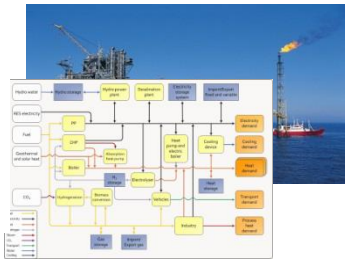
*Enhancing the Impact of Energy Efficiency*

*and Renewable Energy Policies*

**A joint workshop of the IEA Renewable Energy and Energy Efficiency Working Parties**

To be held at the French Ministry of Foreign Affairs' Ministerial Conference Centre
27, rue de la Convention, 15ème arrondissement, Paris, France



# Smart Energy Systems Approach to Heating, Cooling and Transport


Henrik Lund

Professor in Energy Planning

Aalborg University



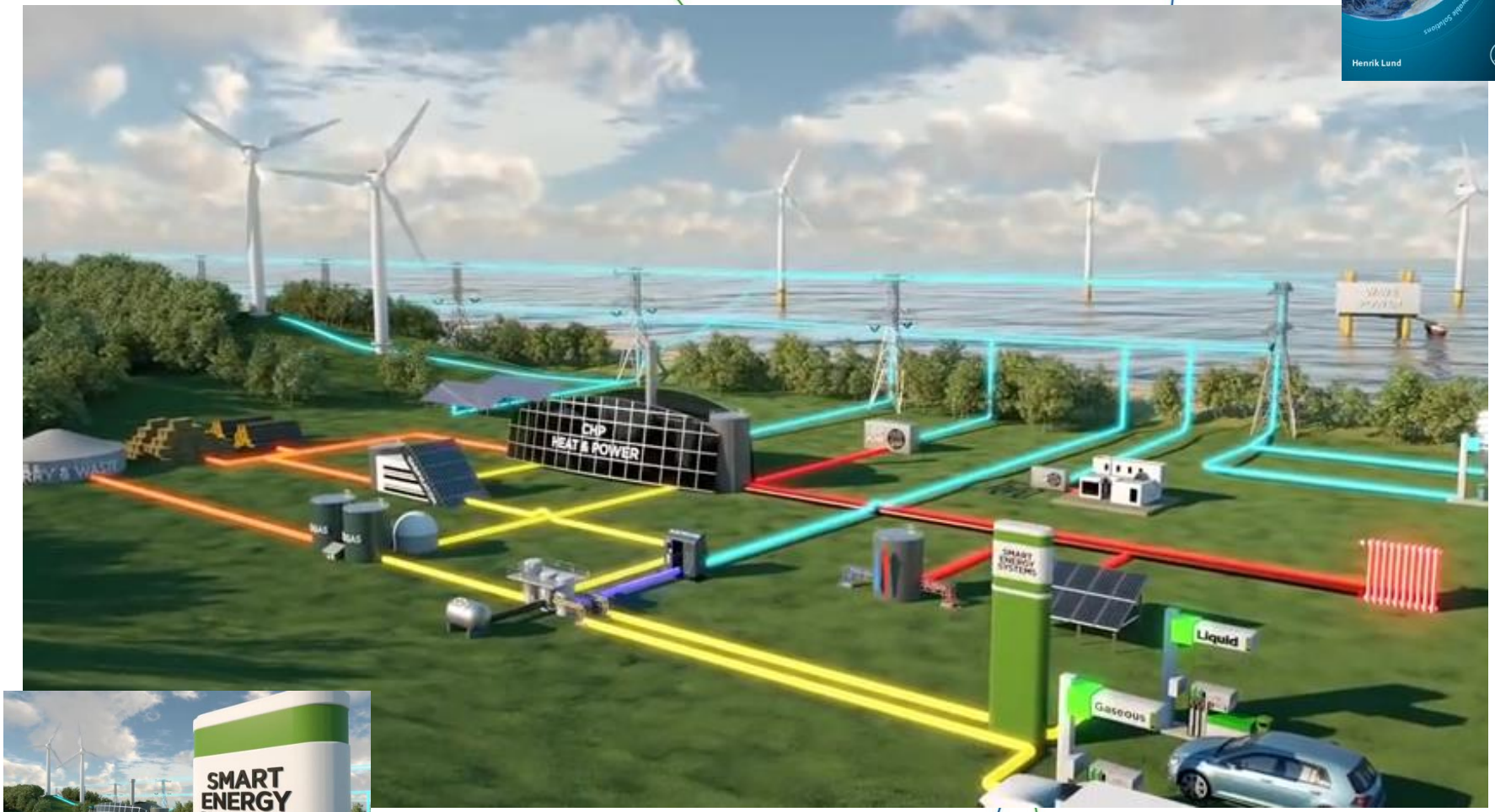

AALBORG UNIVERSITY
DENMARK

reINVEST

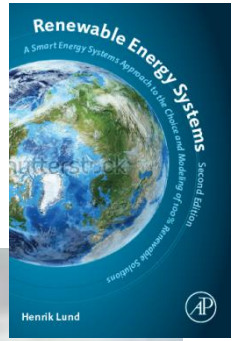
Innovation Fund Denmark

CITIES
Centre for IT Intelligent Energy Systems

# Smart Energy Systems





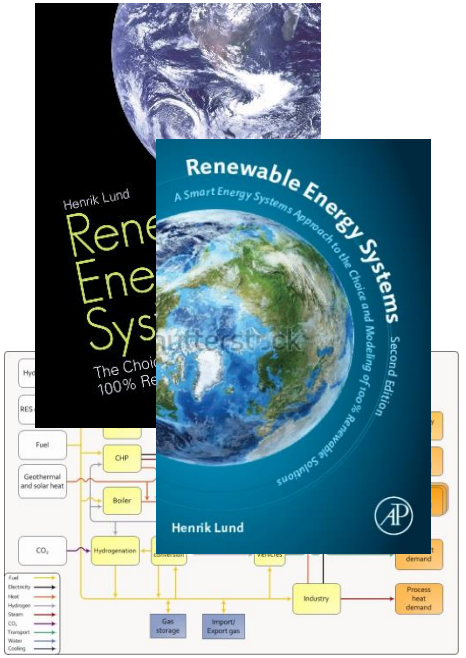


# Smart Energy Systems

## 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…



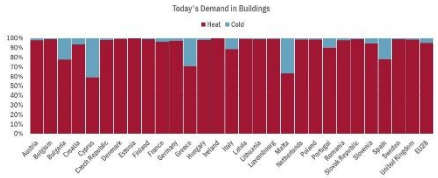

**Power-to-Heat**

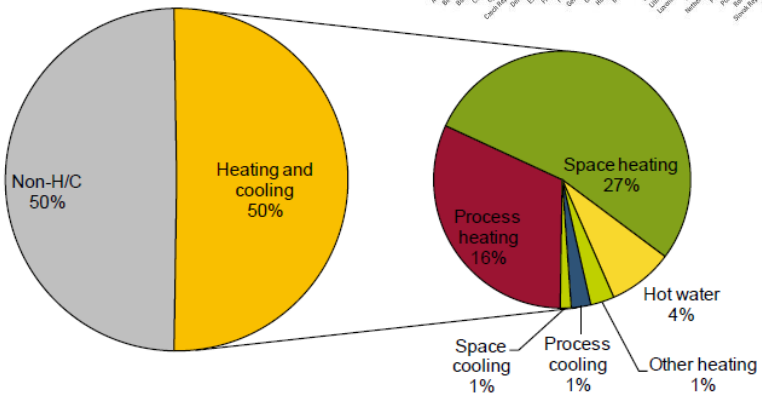
**Power-to-Gas**
**Power-to-Transport**

AALBORG UNIVERSITY
DENMARK

www.heatroadmap.eu
@HeatRoadmapEU

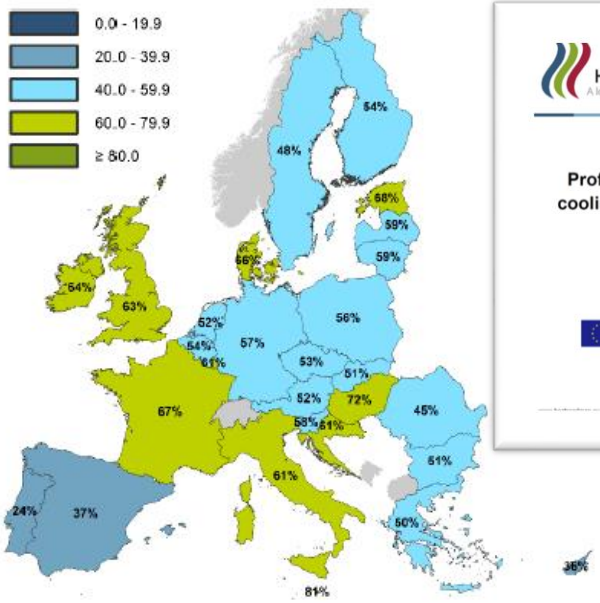
# Heating vs. other sectors



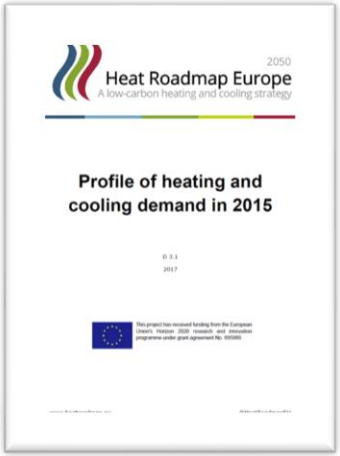




Heating and cooling demand in 2015 in the EU28 by end-use compared to total final energy demand

- Large share for All Member States (not just the 'cold' North)
- Overall cooling share in general is 10-15%




Heating and cooling demand in 2015 in the EU28 by end-use compared to total final energy demand

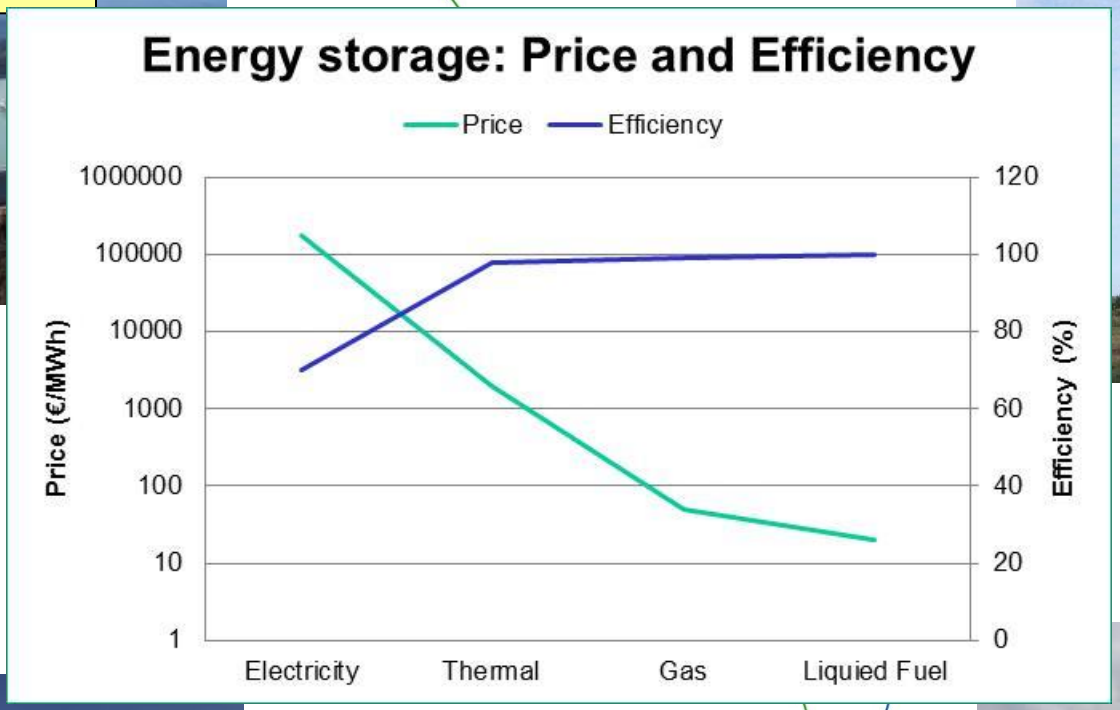



AALBORG UNIVERSITY
DENMARK

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989.

# Energy Storage

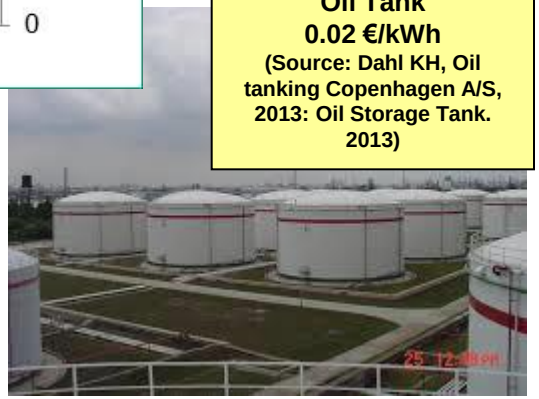
**Pump Hydro Storage**
**175 €/kWh**
**(Source: Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits. Electric Power Research Institute, 2010)**



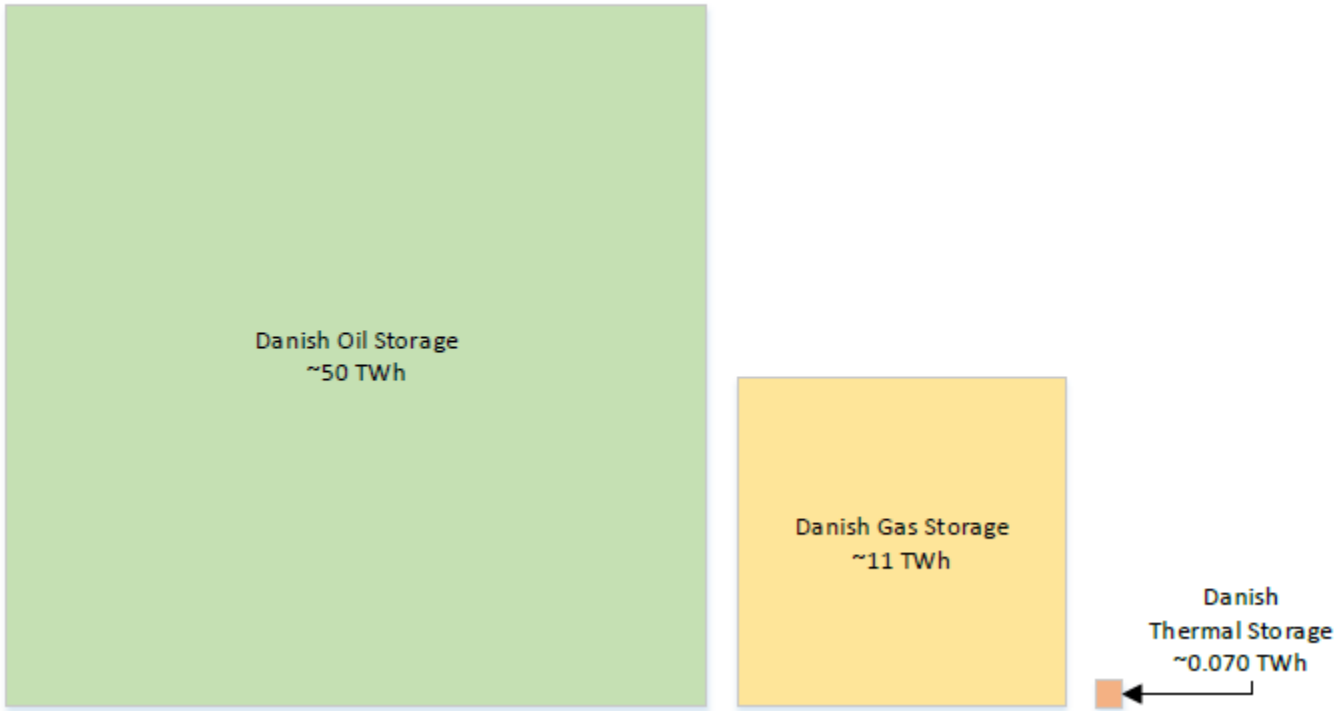

**Thermal Storage**
**1-4 €/kWh**
**(Source: Danish Technology Catalogue, 2012)**

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

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

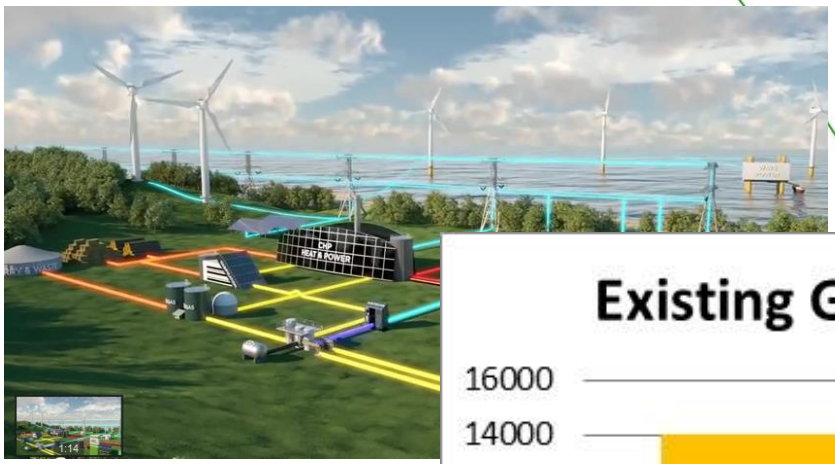


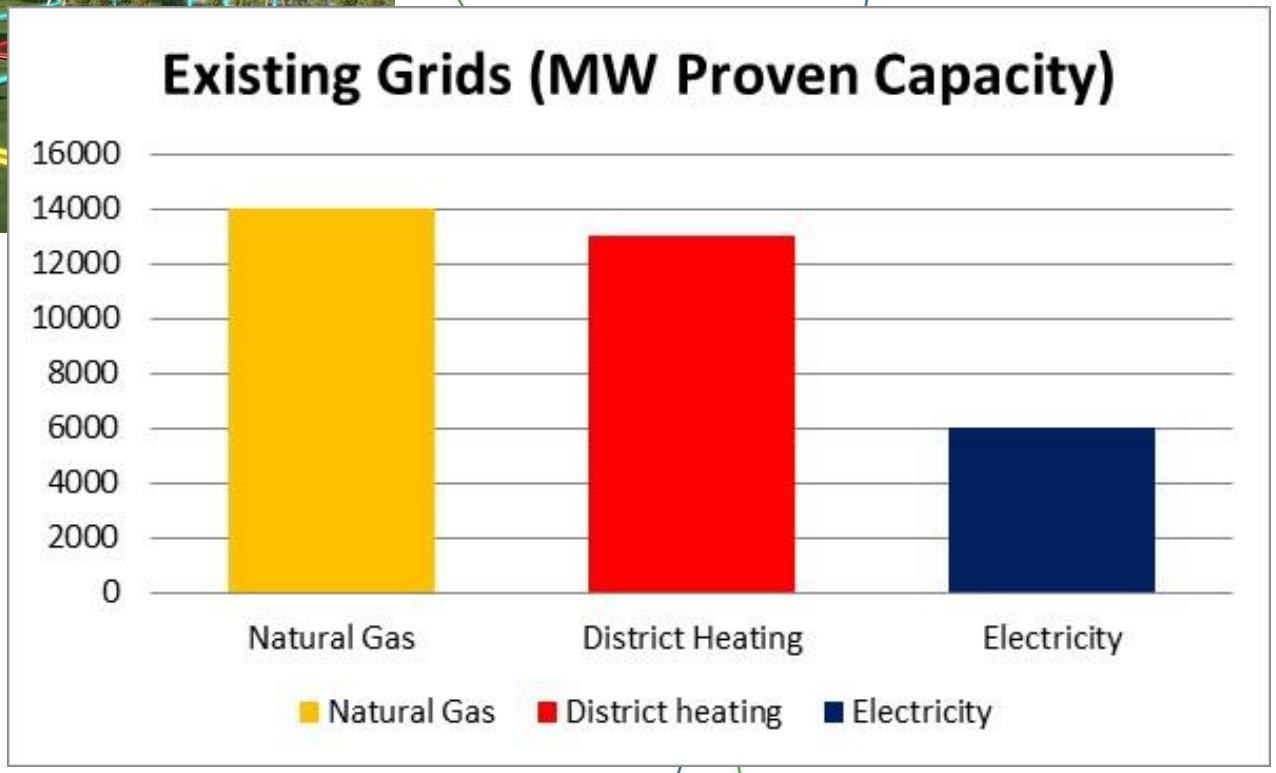
# Energy Storage Capacities in Denmark



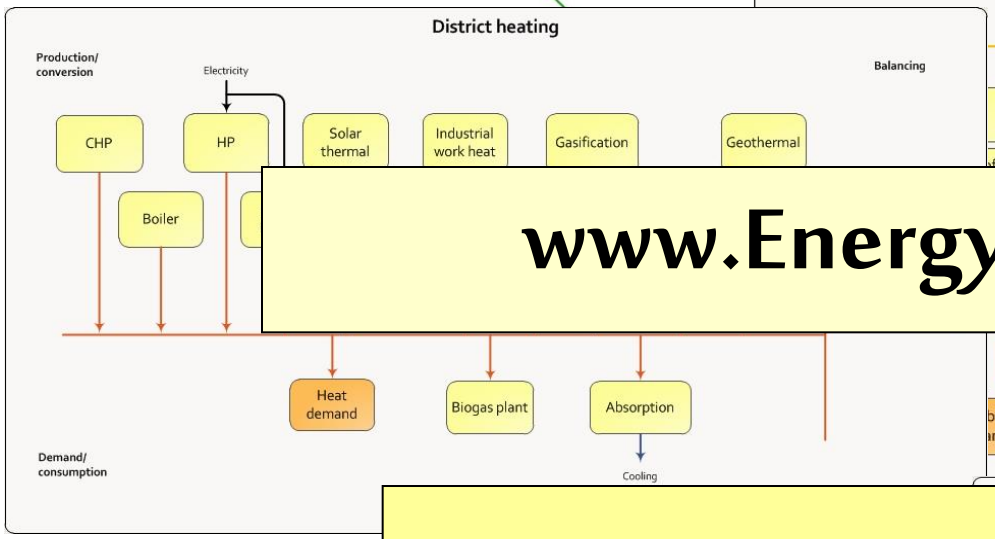

AALBORG UNIVERSITY
DENMARK

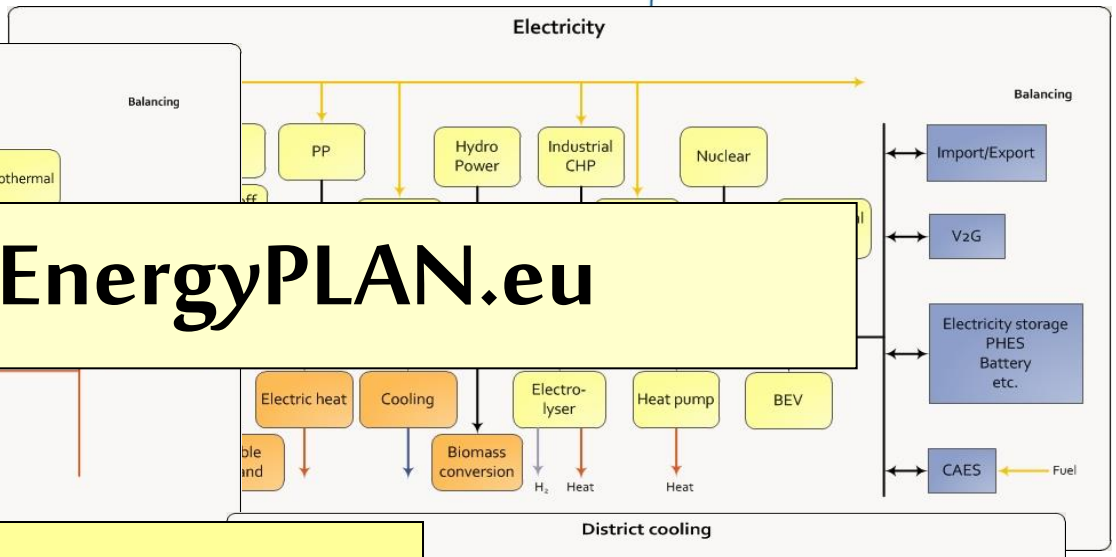
# Existing distribution grids




AALBORG UNIVERSITY
DENMARK

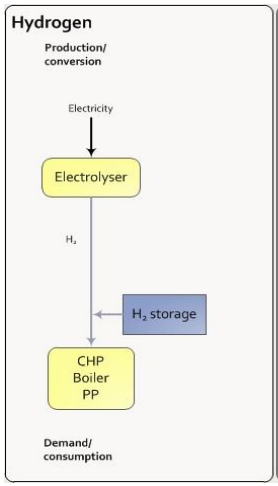


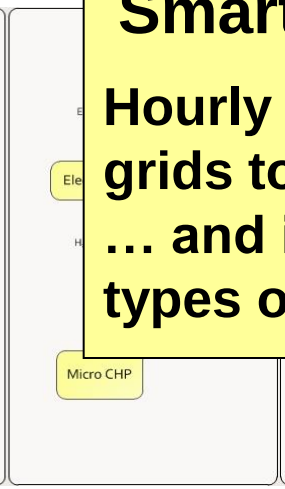



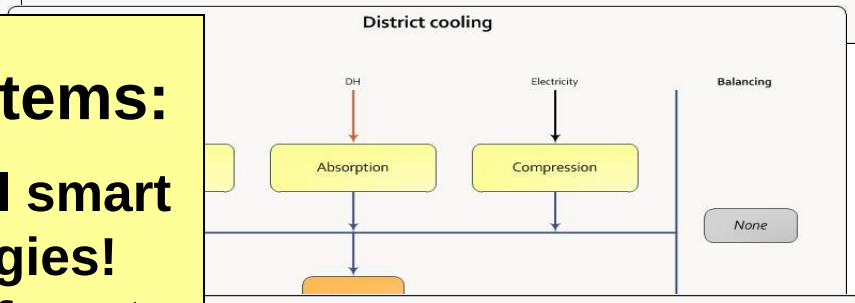

# www.EnergyPLAN.eu

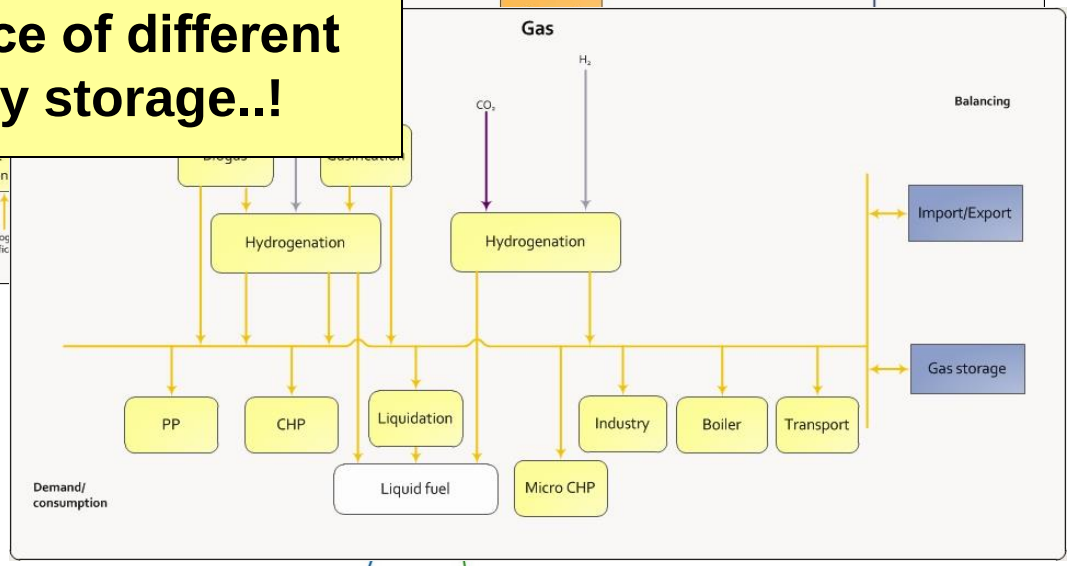
## Smart Energy Systems:

**Hourly modelling of all smart grids to identify synergies!**
**… and influence of different types of energy storage..!**

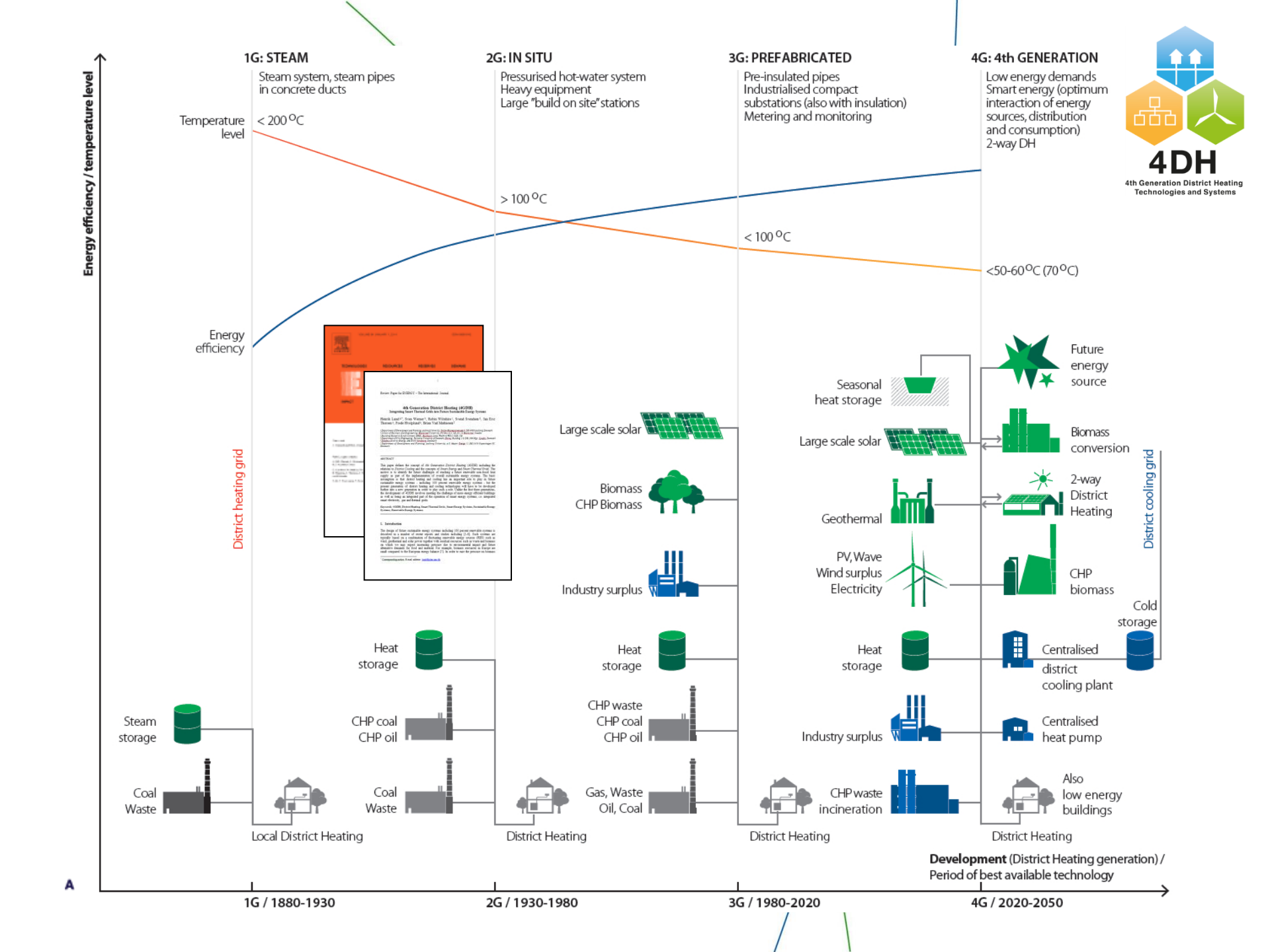


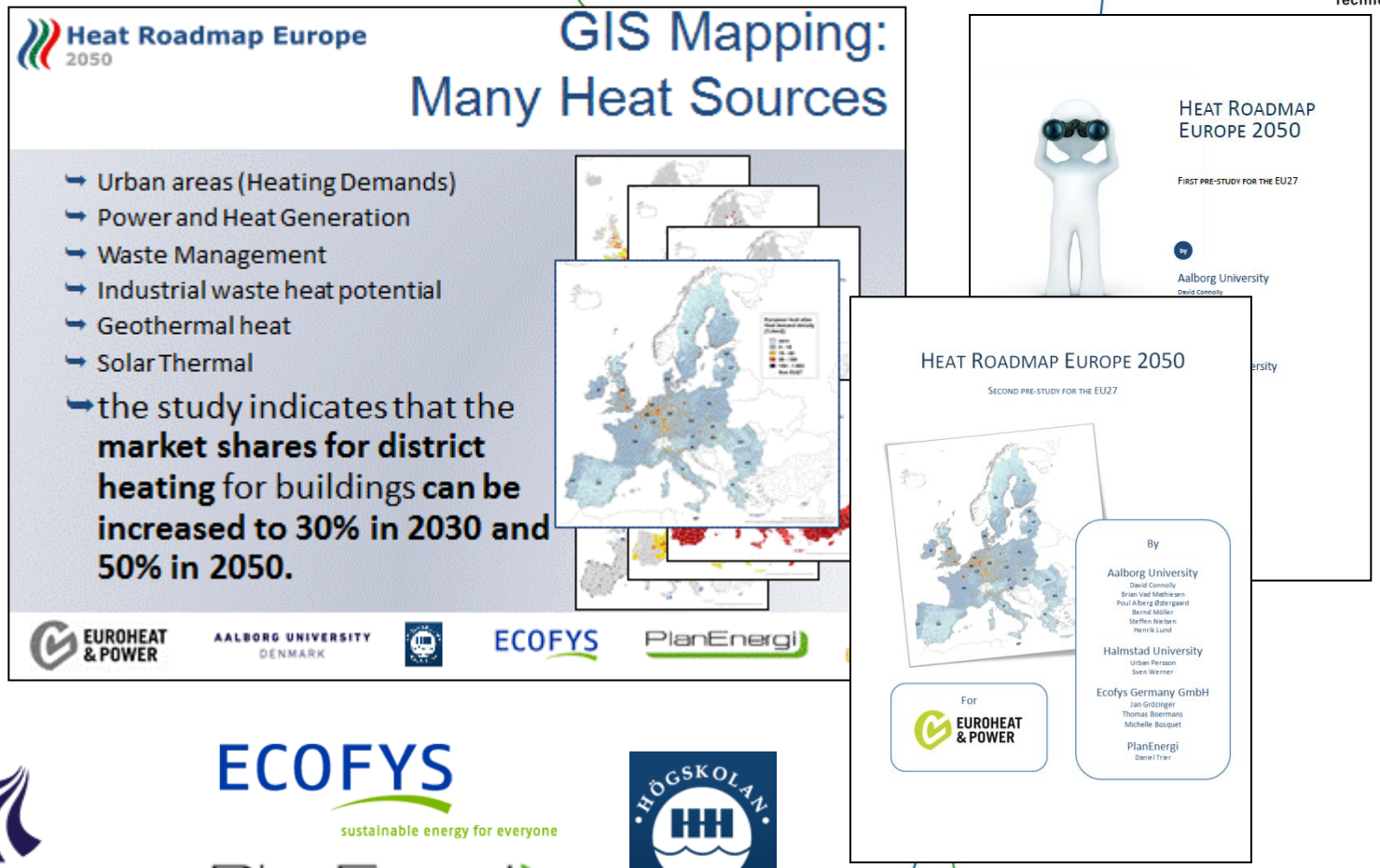




AALBORG UNIVERSITY
DENMARK


Energy efficiency / temperature level
1G: STEAM
Steam system, steam pipes in concrete ducts
2G: IN SITU
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
3G: PREFABRICATED
Pre-insulated pipes
Industrialised compact substations (also with insulation)
Metering and monitoring
4G: 4th GENERATION
Low energy demands
Smart energy (optimum interaction of energy sources, distribution and consumption)
2-way DH
4DH
4th Generation District Heating Technologies and Systems
Temperature level
< 200 °C
> 100 °C
< 100 °C
<50-60 °C (70 °C)
Energy efficiency
District heating grid
Large scale solar
Biomass CHP Biomass
Industry surplus
Heat storage
CHP coal CHP oil
Coal Waste
Steam storage
Coal Waste
Local District Heating
Heat storage
CHP waste CHP coal CHP oil
Gas, Waste Oil, Coal
District Heating
Seasonal heat storage
Large scale solar
Geothermal
PV, Wave Wind surplus Electricity
Heat storage
Industry surplus
CHP waste incineration
District Heating
Future energy source
Biomass conversion
2-way District Heating
CHP biomass
District cooling grid
Cold storage
Centralised district cooling plant
Centralised heat pump
Also low energy buildings
District Heating
Development (District Heating generation) / Period of best available technology
1G / 1880-1930
2G / 1930-1980
3G / 1980-2020
4G / 2020-2050
A

# Heat Roadmap Europe




AALBORG UNIVERSITY
DENMARK

ECOFYS
sustainable energy for everyone

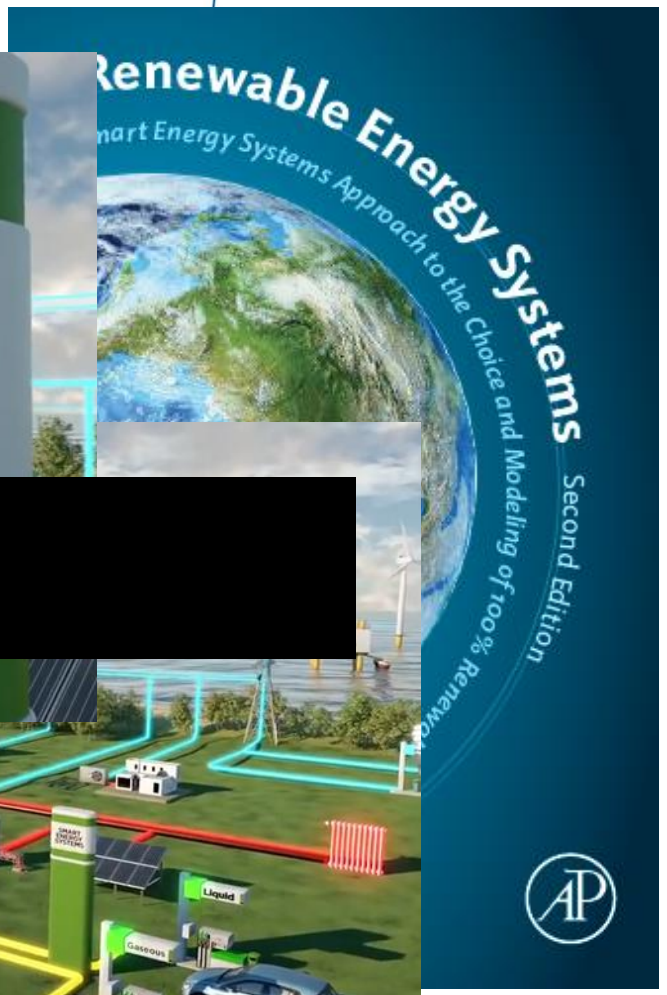
PlanEnergi

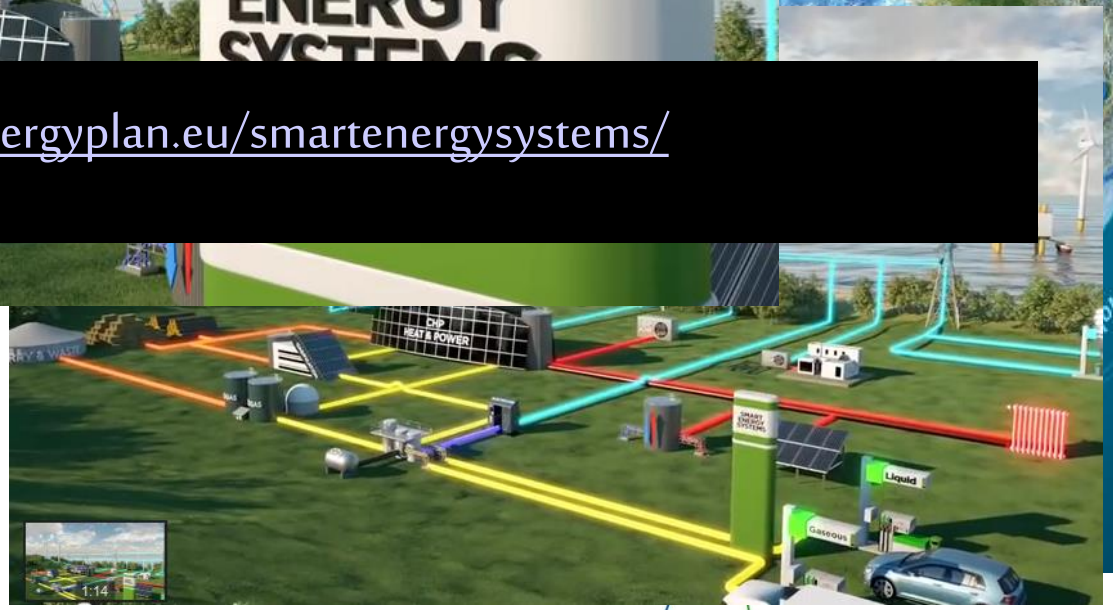
HÖGSKOLAN HALMSTAD

4DH
4th Generation District Heating Technologies and Systems

# Smart Energy Systems


www.energyplan.eu/smartenergysystems/



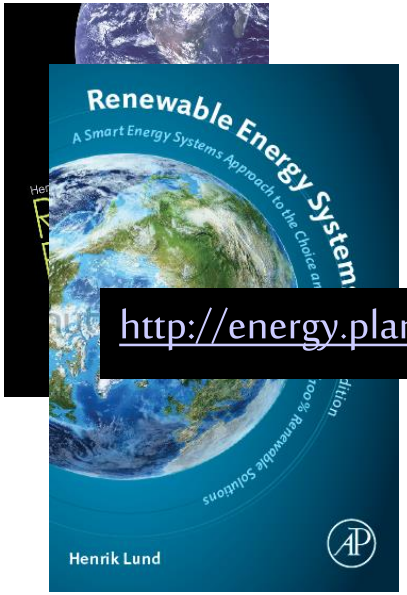

AALBORG UNIVERSITY
DENMARK

# More information:

www.henriklund.eu

www.4DH.dk

4DH
4th Generation District Heating Technologies and Systems

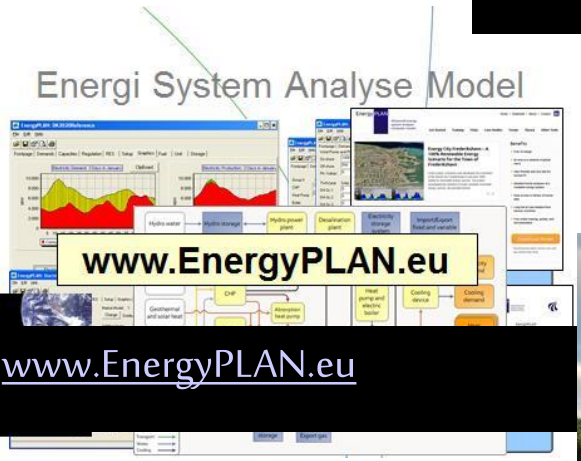



http://energy.plan.aau.dk/book.php

www.energyplan.eu/SmartEnergyEurope



www.heatroadmap.eu




www.EnergyPLAN.eu


www.energyplan.eu/smartenergysystems/

AALBORG UNIVERSITY
DENMARK

4DH
4th Generation District Heating Technologies and Systems

reINVEST

Innovation Fund Denmark

CITIES
Centre for IT Intelligent Energy Systems