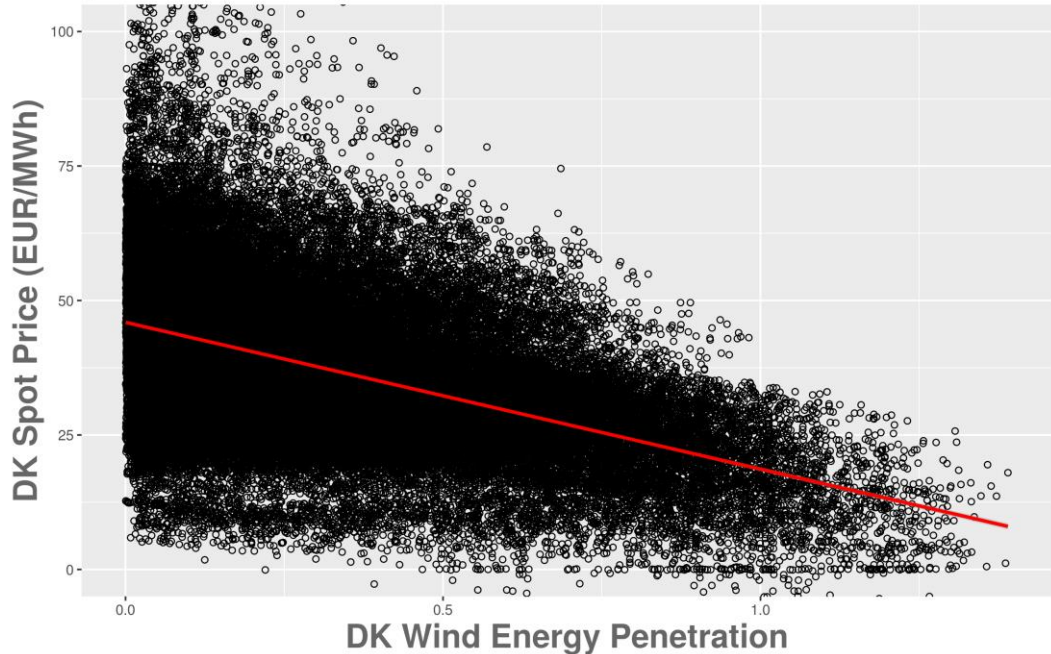
40 YEARS OF ENERGY PLANNING AND MARKET DESIGN

Primary Energy Supply, PJ



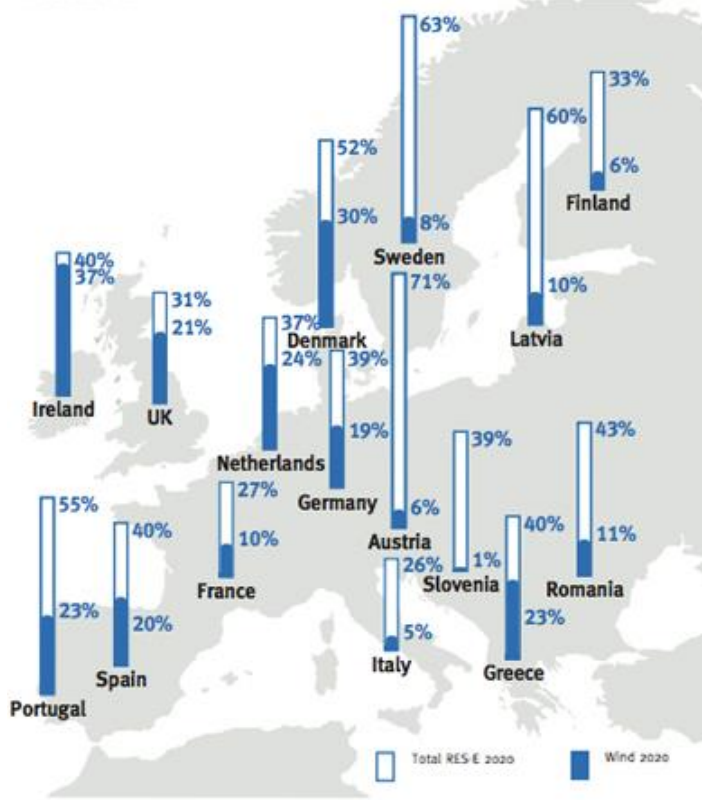


Danish Elspot Price by Danish Wind Power Penetration (2009-2016)



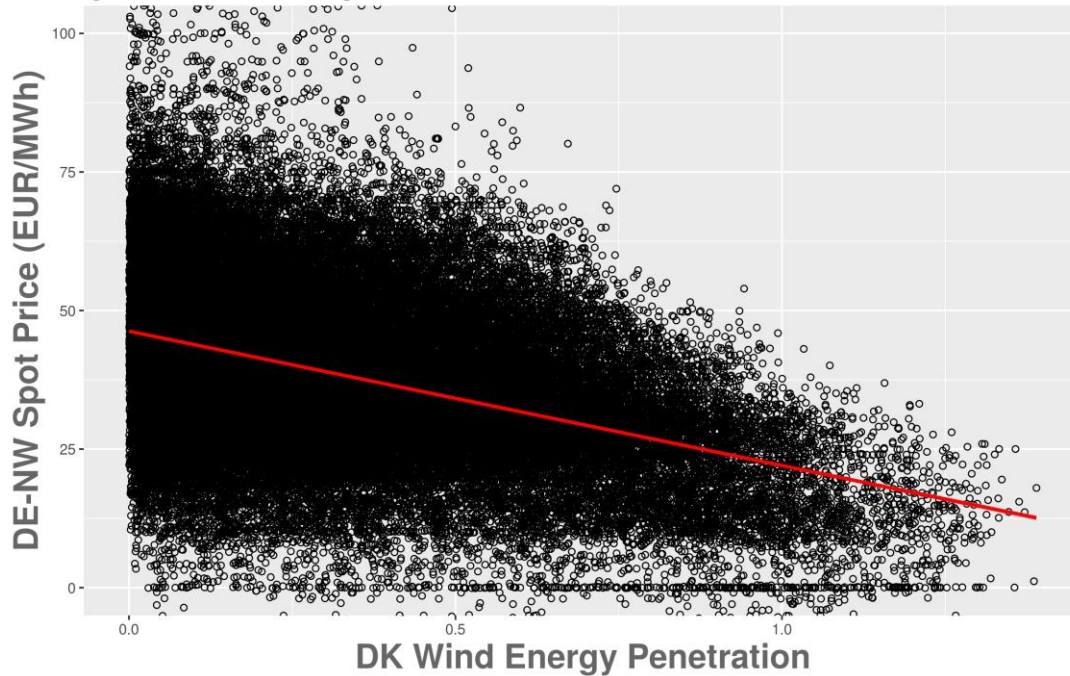
The European Union is a world leader in the deployment of renewable energy.

2020 Renewable Electricity Targets Across the EU





North-western Germany Elspot Price by Danish Wind Power Penetration (2009-2016)



New Report

Towards a sustainable and integrated Europe

Report of the Commission Expert Group on electricity interconnection targets

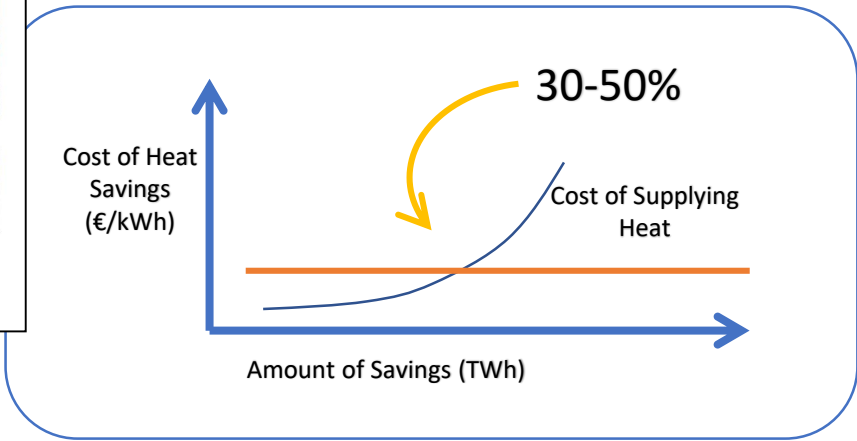
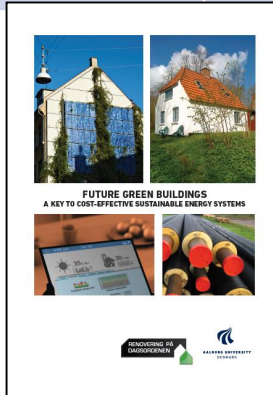
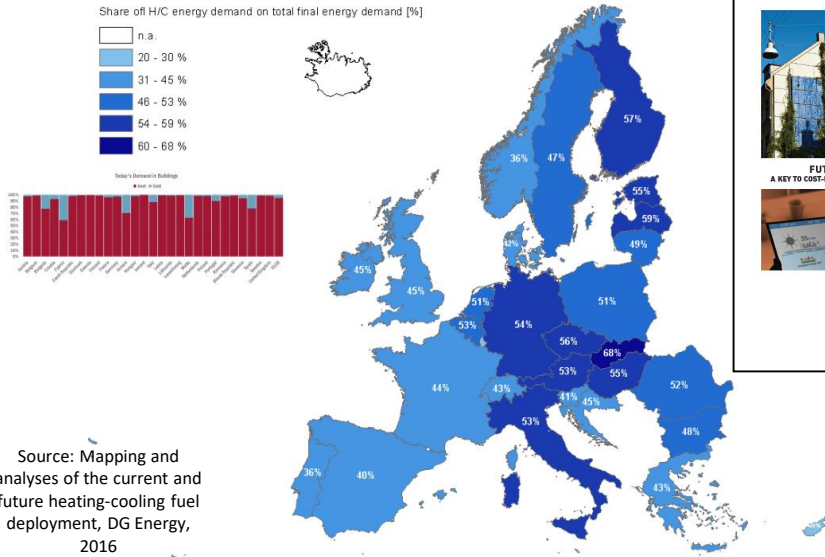
November 2017



Energy System Challenges and opportunities | **Questions and strategic decisions**

- 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

- 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



Three focus areas for buildings

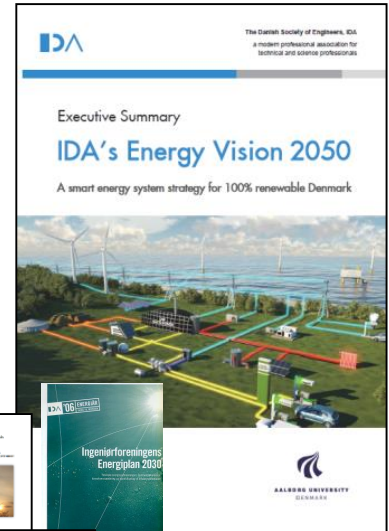
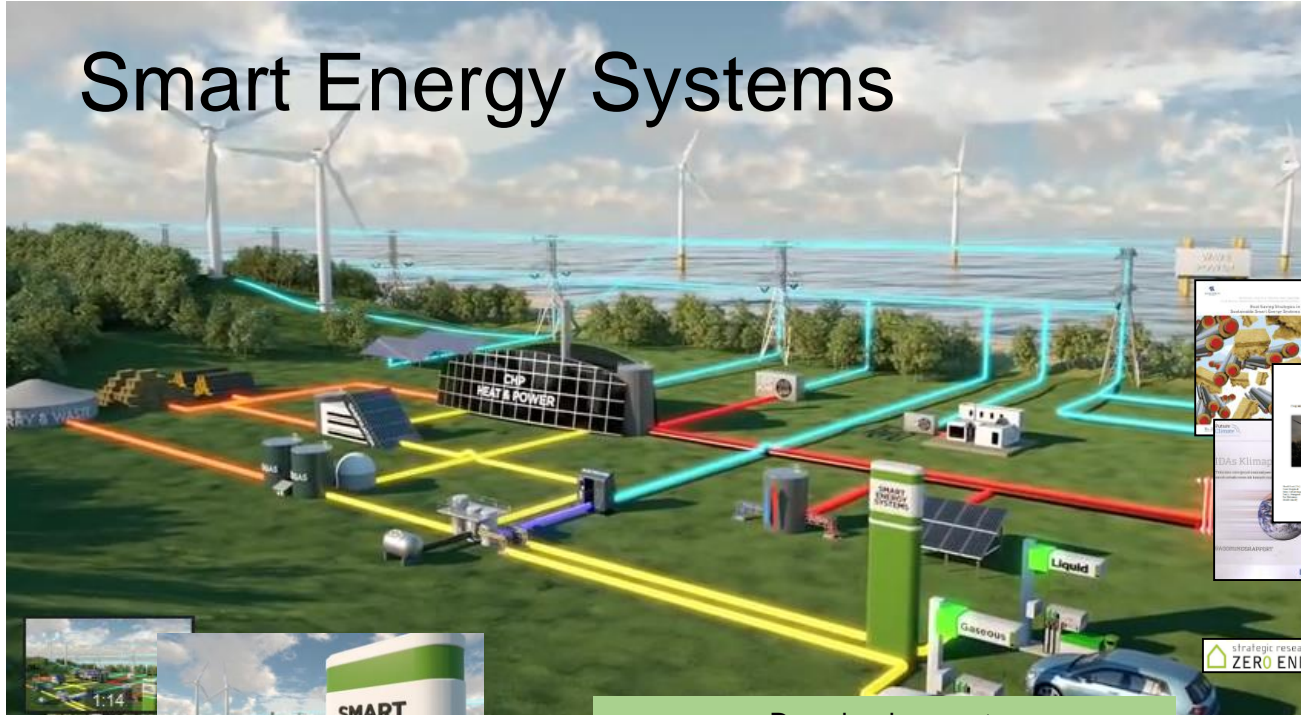


FUTURE GREEN BUILDINGS
A KEY TO COST-EFFECTIVE SUSTAINABLE ENERGY SYSTEMS





Smart Energy Systems



Download rapport:
www.EnergyPLAN.eu/IDA



Unit Investment Costs for Energy Storage

1. Thermal Cheaper at All Scales

Electricity



Thermal





Unit Investment Costs for Energy Storage

1. Thermal Cheaper at All Scales

Electricity



Thermal



2. Bigger is Better i.e. Cheaper





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)

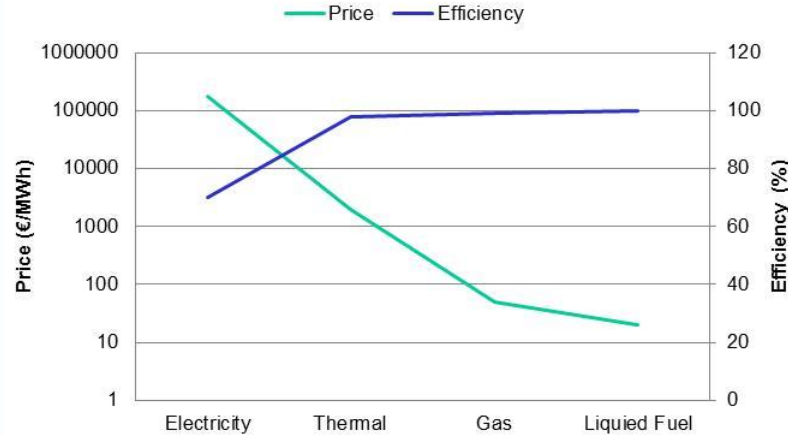


Thermal Storage
1-4 €/kWh

(Source: Danish Technology Catalogue, 2012)



Energy storage: Price and Efficiency



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)



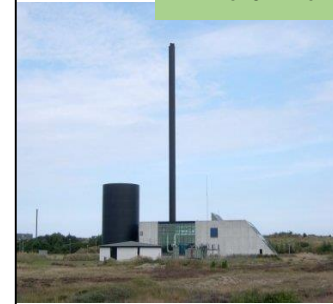


Heat energy storage

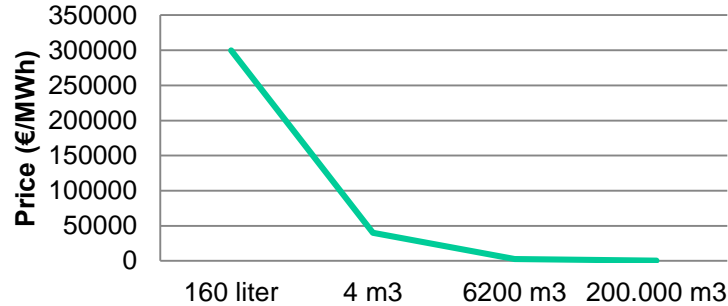
0.16 m³ Thermal Storage
300.000 €/MWh
(Private house: 160 liter
for 15000 DKK)



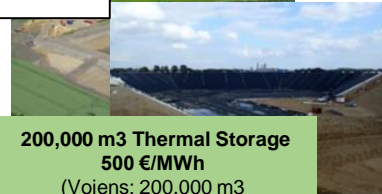
6200 m³ Thermal Storage
2500 €/MWh
(Skagen: 6200 m³
for 5.4 mio. DKK)



Thermal storage: Price and Size



4 m³ Thermal Storage
40,000 €/MWh
(Private outdoor: 4000 m³
for 50,000 DKK)

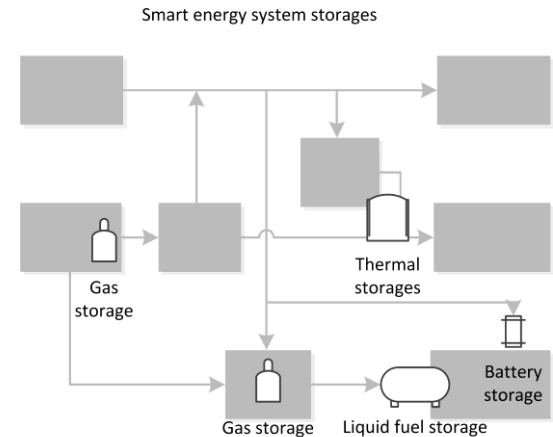
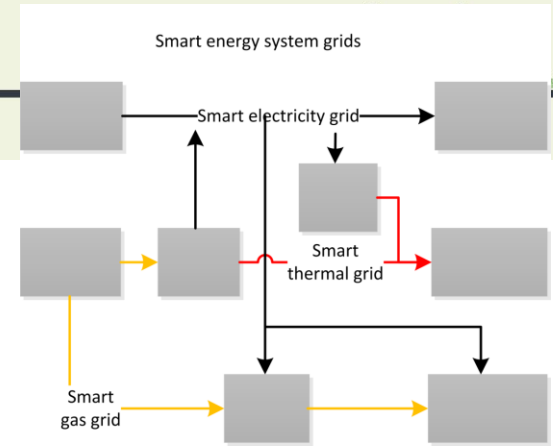


200,000 m³ Thermal Storage
500 €/MWh
(Vojens: 200,000 m³
for 30 mio. DKK)



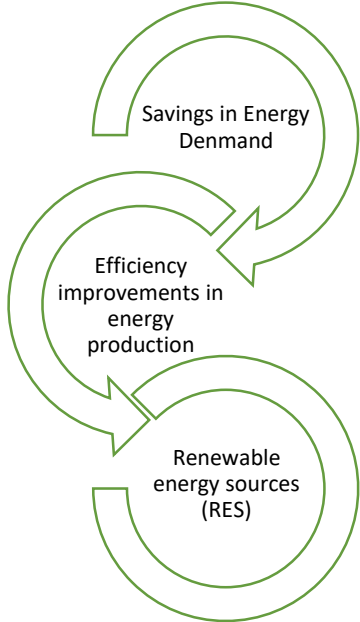
HOW TO USE STORAGES LONG TERM..

- 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



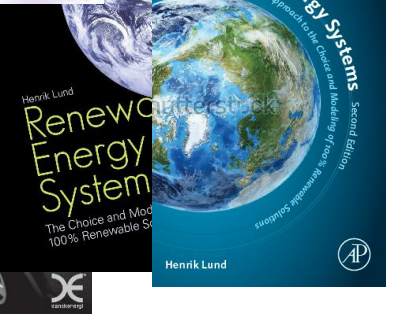
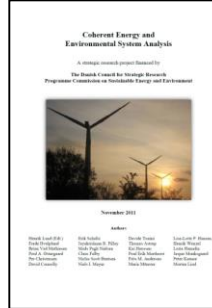
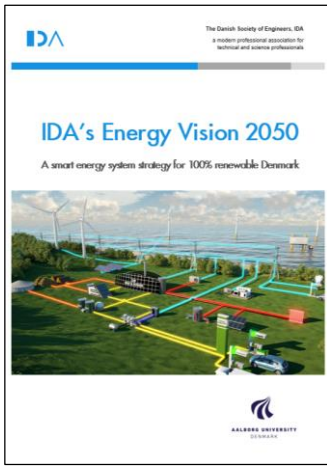


STATE-OF-THE-ART-KNOWLEDGE ON 100% RENEWABLE ENERGY IN 2050



FLEXIBLE TECHNOLOGIES

INTEGRATED ENERGY SYSTEMS





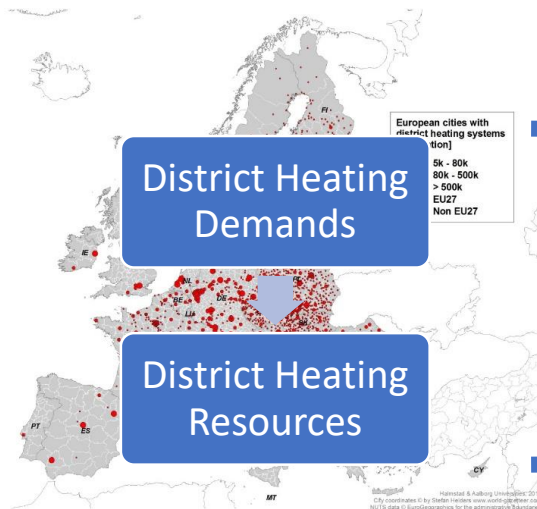
Heat Roadmap Europe Methodology

GIS Mapping

(could be another technology, resource, etc)

Energy System Modelling

(www.EnergyPLAN.eu)



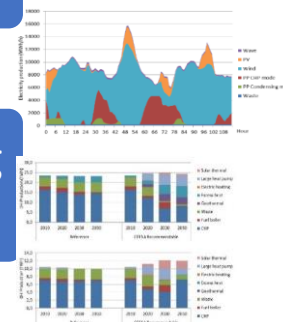
BAU
(References)



District Heating Alternatives



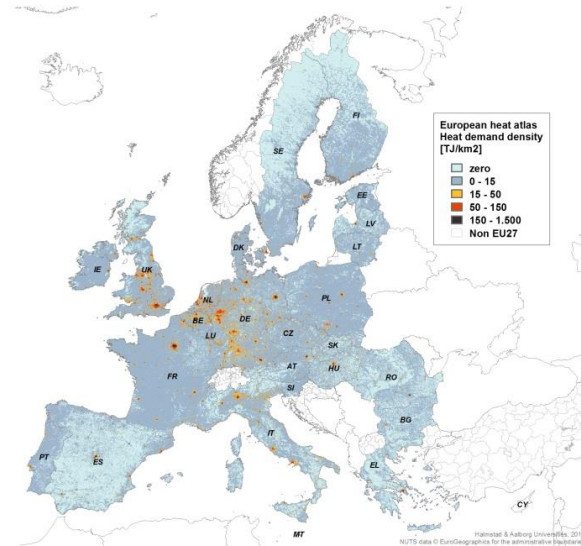
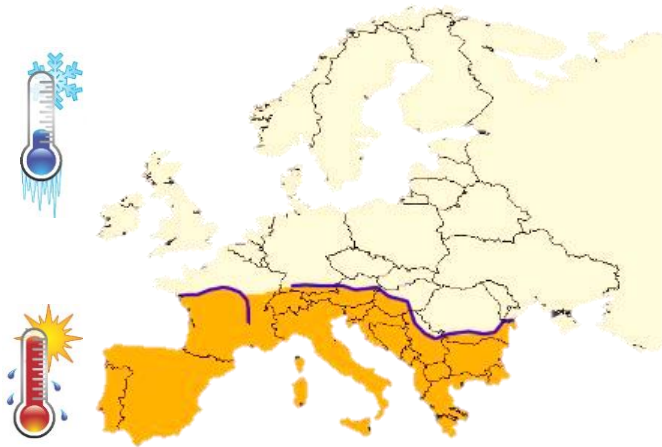
Results (PES,
CO2, Costs)



50% of the heat demand in Europe can be supplied with district heating

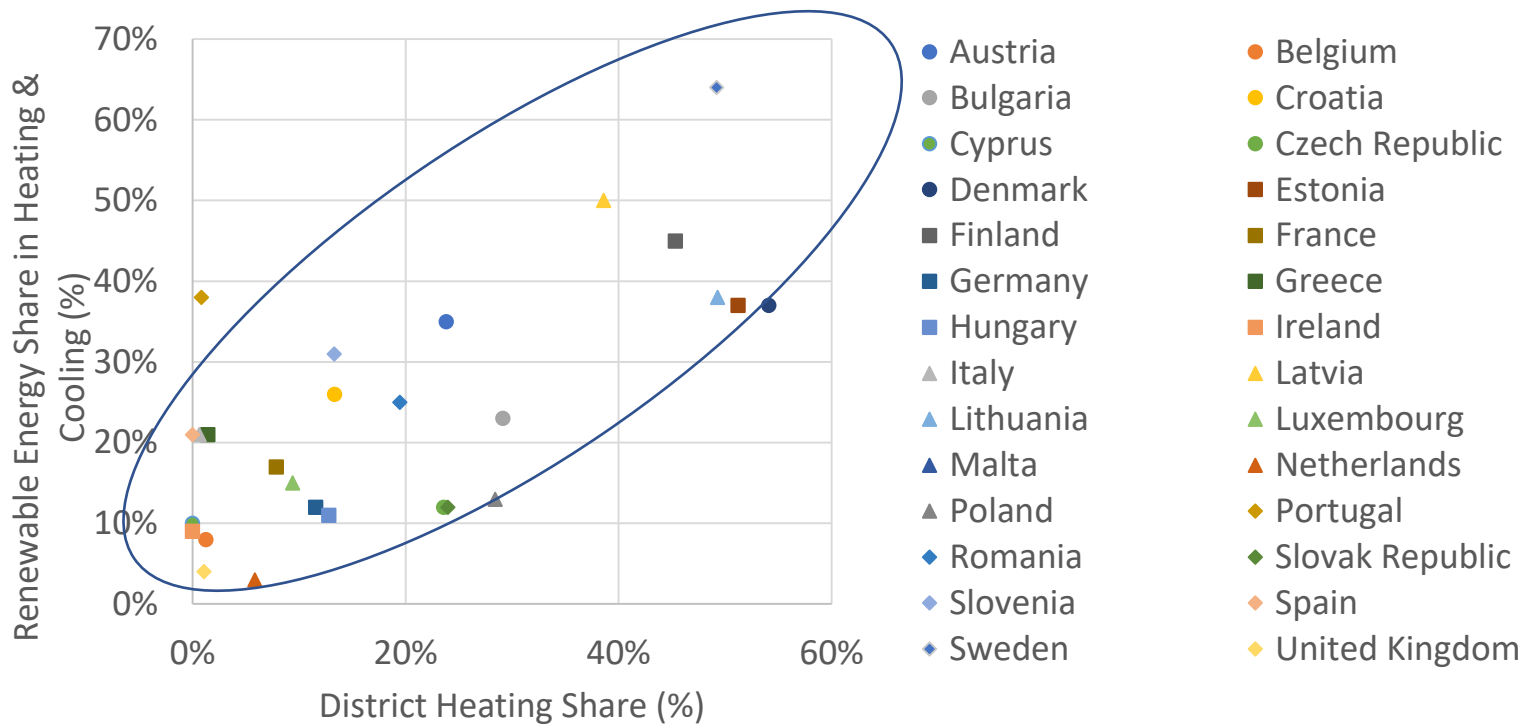
KEY ROLE
FOR CITIES

(www.HeatRoadmap.eu)

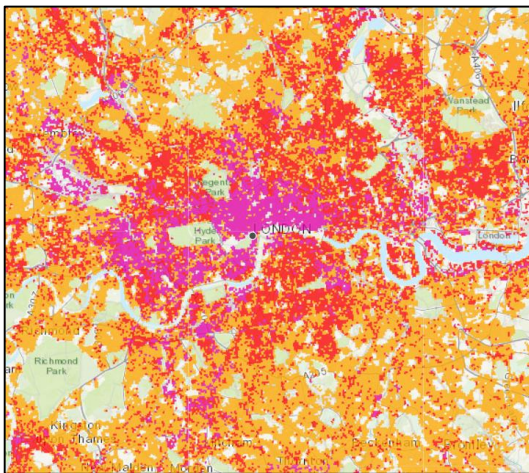




Proven Technology! Renewable Energy vs. District Heating



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

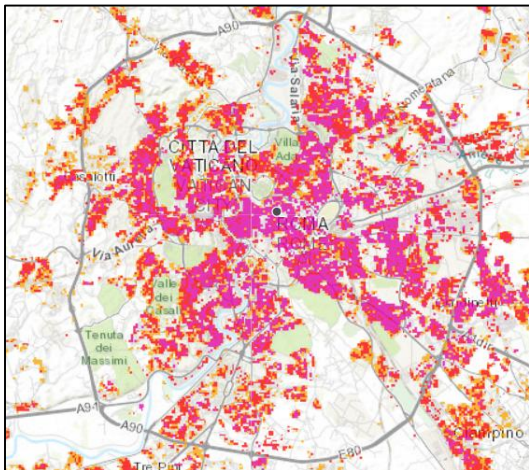
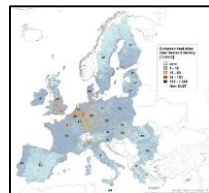
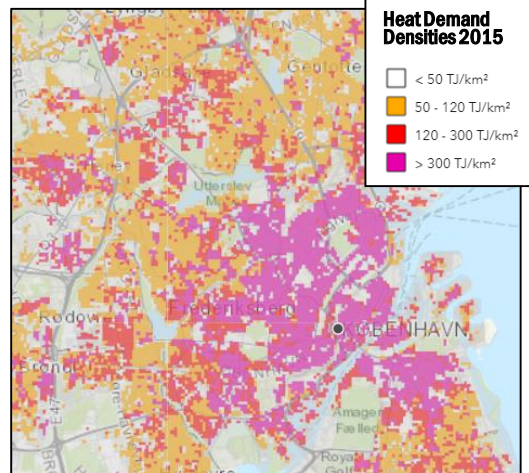


London

← <5% DH

Copenhagen

>90% DH →

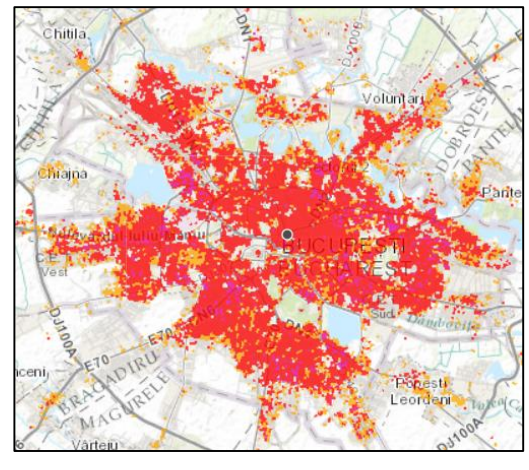


Roma

← <5% DH

Bucharest

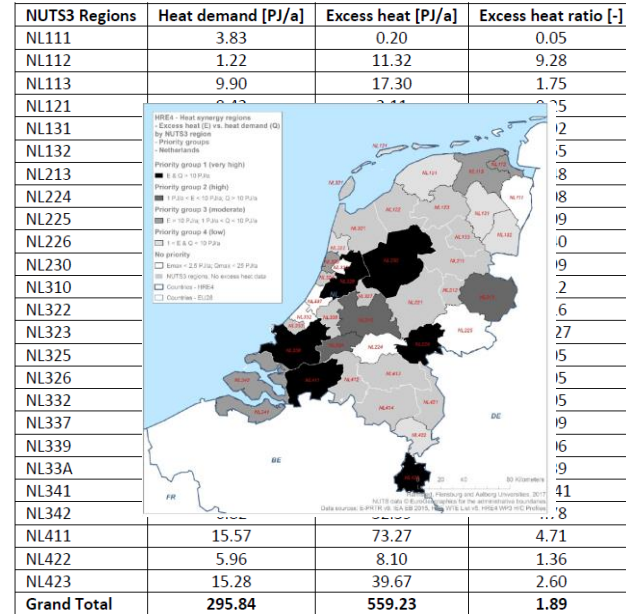
~75% DH →





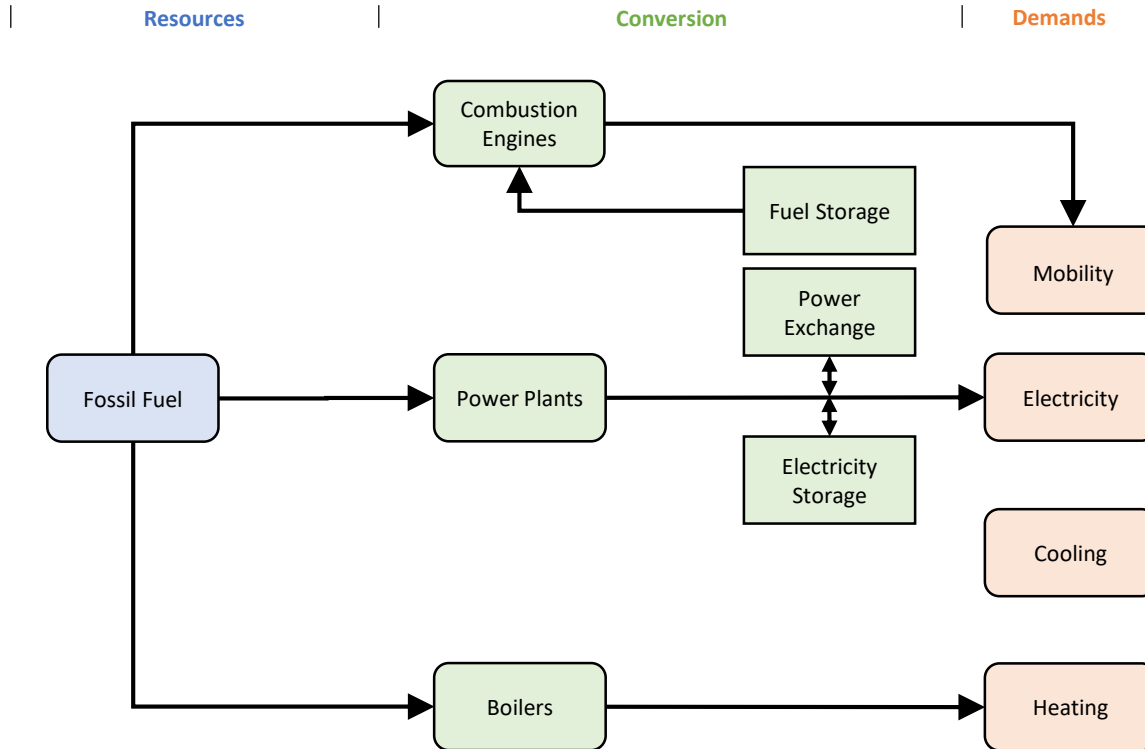
Heat synergies map in PETA4 example: Netherlands

- Heat demands: 296 PJ/y
- Excess heat: 560 PJ/y
- District heating share: 5%
- Renewable energy in heating: 3%
- Not a Technical barrier to improve energy efficiency



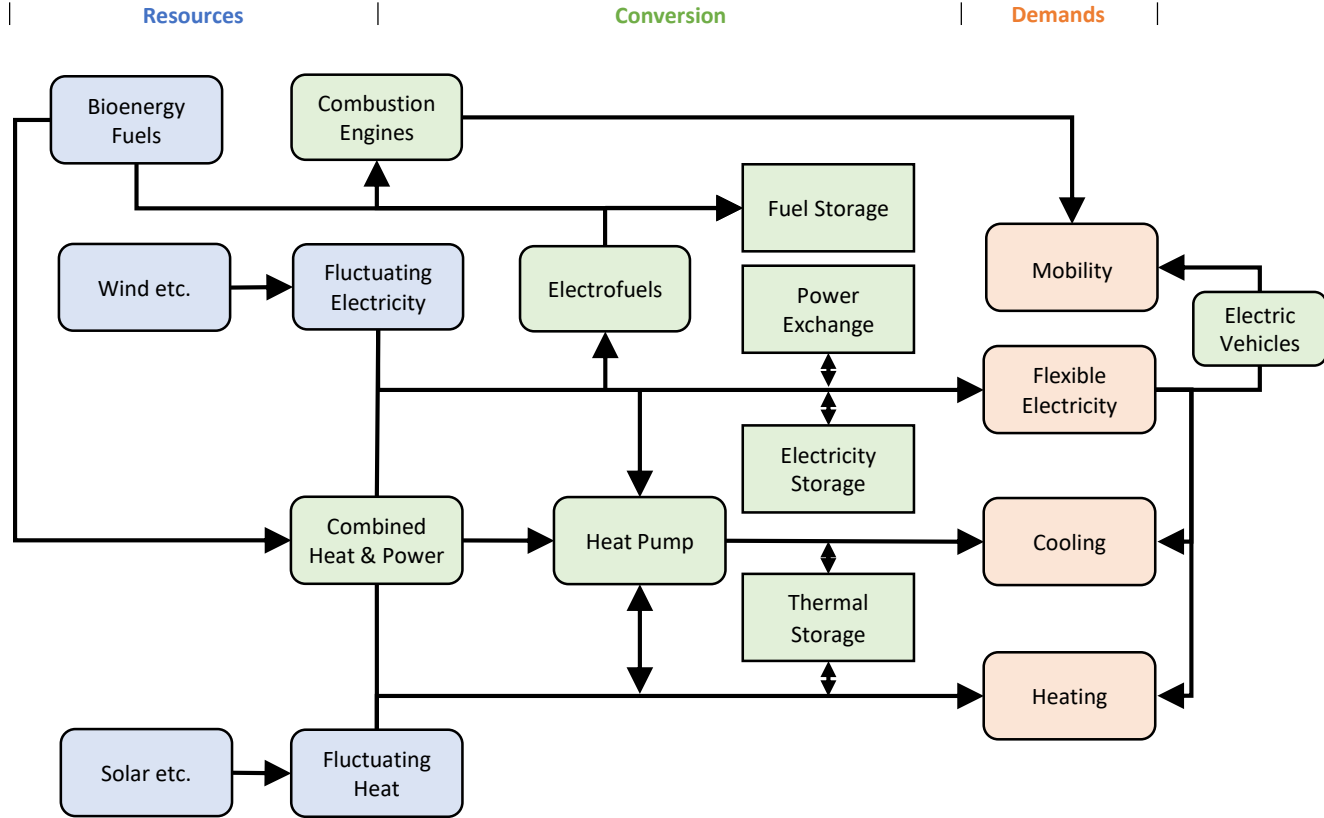


Today's Energy System

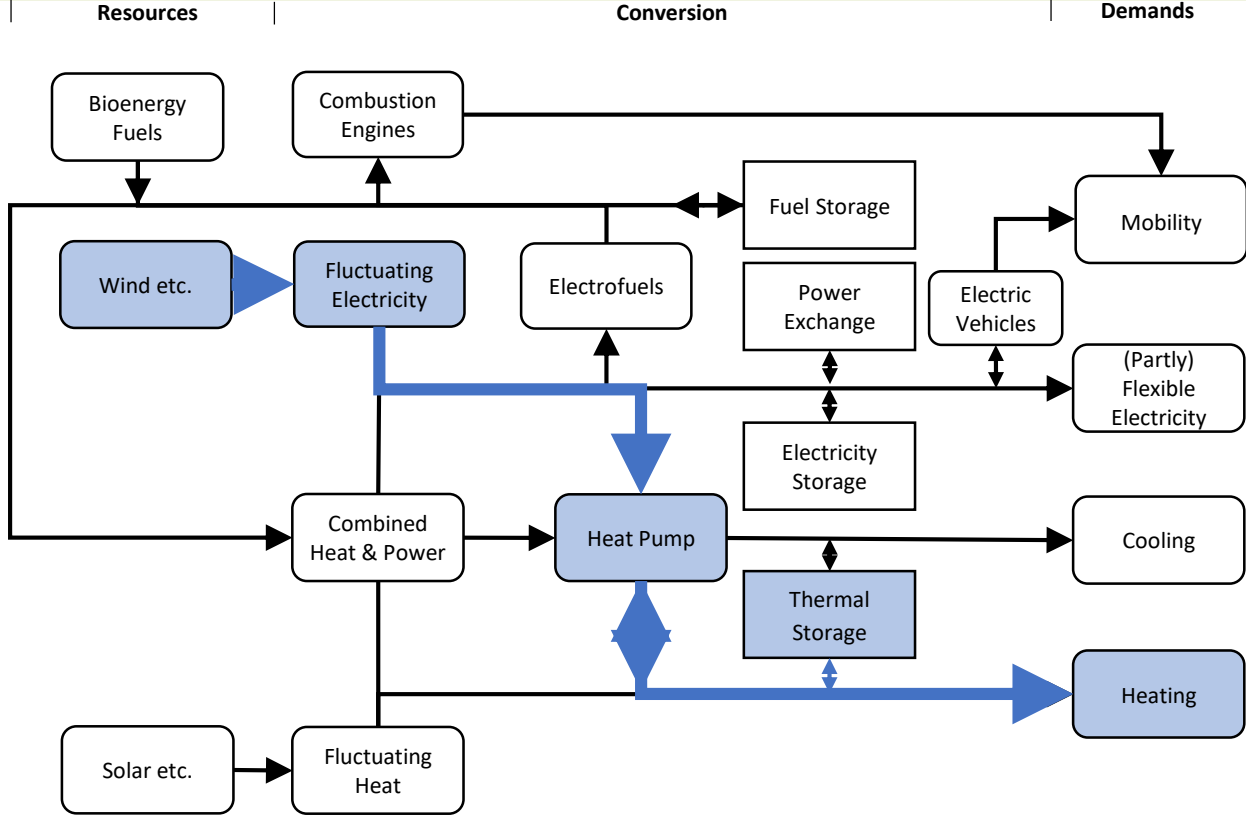




Smart Energy System

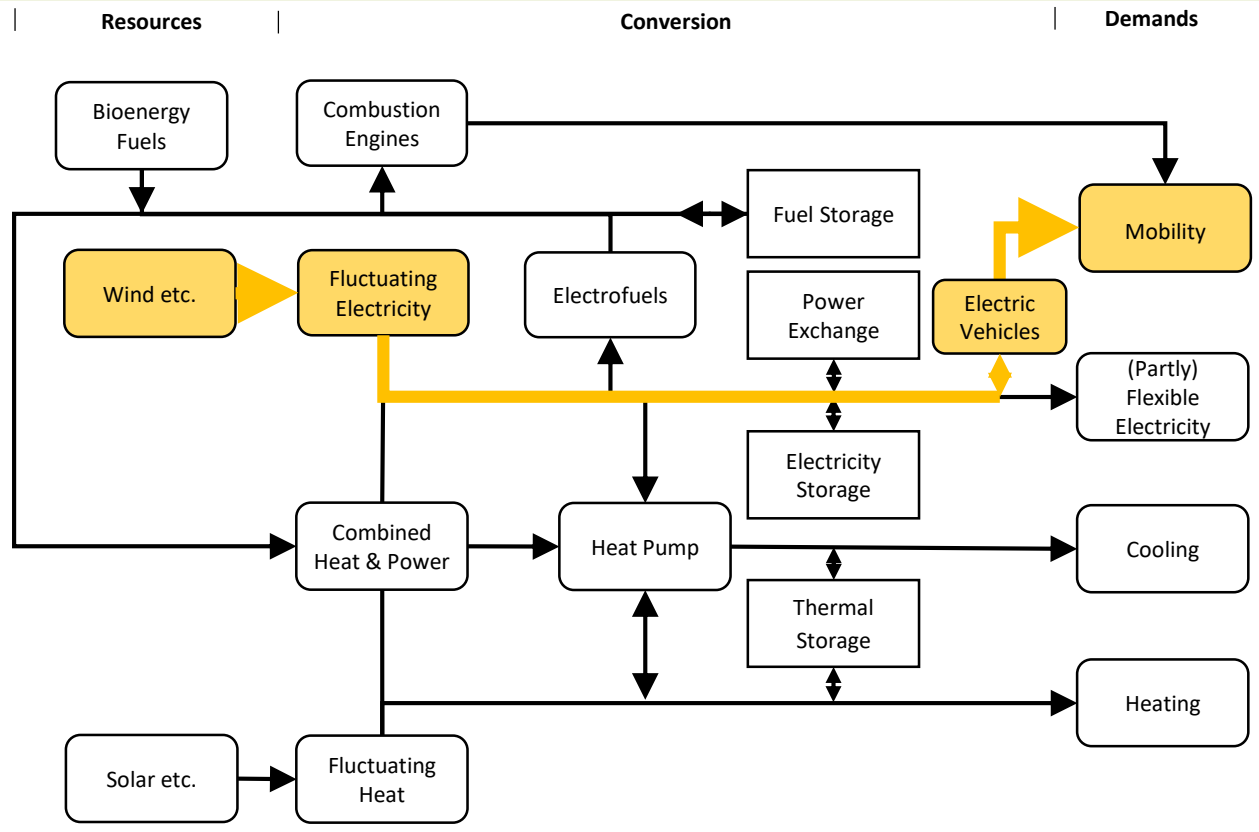


Smart Energy System: Thermal Storage



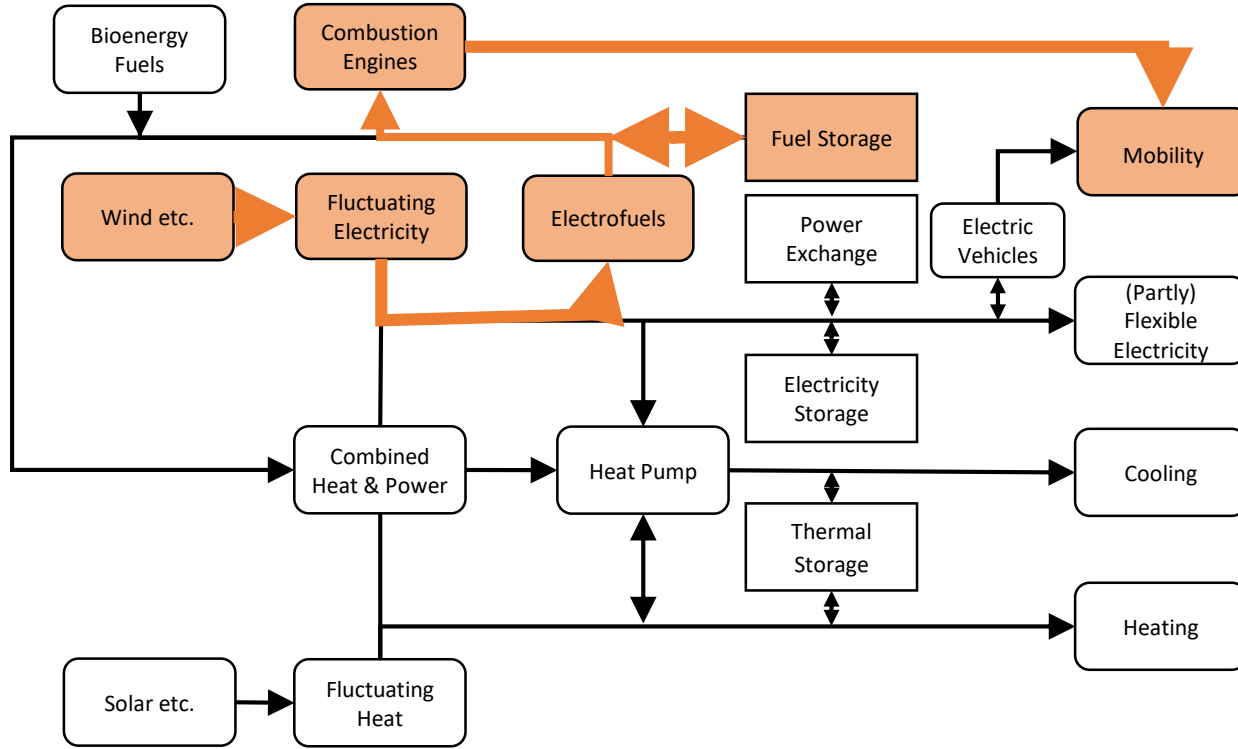


Smart Energy System: Battery/Mobility Storage





Smart Energy System: Fuel Storage





We need two-dimensional approach - technically and in regards to markets

TWO-DIMENSIONAL APPROACH

