4th Generation District Heating and Smart Energy Systems
Insights from the 4DH Research Centre

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Smart Energy Europe: The technical and economic impact of one potential 100% renewable energy scenario for the European Union

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www.EnergyPLAN.eu/SmartEnergyEurope

- Report Online
- Paper Published
Smart Energy Systems
Smart Energy Systems

www.energyplan.eu/smartenergysystems/
Smart Energy Systems
The key to cost-efficient 100% Renewable Energy

• A sole focus on renewable electricity (smart grid) production leads to electricity storage and flexible demand solutions!

• Looking at renewable electricity as a part smart energy systems including heating, industry, gas and transportation opens for cheaper and better solutions…

Power-to-Heat
Power-to-Gas
Power-to-Transport
Energy Storage

**Pump Hydro Storage**
- 175 €/kWh

**Natural Gas Underground Storage**
- 0.05 €/kWh

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

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

**Energy storage: Price and Efficiency**

![Graph showing energy storage: Price and Efficiency](image-url)
Thermal Storage

0.16 m³ Thermal Storage
300,000 €/MWh
(Private house: 160 liter for 15,000 DKK)

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

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

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

Pump Hydro Storage
100 €/kWh
(Source: Goldisthal Pumped Storage Station, Germany, www.store-project.eu)

Sodium-Sulphur Battery
600 €/kWh
(Source: Table 4: http://large.stanford.edu/courses/2012/ph240/doshay1/docs/EPRI.pdf)

Compressed Air Energy Storage
125 €/kWh
(Source: http://www.sciencedirect.com/science/article/pii/S0196890409000429)

Tesla PowerWall
800 €/kWh
(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)

Electricity Storage: Price and Size

<table>
<thead>
<tr>
<th>Price (€/MWh)</th>
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<tbody>
<tr>
<td>Tesla PowerWall</td>
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<tr>
<td>3.3 kW</td>
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</table>
Energy Storage and Smart Energy Systems

Henrik Lund¹, Poul Alberg Østergaard¹, David Connolly², Iva Ridjan², Brian Vad Math Frøde Hvelplund³, Jakob Zinck Thellufsen³, Peter Sorknaes¹

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Figure 1: Investment cost and cycle efficiency comparison of electricity, thermal, gas and liquid fuel storage technologies. See assumptions, details and references in Appendix 1.

Figure 2: Annualized investment cost per use-cycle vs annual numbers of use-cycles. In the diagram the cost is also benchmarked against the cost of producing renewable energy, here shown for a wide cost span by grey (extension along horizontal axis is for presentation only, there is no cycle dependence for renewable energy production). See assumptions, details and references in Appendix 1.

Figure 3: Investment cost comparison of different sizes of thermal energy storage technologies. The sizes correspond to storages for a dwelling, a larger building, a CHP plant and a solar DH system (see Footnote 2). See assumptions, details and references in Appendix 1.

Figure 4: Investment cost comparisons of different sizes of electricity energy storage technologies. See assumptions, details and references in Appendix 1.
Energy System Analysis Model

www.EnergyPLAN.eu
Smart Energy Systems:
Hourly modelling of all smart grids to identify synergies!
... and influence of different types of energy storage...!
IDA Energiplan 2030

Primary energy supply

<table>
<thead>
<tr>
<th>Year</th>
<th>Export</th>
<th>RE electricity</th>
<th>Solar therm</th>
<th>Biomass</th>
<th>Natural gas</th>
<th>Oil</th>
<th>Coal</th>
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<td>Ref. 2030</td>
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CO₂ emissions

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<tr>
<th>Year</th>
<th>Export</th>
<th>Danish consumption</th>
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<tbody>
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<td>1990</td>
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<td></td>
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<tr>
<td>Ref. 2030</td>
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<tr>
<td>IDA 2030</td>
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</table>

Business

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<tr>
<th>Year</th>
<th>Fuel cells</th>
<th>Wave power</th>
<th>Solar thermal</th>
<th>Photovoltaics</th>
<th>Management and measuring</th>
<th>Electricity, oil and gas management</th>
<th>Wind power</th>
<th>District heating and CHP</th>
</tr>
</thead>
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<tr>
<td>2004</td>
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Energy Storage Capacities in Denmark

Danish Oil Storage
\~50 TWh

Danish Gas Storage
\~11 TWh

Danish Thermal Storage
\~0.090 TWh
Energy Storage Capacities in 100% RES Denmark 2050 (IDA)

- Danish Oil Storage: ~50 TWh
- Danish Gas Storage: ~11 TWh
- Danish H₂ Storage: ~0.550 TWh
- Danish Thermal Storage: ~0.200 TWh
- Danish Electricity Storage: ~0.015 TWh
Eksisterende distributionsnet
**Transport:**
Electric vehicles is best from an energy efficient point of view. But gas and/or liquid fuels is needed to transform to 100%.

**Biomass:**
.. is a limited resource and can not satisfy all the transportation needs.

**Consequence**
… Electricity from Wind (and similar resources) needs to be converted to gas and liquied fuels in the long-term perspective…
Electro-fuels
100% Renewable Energy 2050
Power-to-Transportation
WELCOME TO 4DH

4DH is an international research centre which develops 4th generation district heating technologies and systems. This development is fundamental to the implementation of the Danish objective of being fossil fuel-free by 2050 and the European 2030 goals.

With lower and more flexible distribution temperatures, 4th generation district heating (4DH) can utilize renewable energy sources, while meeting the requirements of low-energy buildings and energy conservation measures in the existing building stock.
Three pillars

Supply:
Low temperature District heating

Production:
Renewable Systems Integration

Organisation:
Planning and Implementation
Supply:
Low temperature District heating

Grids and components:
- low-temperature district heating systems based on renewable energy.
- new knowledge of the hardware and software technologies of the new generation of district heating systems
- existing energy renovated buildings and new low-energy buildings.
Production: Renewable Systems Integration

Production and system integration:
- the development of energy systems analysis tools, methodologies and theories
- scenario building of future sustainable energy systems.
- The aim is to identify the role of district heating systems and technologies in various countries.
Organisation:
Planning and Implementation

Planning and implementation:
- further development of the planning and management systems
- spatial analysis and geographical information systems (GIS) as a tool for planners and decision-makers.
- organisation and design of specific public regulation measures including ownership, tariffs, reforms etc.
Heat Roadmap Europe

GIS Mapping: Many Heat Sources

- Urban areas (Heating Demands)
- Power and Heat Generation
- Waste Management
- Industrial waste heat potential
- Geothermal heat
- Solar Thermal

the study indicates that the market shares for district heating for buildings can be increased to 30% in 2030 and 50% in 2050.

Sustainable energy for everyone
STRATEGO WP2
Enhanced National Heating and Cooling Strategies

Co-funded by the Intelligent Energy Europe Programme of the European Union
HRE4 Countries: 14 Largest EU Countries by Heat Demand = 90% of EU Heat

- Belgium (BE)
- Czech Republic (CZ)
- Germany (DE)
- Spain (ES)
- France (FR)
- Italy (IT)
- Hungary (HU)
- Netherlands (NL)
- Austria (AT)
- Poland (PL)
- Romania (RO)
- Finland (FI)
- Sweden (SE)
- United Kingdom (UK)
Smart Heating Europe
4th International Conference on
Smart Energy Systems and
4th Generation District Heating

13-14 November 2018 · Aalborg
More information:


www.henriklund.eu

www.4DH.dk

www.energyplan.eu/SmartEnergyEurope

www.energyplan.eu/smartenergysystems/

www.heatroadmap.eu

www.EnergyPLAN.eu