CITIES 5th General Consortium Meeting
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Energy Storage in a Smart Energy System
- Policy and Planning Perspectives

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CITIES / Inno-SE workshop

- Energy storage systems in a life cycle perspective

Summary 1/3

- Poul Norby (DTU):
  - Potential Li-battery cost decrease from 200 $/kWh to 100 $/kWh
  - New battery types: Li-Air, Zi-Air → Factor 10 weight decrease, factor 5 volume decrease
- Allan Schrøder Pedersen (DTU):
  - HT thermal storage in rock beds: 600 °C, experimental RT thermal efficiency up to 68%
  - 5 mio €/MW investment cost, 10 €/kWh heat production cost
  - Potential for district heating plants


Image: Allan Schrøder Pedersen

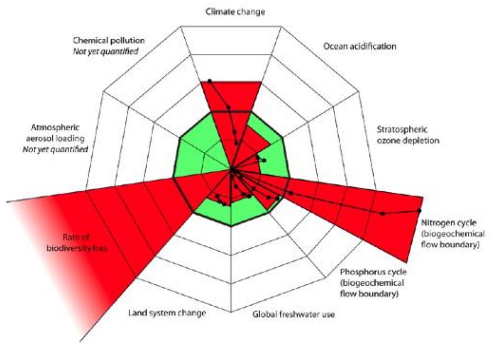
- Brian Vad Mathiesen (AAU):
  - 60-70% of electric capacity in 2050 will be based on fluctuating RE → 20-25,000 MW
  - Problematic to try and solve this only by cross-country exchange of electricity
  - Storage and flexibility units like electrolysers will only be in operation for around 50% of the time → need for appropriate regulative framework

CITIES / Inno-SE workshop
- Energy storage systems in a life cycle perspective

Summary 2/3

- Iva Ridjan (AAU):
  - Geographical analysis of electrolyser potentials based on CO_2 sources (biogas, industry) and possible grid connections (electricity, gas, district heating)
  - With a model 50 GWh plant, feasible locations vary greatly depending on electrolyser technology and CO_2 source (between 50 and several thousand)

- Alexis Laurent (DTU):
  - LCA of energy systems: relative vs. absolute sustainability
  - Absolute: downscale planetary boundaries to product level
  - Need for full integration of LCA into energy system models



Rockström et al. 2009

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Summary 3/3

- Guangling Zhao (DTU):
  - LCA of electrolysis: factor 20 difference in global warming potential between SOEC, PEM, AEC
  - Recycling can bring down GWP significantly
- Eirik Resch (NTNU/DTU):
  - Embodied emissions in building materials: steel factor 2,5 higher than concrete
  - Relatively high emissions from PV systems → challenge for ZEBs
  - My conclusion: better to install collective/neighbourhood PV systems

Paradigmatic change

”Natural” storage infrastructure

Fixed energy content + good storability

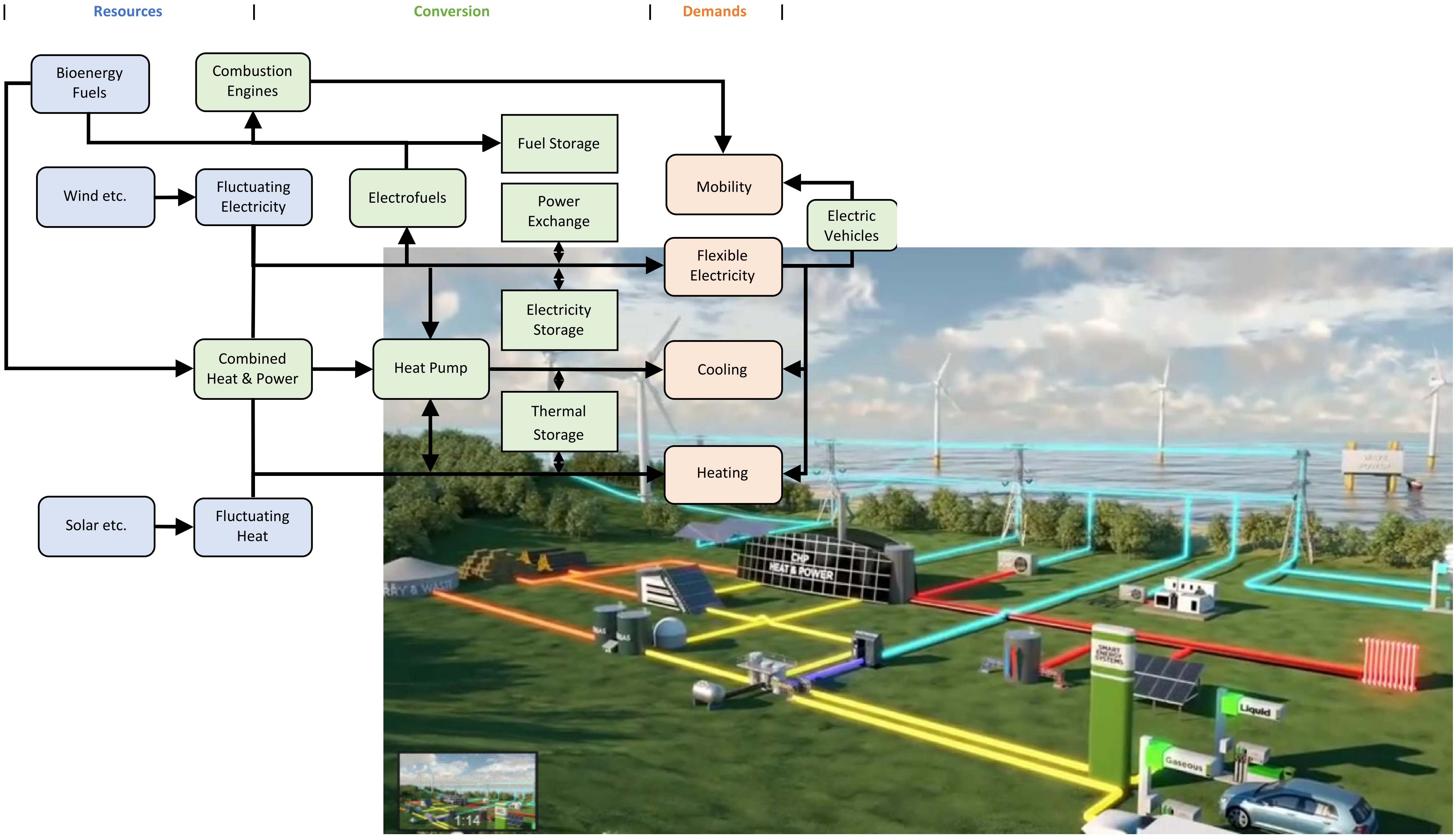
Variable energy content

+

External flexibility/storage

Images: Ørsted, Nordjyske.dk, Kia.com, Samsø Vindenergi, Colourbox, Energinet.dk, Santos et al. 2012, SEAS-NVE, naturplan.dk, energytrendinsider.com, Berlingske Business

Smart Energy System



Energy storage pyramid

Most Preferable

Integrate fluctuating renwable energy

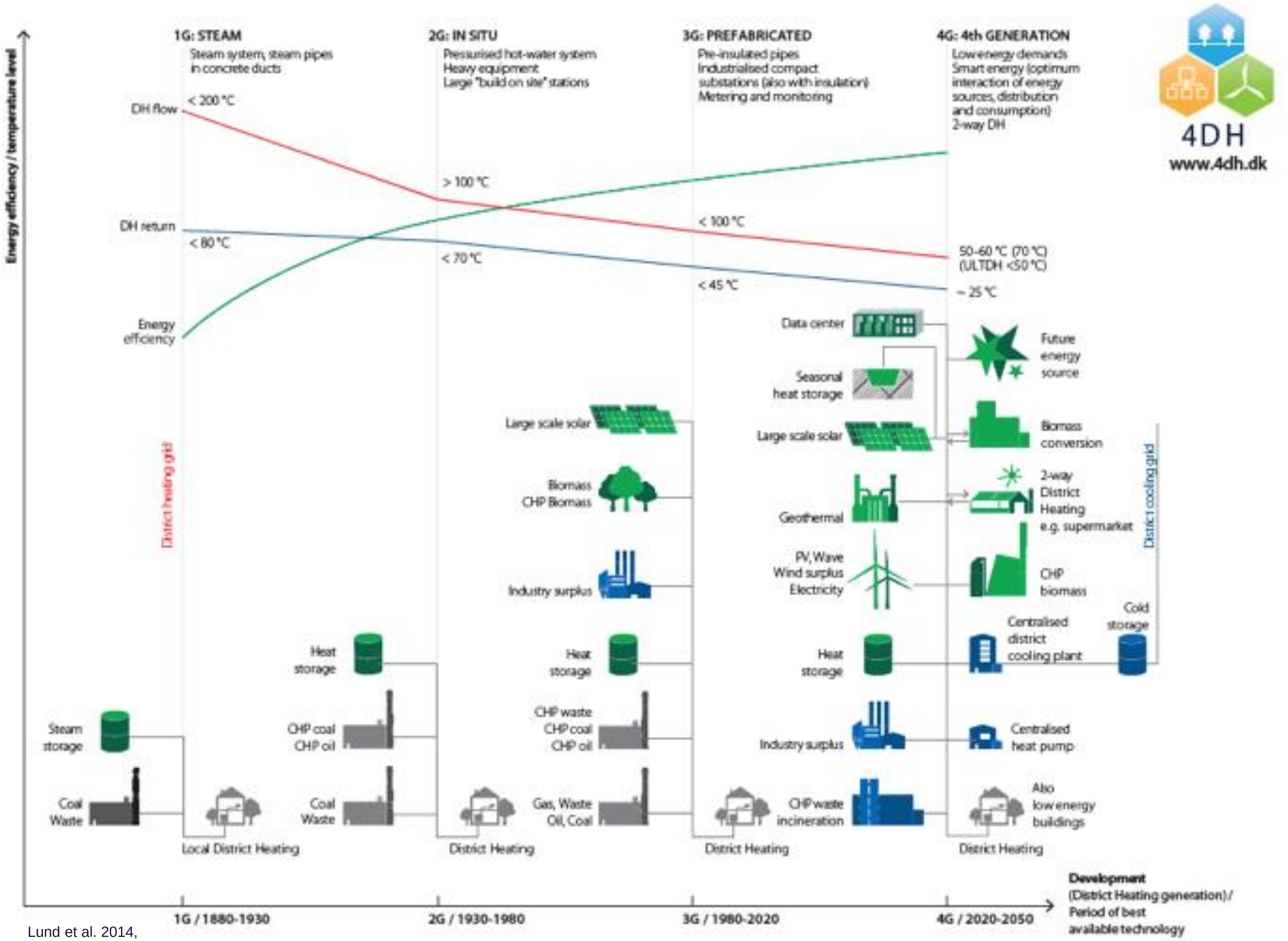
Least Preferable

USE EXCESS ENERGY…elsewhere	= Cross-sector relocation
STORE CHEAPER…elsewhere	= Cross-sector integration
Single-sector **DEMAND FLEXIBILITY**	= E.g. flexible electricity demand
Single-sector **EXCHANGE**	= Cross-country integration
COMPLEX Single-sector **STORAGE**	= E.g. large batteries
CURB RE production	= E.g. stop wind power production

Smart energy storage challenges

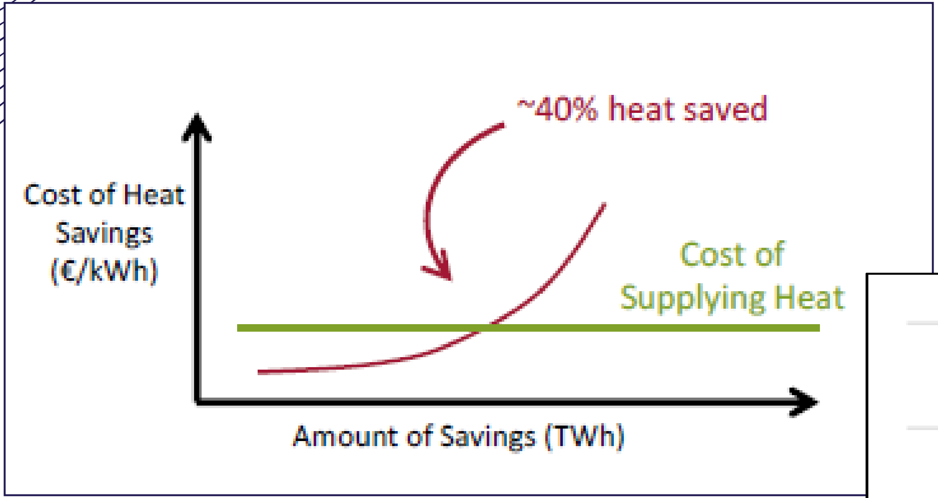
- Timing & Coordination
- Removal of barriers at the bottom of the storage pyramid

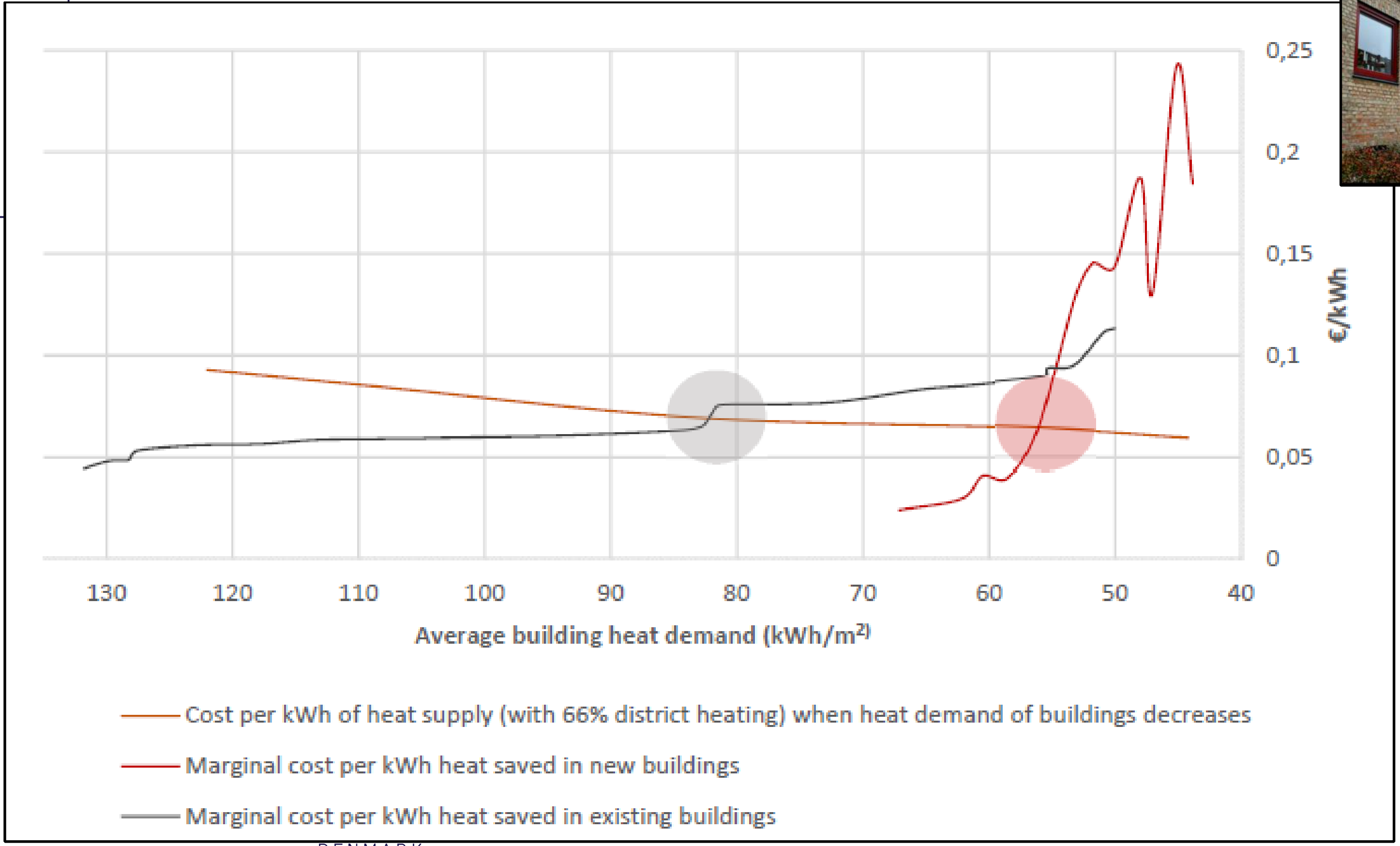
Timing and Coordination

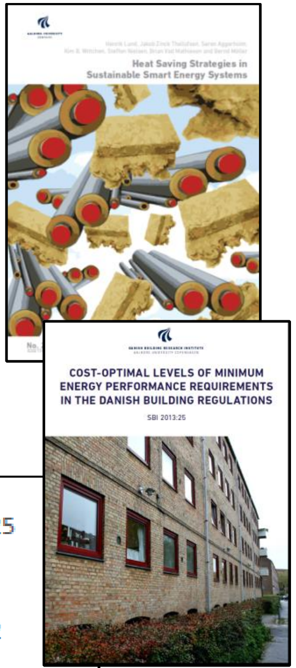


Lund et al. 2014,

Timing and Coordination







Lund et al. 2014, Aggerholm 2013

The top 10 technologies that require additional investment in the 100% renewable energy system in 2050

- From Electricity markets to Smart Energy System Markets?

	Technology	Required additional investment from today to 2050 (Billion €)
1	Energy renovations of the existing building stock	29.9
2	Offshore wind	28.4
3	Individual heat pumps	14.7
4	District heating grid expansion	5.5
5	Electrofuel production	4.4
6	Photovoltaic	2.6
7	Individual solar thermal	2.6
8	Biogas plants	2.6
9	Charging stations	2.2
10	Large-scale heat pumps	2.0

Mathiesen 2018

Types of policies needed

- Demand reduction policies
- Policies for cross-sector relocation and integration

Demand reduction policies: Heat

- In District Heating Areas:
  - Neighbourhood refurbishment programmes
  - 100% variable DH tariffs based on future DH price → test zones (?)
  - Coordination between DH companies, industry, housing associations
  - No tax on (green, low-temp) net-excess heat (after internal use and demand reduction)

- In all heated buildings:
  - Free energy audits
  - Guaranteed, long-term, low interest loans
  - 20-30% refurbishment subsidy (for target groups, single-family houses)

Image: arkitekthusetvodskov.dk

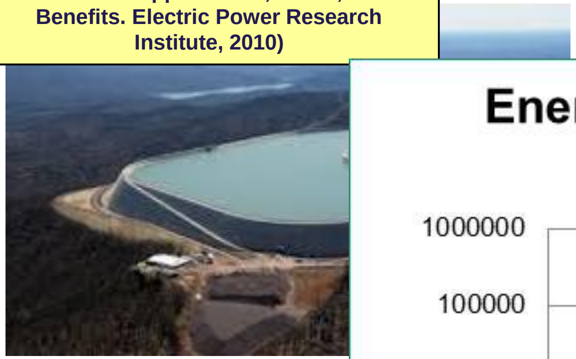
Cross-sector policies: bottom of the pyramid

- General principle:
  - Make it easy to use excess electricity in other sectors where it is otherwise expensive to replace fossil fuels (heating, transport, gas)

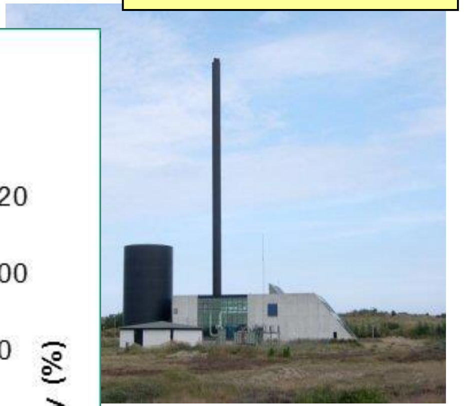
  - Dynamic taxes and tariffs on e.g. electricity for heating/electrolysis, depending on:
    - Renewable electricity share/pollution
    - System benefits (e.g. avoided transmission cost)
    - Integration priorities

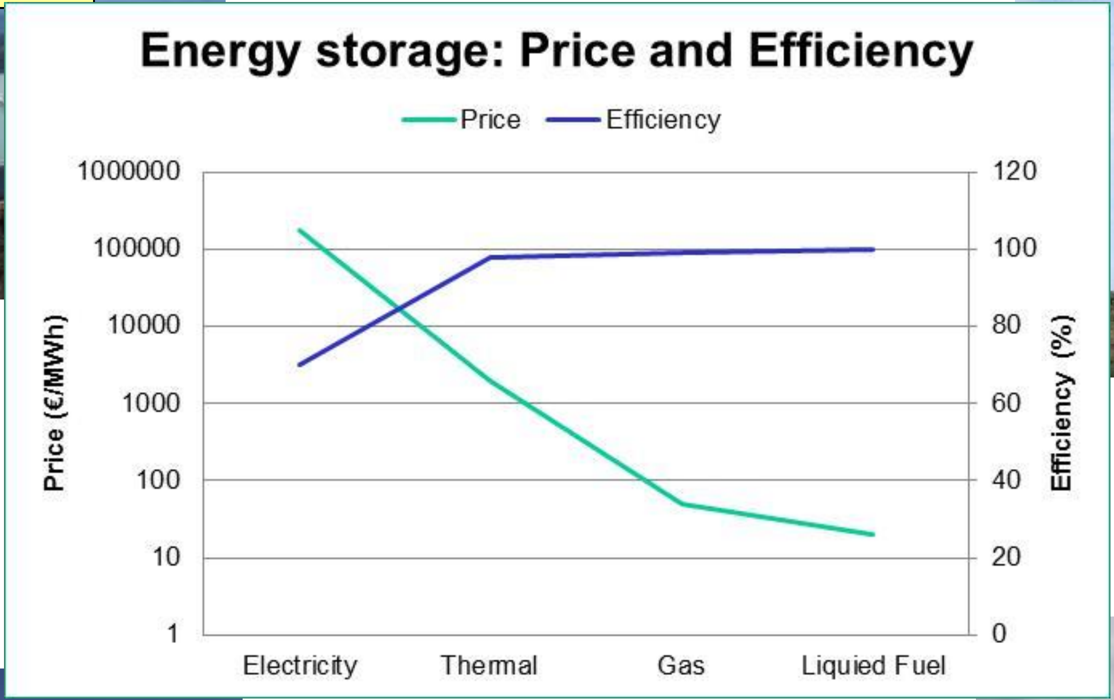
Energy Storage

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)

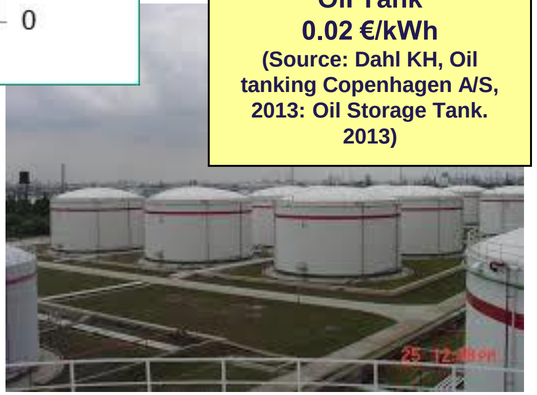


Thermal Storage
1-4 €/kWh
(Source: Danish Technology Catalogue, 2012)





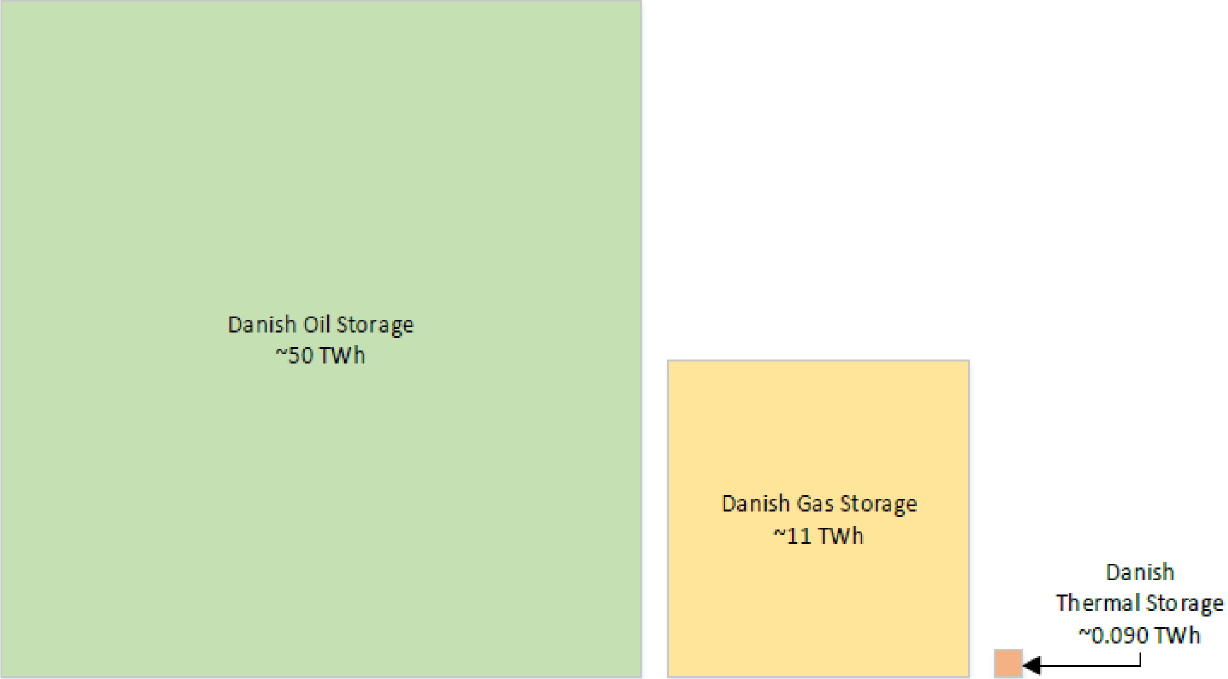
Oil Tank
0.02 €/kWh
(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)



Natural Gas Underground Storage
0.05 €/kWh
(Source: Current State Of and Issues Concerning Underground Natural Gas Storage. Federal Energy Regulatory Commission, 2004)



Energy Storage Capacities in Denmark



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4DH
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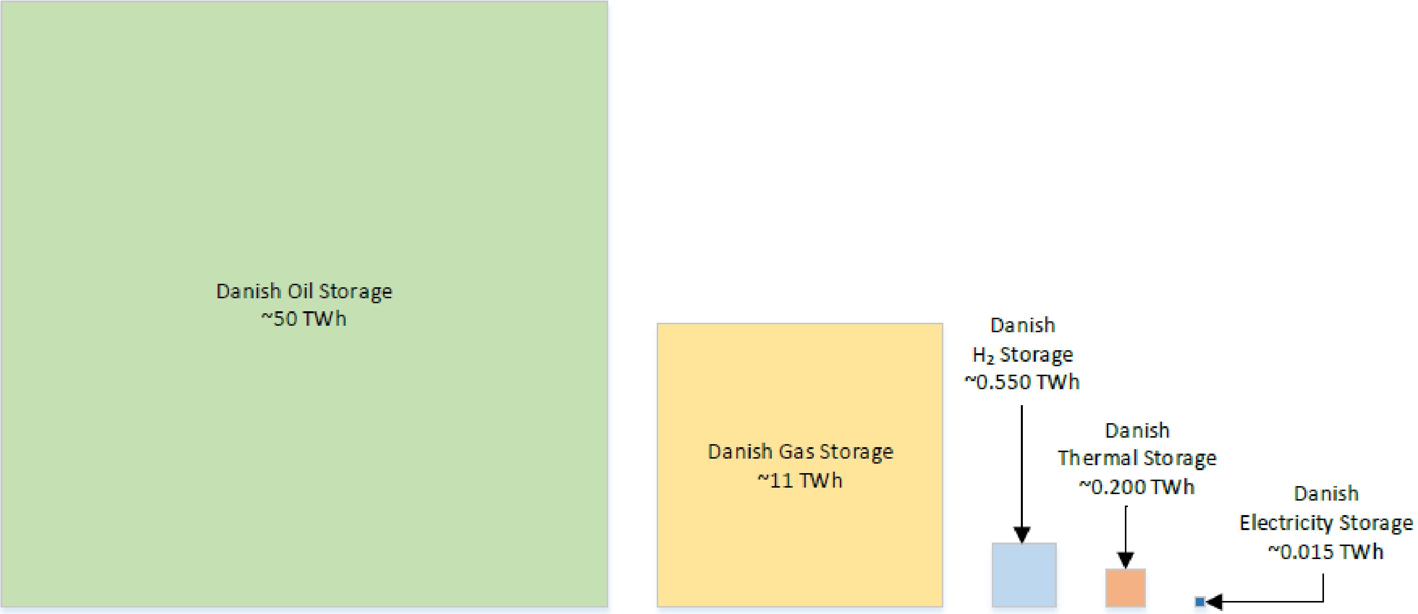
Innovation Fund Denmark

Energy Storage Capacities in 100 % RES Denmark 2050 (IDA)



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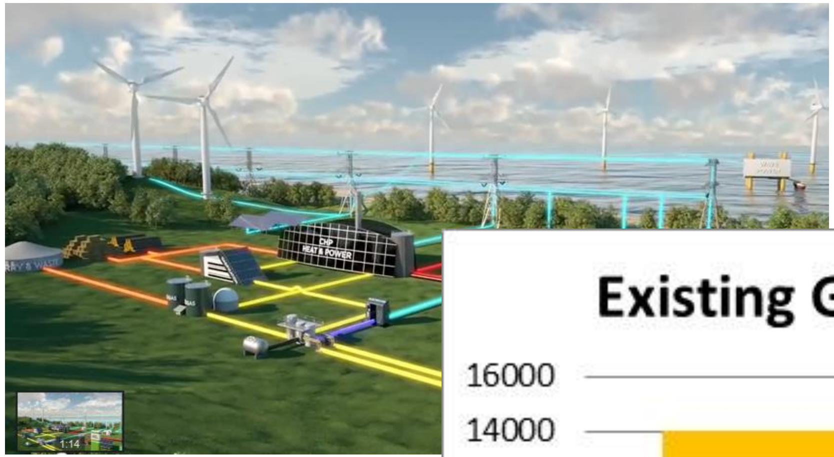
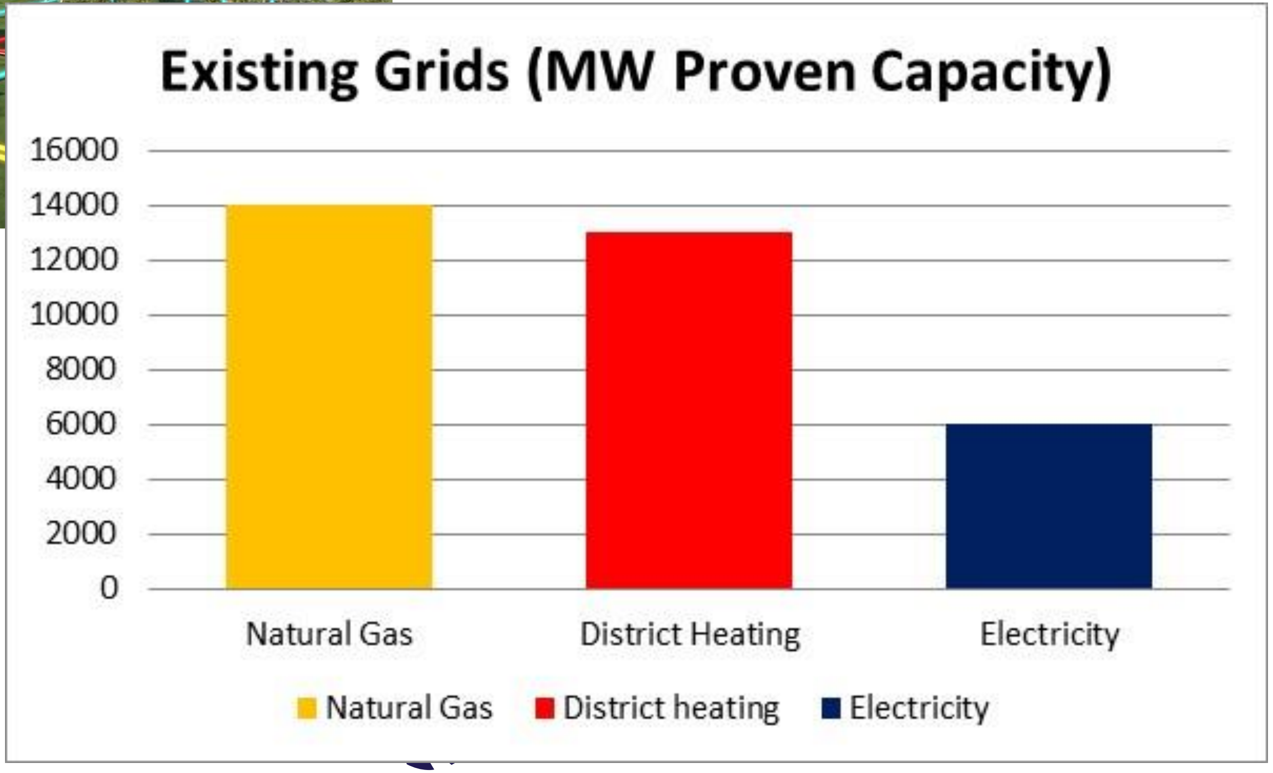
Existing distribution grids

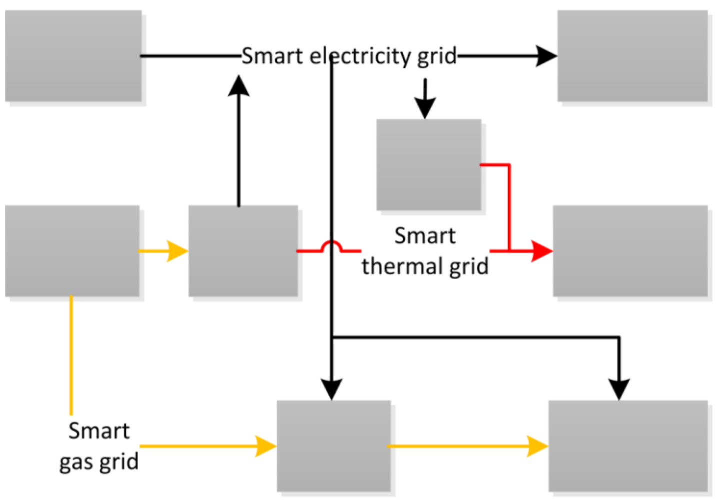




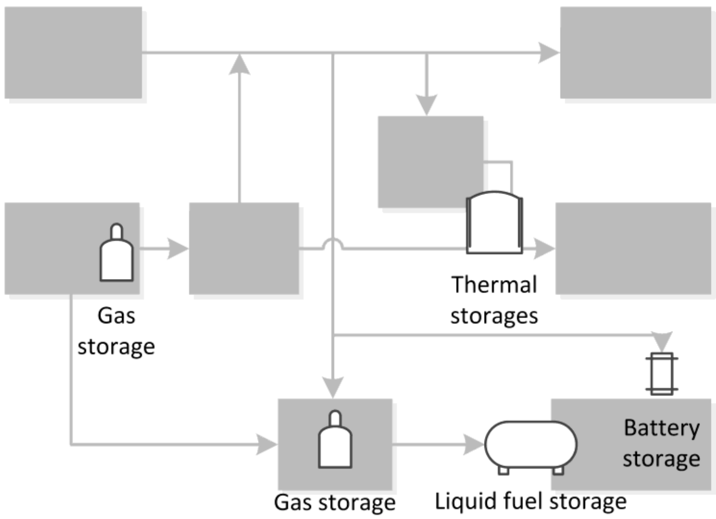
HOW TO USE STORAGES LONG TERM..
(IN SMART ENERGY MARKETS)

- Three crucial grids in Smart Energy Systems
  - Smart electricity grids
  - Smart thermal grids
  - Smart gas grids
- High capacity electrolysers (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

Smart energy system grids



Smart energy system storages



Mathiesen et al. 2015

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Thank you.

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