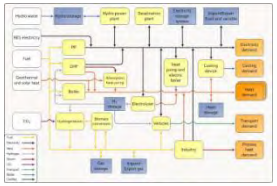
中丹区域能源和节能改造综合示范项目专家研讨会

The Sino-Danish Expert Panel Workshop on District Heating and Energy Efficiency Improvement

20 March 2019

Danish Energy Agency



4DH
4th Generation District Heating Technologies and Systems

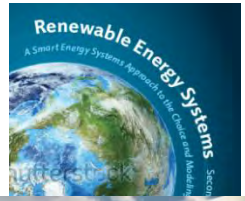
# District Heating
# 第四代区域供暖技术
## and The design of affordable Future Renewable Energy Systems
## 平价可再生能源系统的设计


Henrik Lund

Professor in Energy Planning

Aalborg Universitet

奥尔堡大学能源规划教授



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# Smart Energy Europe 欧洲智慧能源

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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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欧洲智慧能源：关于欧盟实现100%可再生能源体系情景的技术及经济影响评估
(2016年发表于可再生和和持续能源综述期刊)

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ABSTRACT

www.EnergyPLAN.eu/SmartEnergyEurope

- Report Online 在线报告
- Paper Published 发表文献

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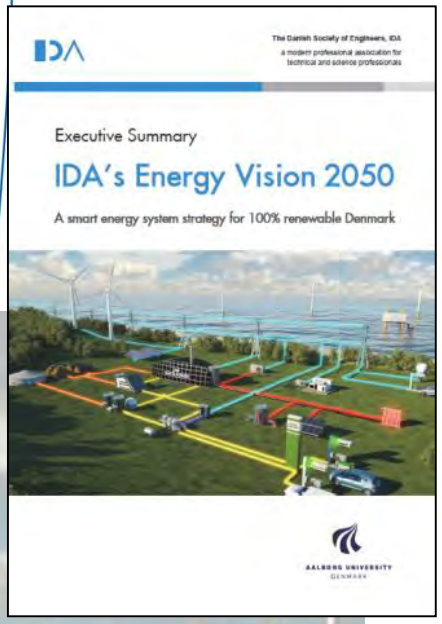
# Smart Energy Systems
# 智慧能源系统





# Smart Energy Systems智慧能源系统

## The key to cost-efficient 100% Renewable Energy

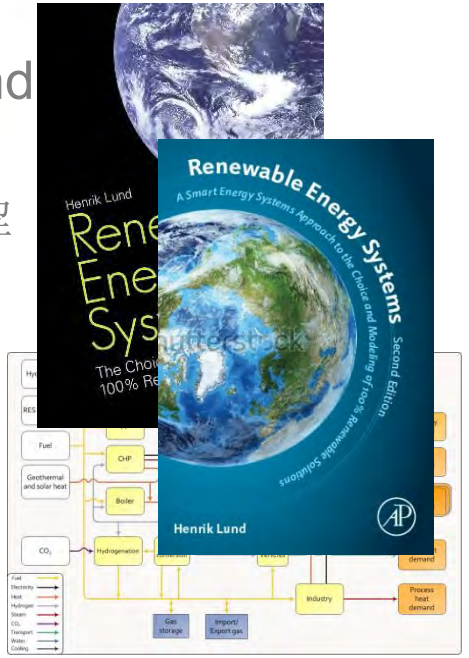
## 实现具有成本效益的100%可再生能源体系的关键点

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

专注可再生电力生产（智能电网）的电力存储和灵活供给解决方案

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

将可再生电力看作智能能源系统的一部分，包括采暖、工业、天然气和交通，可以找到更便宜和更好的解决方案。

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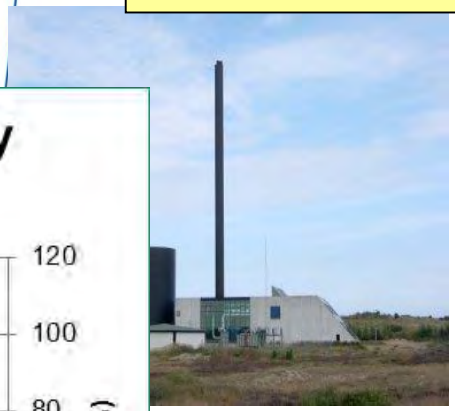
**Power-to-Heat**
**热电联产**

**Power-to-Gas燃气发电**
**Power-to-Transport电力交通**

# nergy Storage 储能

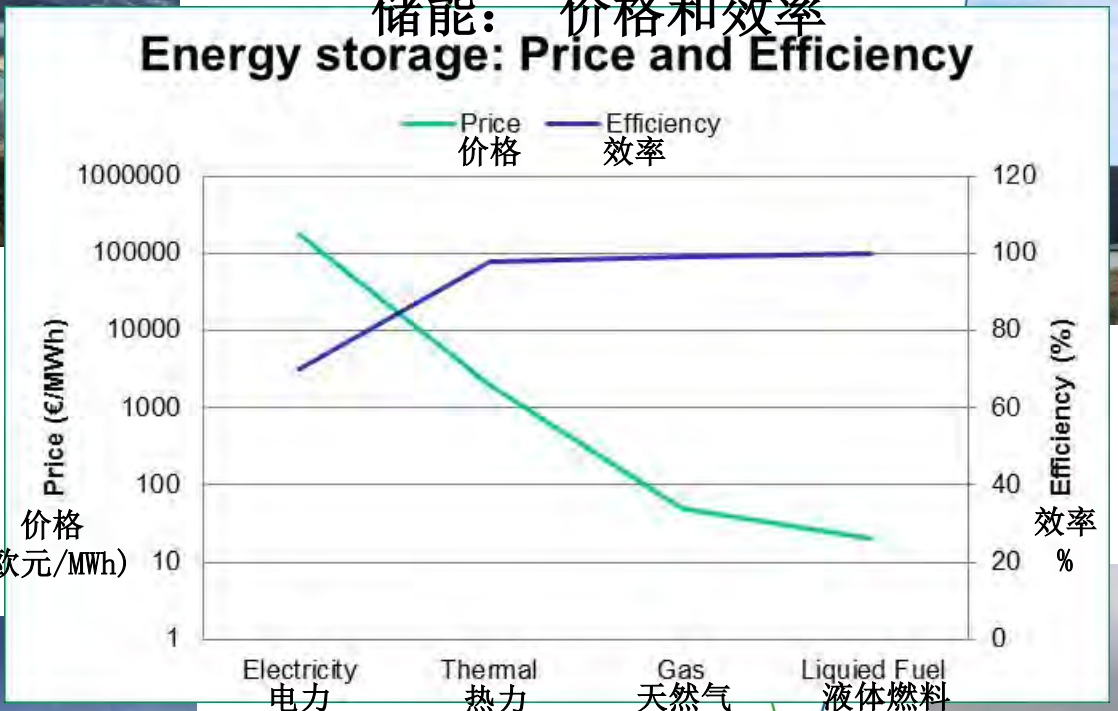
**Pump Hydro Storage抽水蓄能电站**
**175 €/kWh**
**(Source: Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits. Electric Power Research Institute, 2010)**

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



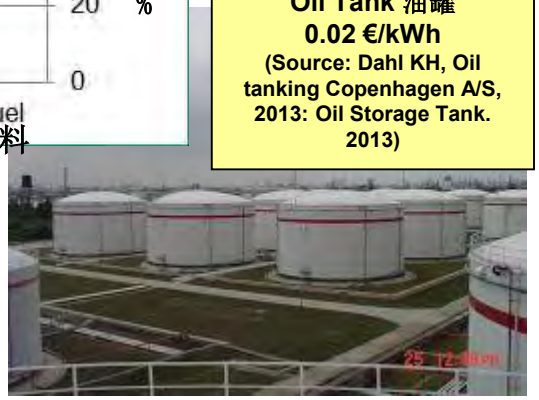
## 储能： 价格和效率

## Energy storage: Price and Efficiency



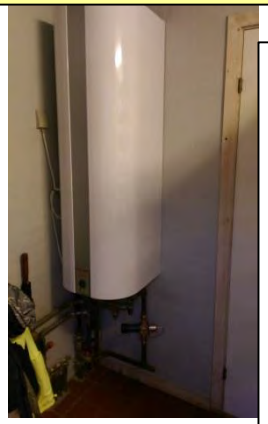

**Natural Gas Underground Storage**
**天然气地下储存**
**0.05 €/kWh**
**(Source: Current State Of and Issues Concerning Underground Natural Gas Storage. Federal Energy Regulatory Commission, 2004)**

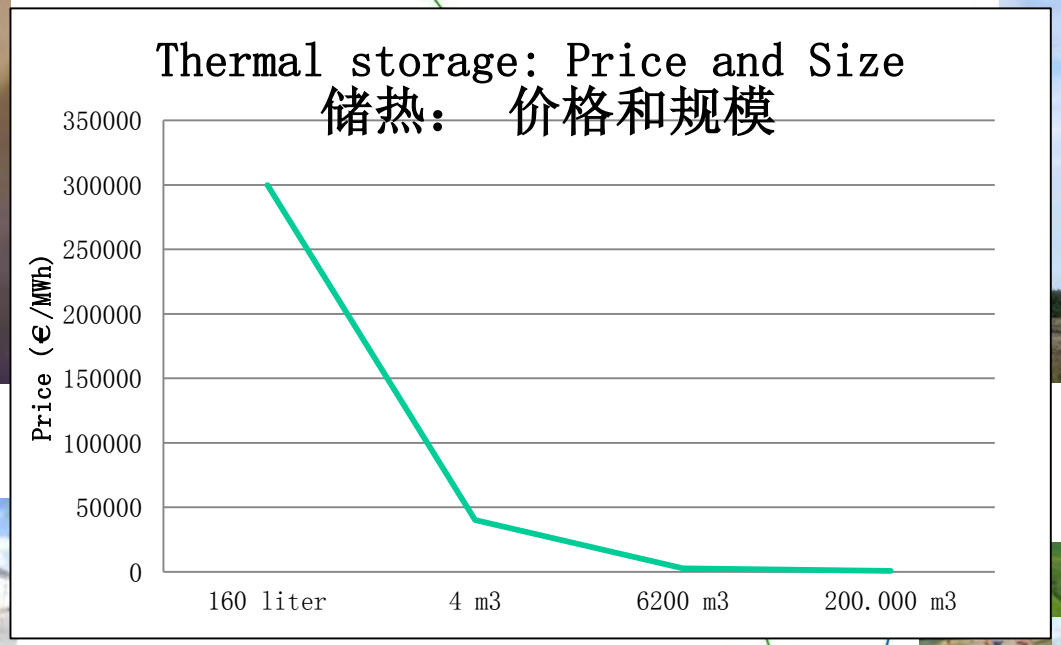
**Oil Tank 油罐**
**0.02 €/kWh**
**(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)**



# Thermal Storage储热

**0.16 m3 Thermal Storage**
**0.16立方储热设施**
**300.000 €/MWh**
**(Private house: 160 liter for 15000 DKK)**






**6200 m3 Thermal Storage**
**6200立方储热设施**
**2500 €/MWh**
**(Skagen: 6200 m3 for 5.4 mio. DKK)**

**4 m3 Thermal Storage**
**4立方储热设施**
**40,000 €/MWh**
**(Private outdoor: 4000 m3 for 50,000 DKK)**

**200,000 m3 Thermal Storage**
**20万立方储热设施**
**500 €/MWh**
**(Vojens: 200,000 m3 for 30 mio. DKK)**

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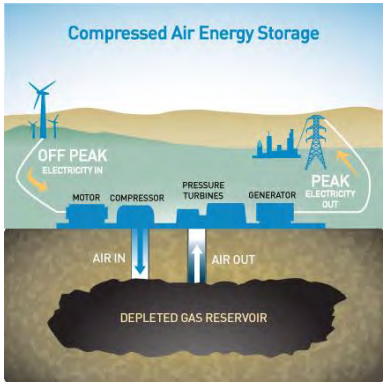
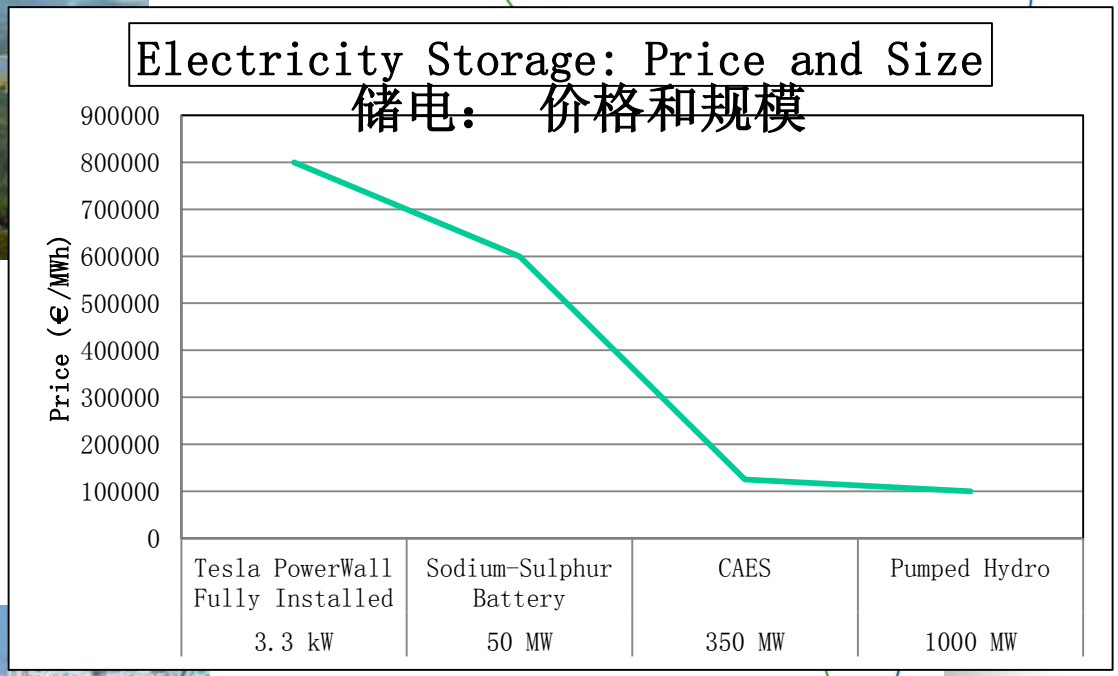
# ectricity Storage

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

**Compressed Air Energy Storage**
**压缩空气储能站**
**125 €/kWh**
**(Source: http://www.sciencedirect.com/science/article/pii/S0196890409000429)**




## Electricity Storage: Price and Size
## 储电： 价格和规模




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

**Tesla PowerWall**
**特斯拉蓄能板**
**800 €/kWh**
**(Source: Dahl KH, Oil tanking Copenhagen A/S, 2013: Oil Storage Tank. 2013)**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Sustainable Energy Planning and Management

# Energy Storage and Smart Energy Systems

**Henrik Lund[1], Poul Alberg Østergaard[1], David Connolly[2], Iva Ridjan[2], Brian Vad Mathiesen[2], Frede Hvelplund[1], Jakob Zinck Thellufsen[1], Peter Sorknæs[1]**

[1] *Aalborg University, Skibbrogade 5, 9000 Aalborg, Denmark*

*Henrik Lund, Poul Østergaard, David Connolly, Iva Ridjan, Brian Mathiesen, Frede Hvelplund, Jakob Thellufsen, Peter Sorknæs*

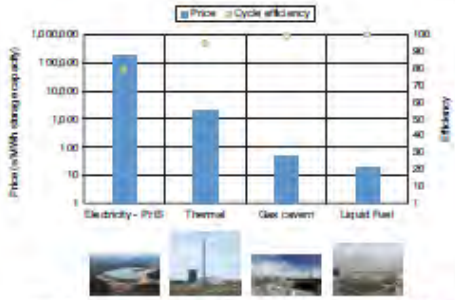



Figure 1: Investment cost and cycle efficiency comparison of electricity, thermal, gas and liquid fuel storage technologies. See assumptions, details and references in Appendix 1.

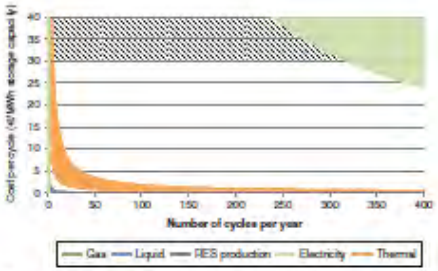



Figure 2: Annualized investment cost per use-cycle vs annual numbers of use-cycles. In the diagram the cost is also benchmarked against the cost of producing renewable energy, here shown for a wide cost span by grey (extension along horizontal axis is for presentation only; there is no cyclic dependence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

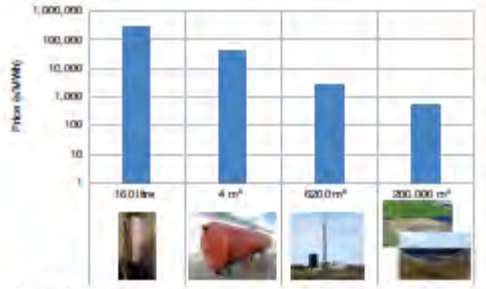



Figure 3: Investment cost comparison of different sizes of thermal energy storage technologies. The sizes correspond to storages for a dwelling, a larger building, a CHP plant and a solar DH system (see Footnote 2). See assumptions, details and references in Appendix 1.

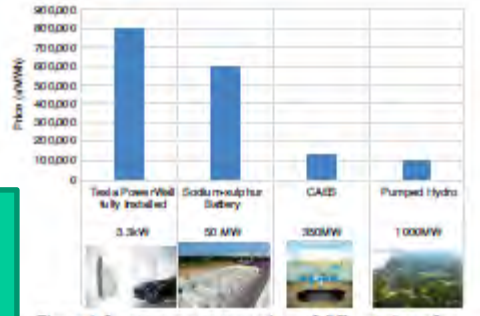
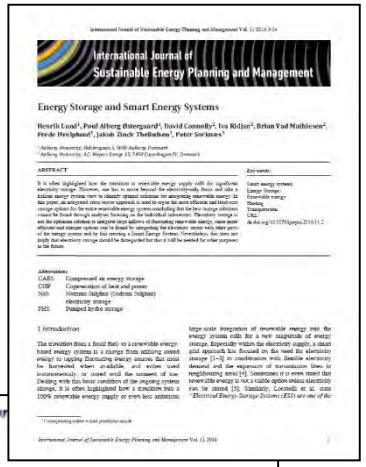



Figure 4: Investment cost comparison of different sizes of electricity energy storage technologies. See assumptions, details and references in Appendix 1.

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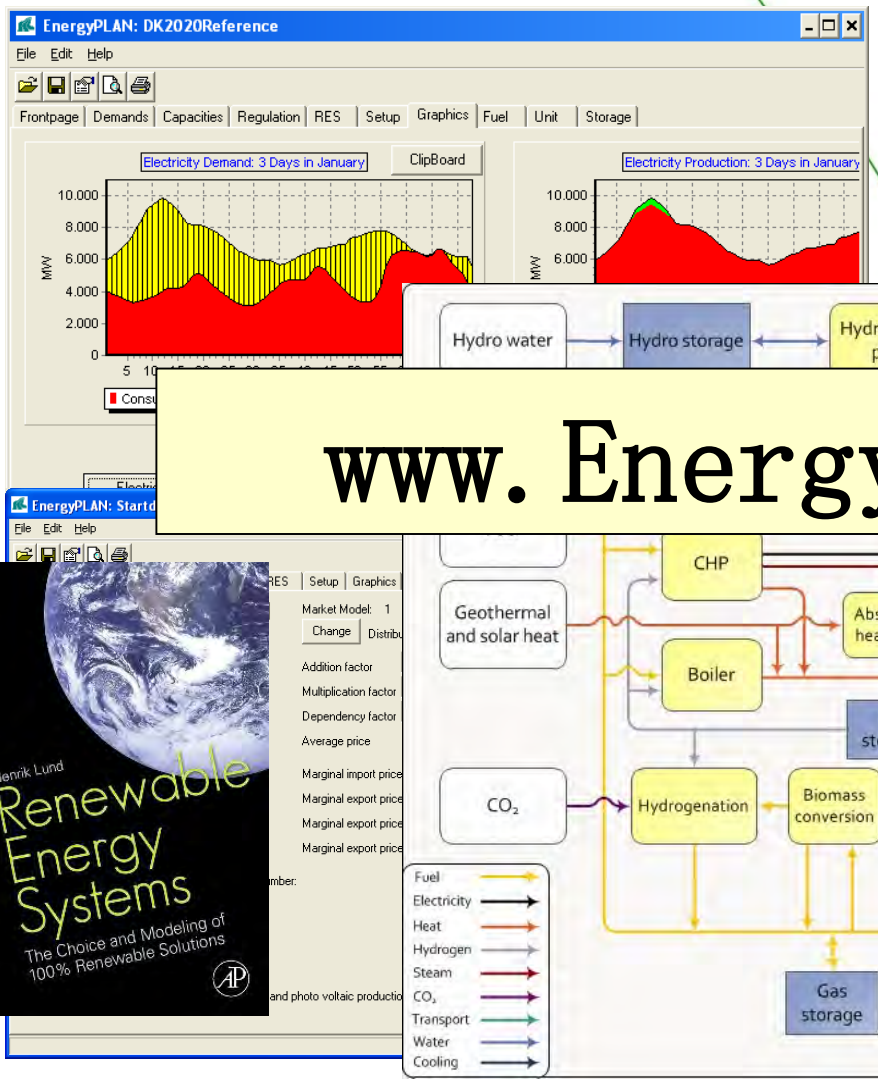
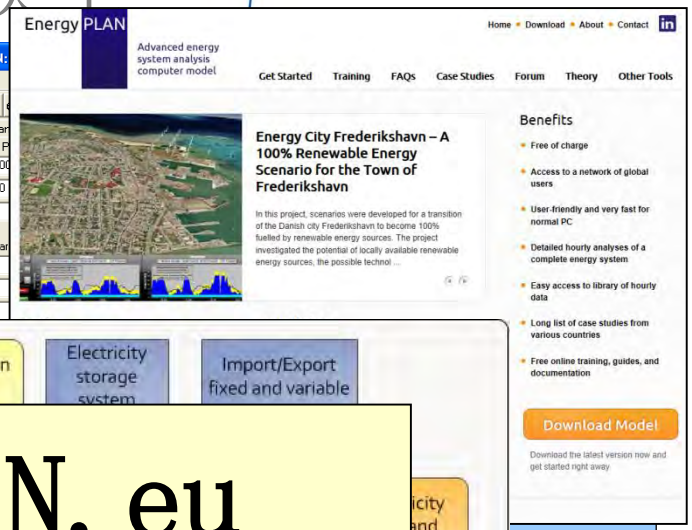
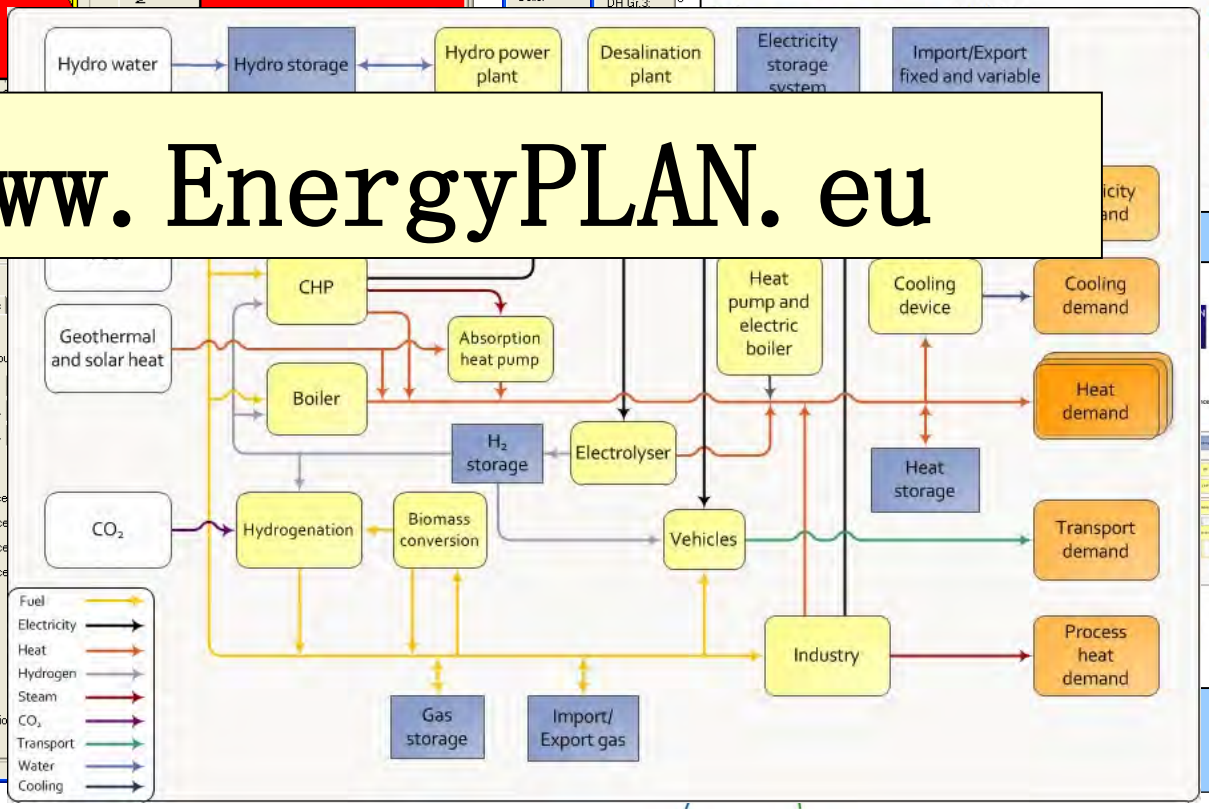
# Energy System Analysis Model

## 能源系统分析模型

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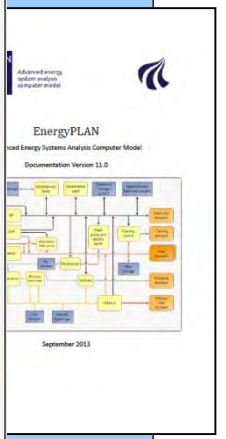

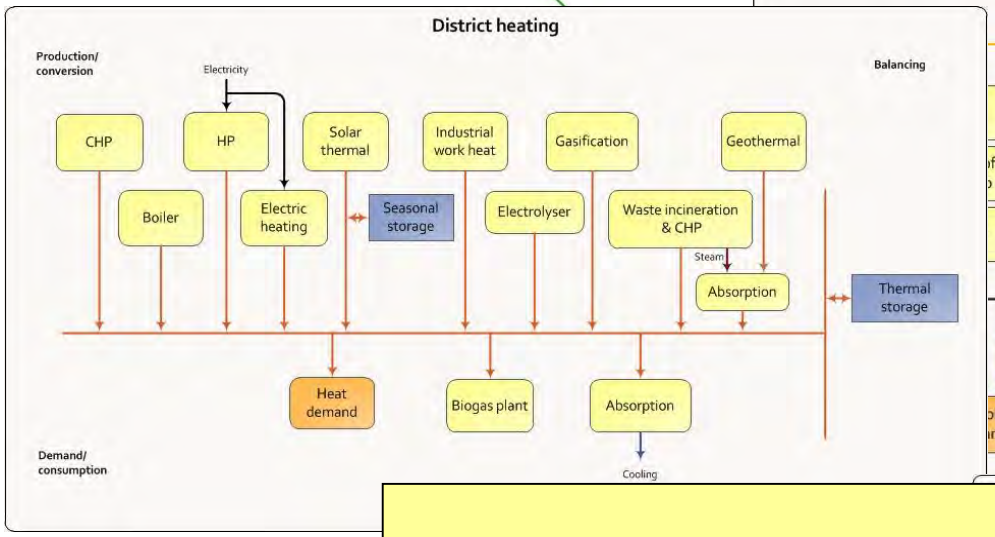


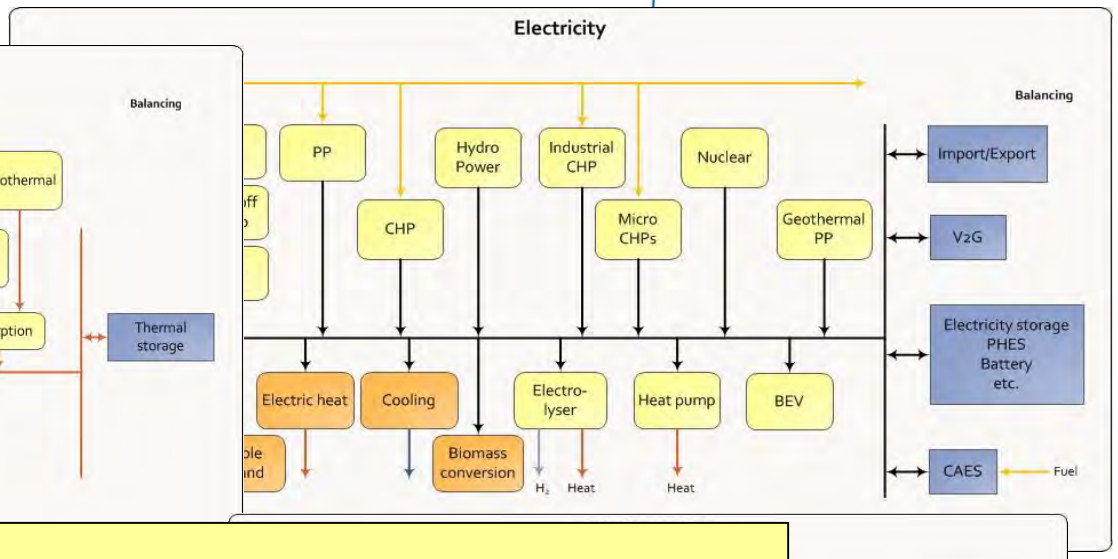


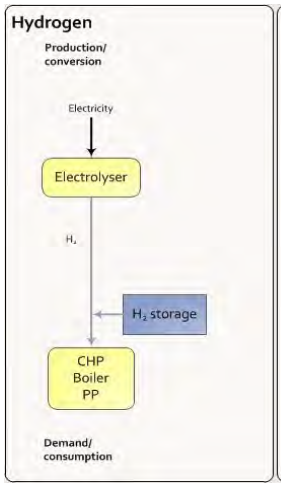


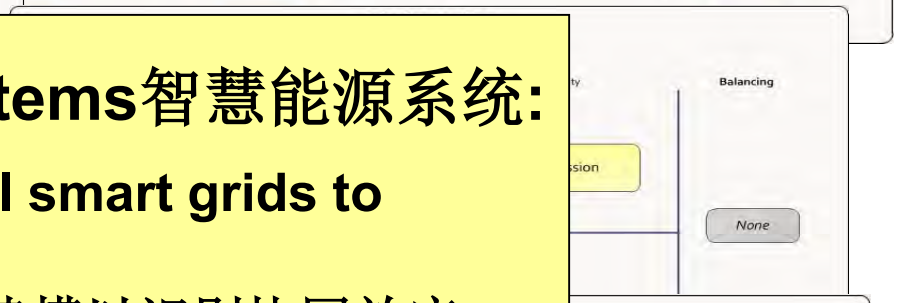


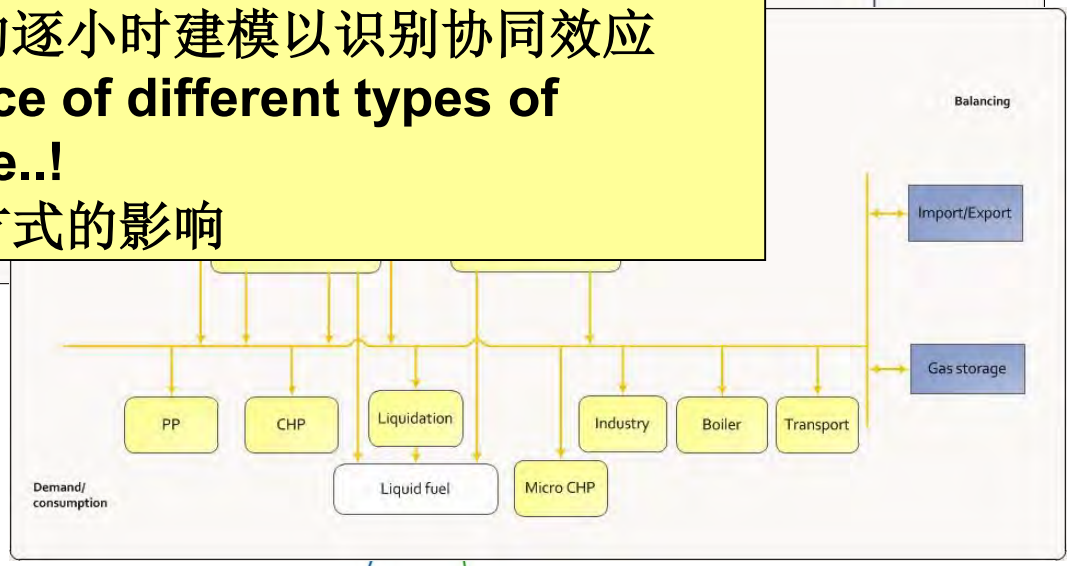


# Smart Energy Systems智慧能源系统:

**Hourly modelling of all smart grids to identify synergies!**

**所有智能电网的逐小时建模以识别协同效应**

**… and influence of different types of energy storage..!**

**以及不同储能方式的影响**

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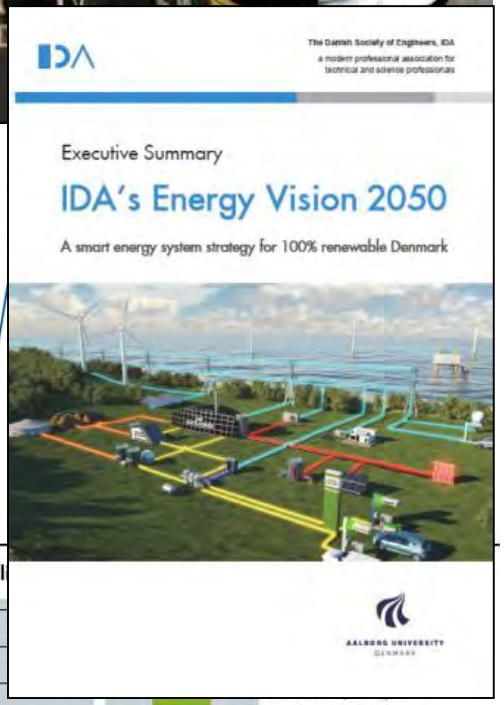
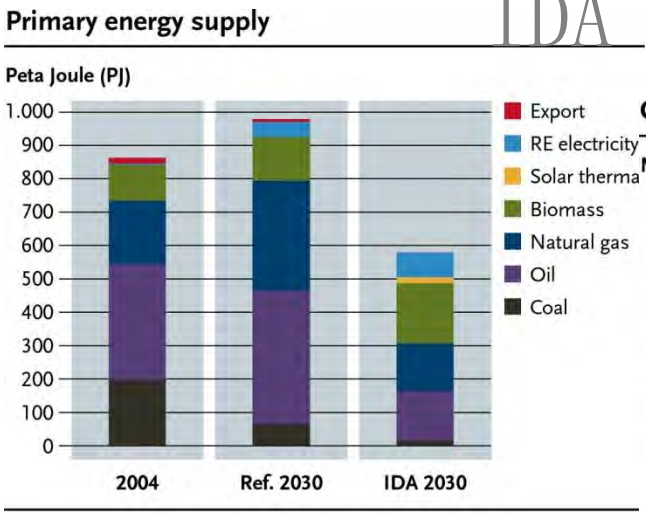
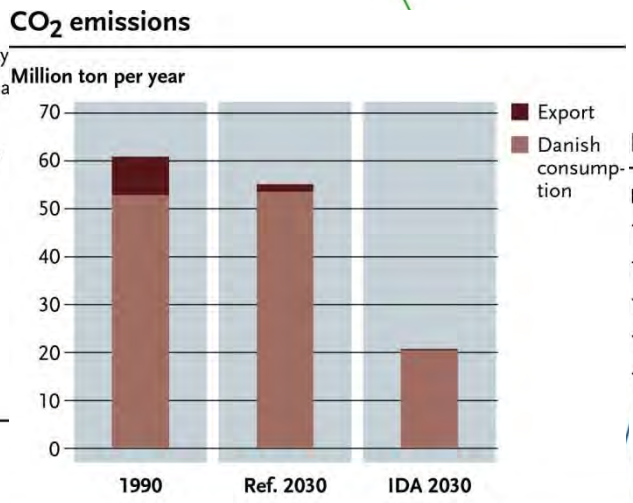
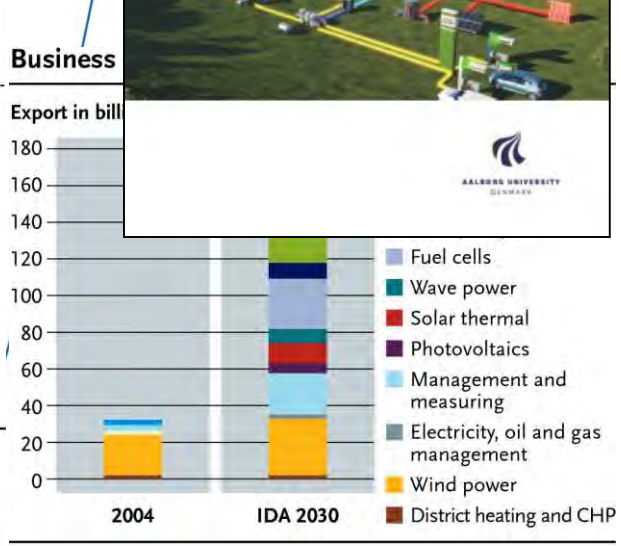
# IDA Energiplan 2030

## IDA 能源计划2030

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# Energy Storage Capacities in Denmark

丹麦储能水平

丹麦石油储备约 50TWh

Danish Oil Storage
~50 TWh

丹麦天然气储备约11TWh

Danish Gas Storage
~11 TWh

丹麦储热约0.09TWh

Danish
Thermal Storage
~0.090 TWh

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# 2050丹麦100%可持续能源储备能力

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

丹麦石油储备约 50TWh

Danish Oil Storage
~50 TWh

丹麦储氢能约0.550TWh

丹麦天然气储备约11TWh

Danish Gas Storage
~11 TWh

Danish
$H_2$ Storage
~0.550 TWh

丹麦储热约0.200TWh

Danish
Thermal Storage
~0.200 TWh

Danish
Electricity Storage
~0.015 TWh

丹麦储电约0.015TWh

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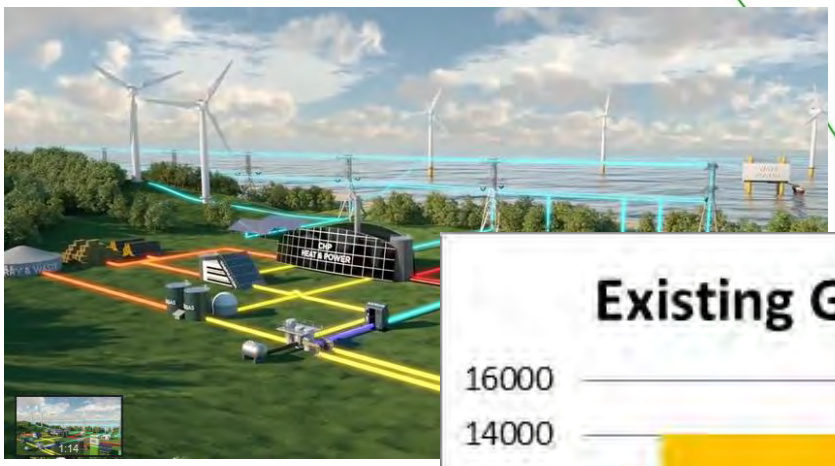
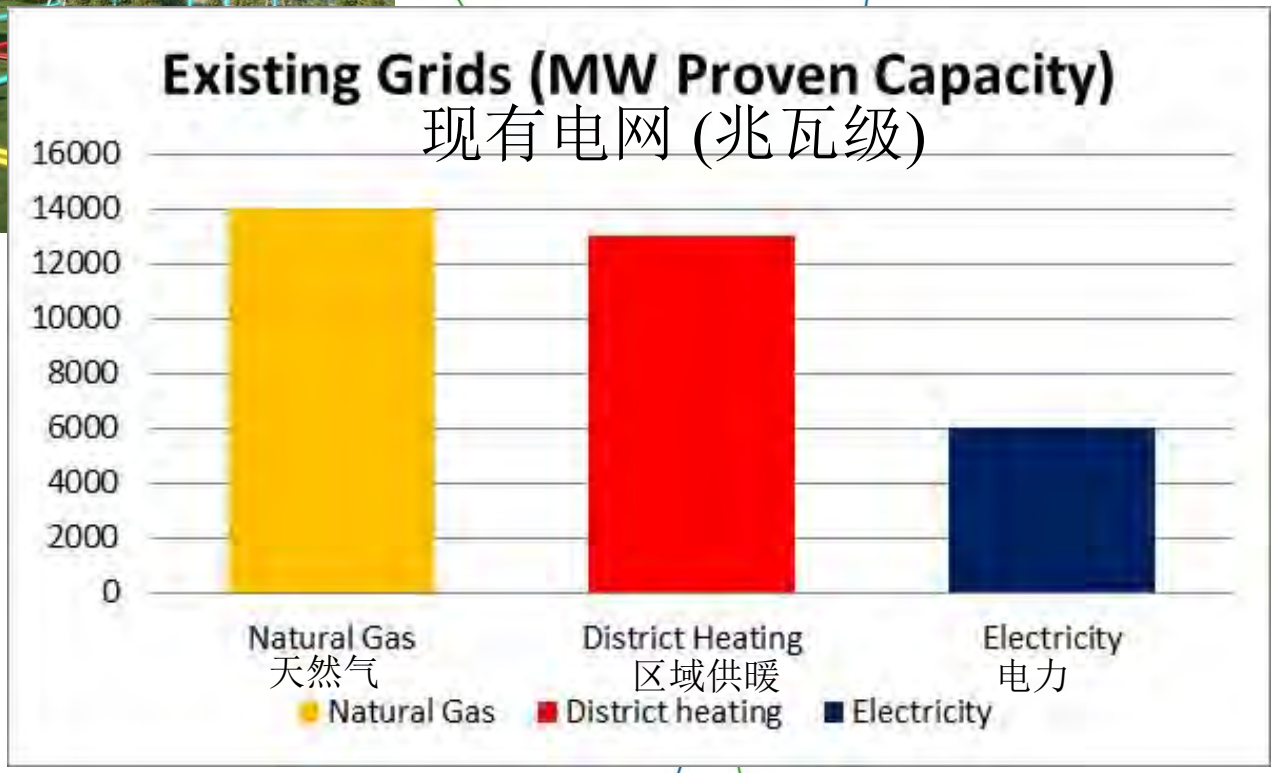
# Eksisterende distributionsnet 现有电网



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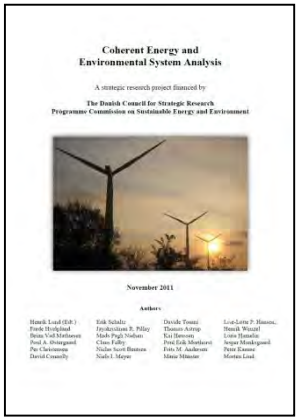
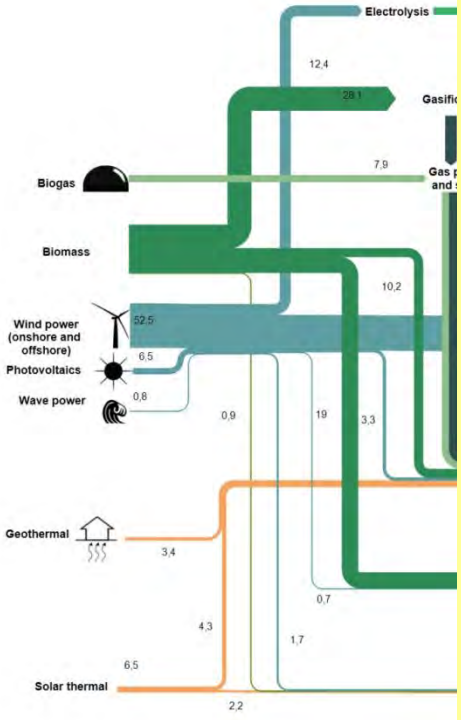
# CEESA Project 2011/2012

# CEESA项目 2011/2012




*Transport交通*:
Electric vehicles is best from an energy efficient point of view. But gas and/or liquid fuels is needed to transform to 100%.
从能源效率的角度来看，电动汽车是最好的。但是气体和/或液体燃料转化需达100%。

*Biomass生物质*:
.. is a limited resource and can not satisfy all the transportation needs.
是一种有限的资源，不能满足所有的运输需求

*Consequence推论*
… Electricity from Wind (and similar resources) needs to be converted to gas and liquid fuels in the long-term perspective…
从长期来看，风（和类似资源）的电力需要转化为天然气和液态燃料

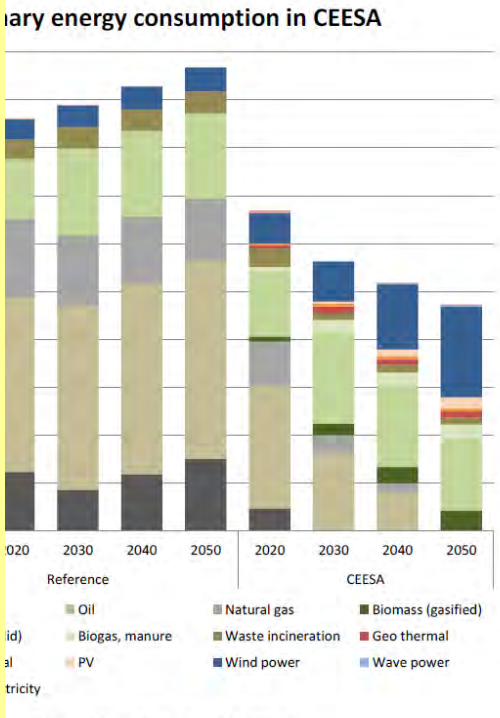



Figure 2: Primary Energy Supply in CEESA.

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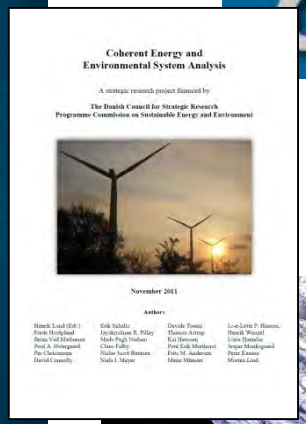
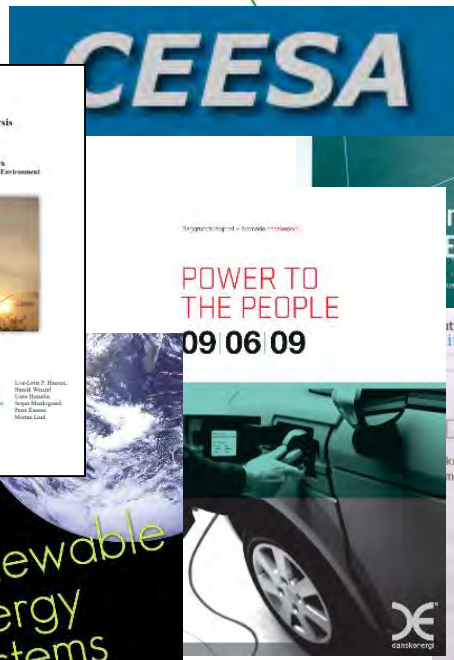
# Electro-fuels 电力燃料

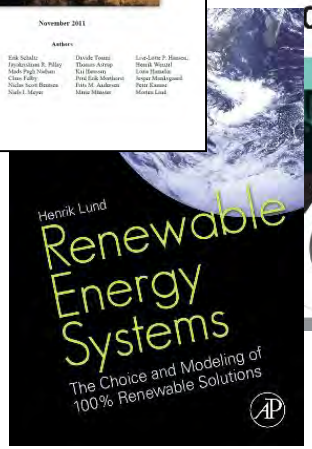
## 100% Renewable Energy 2050

## Power-to-Transportation

## 2050年实现100%可再生能源交通







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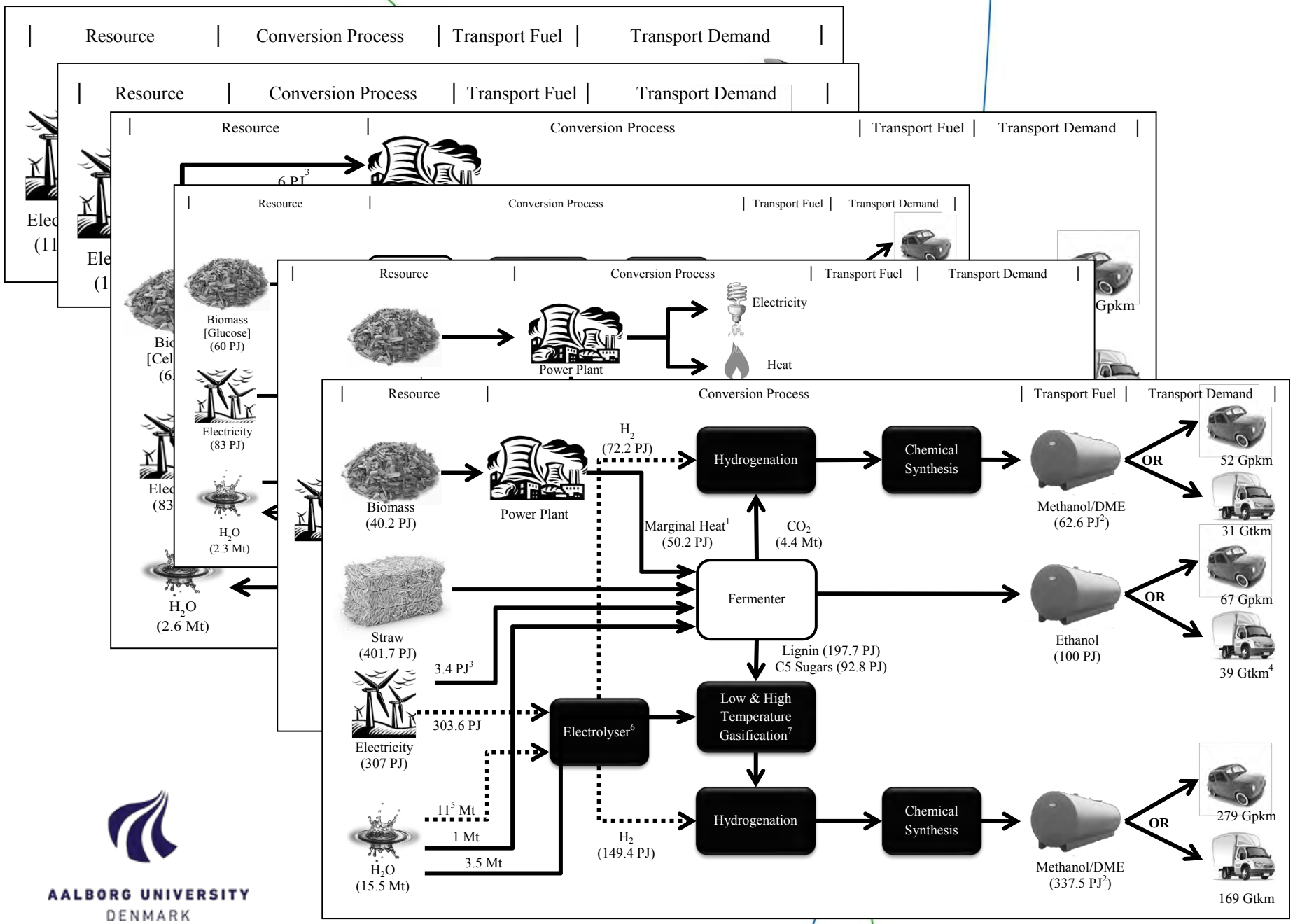


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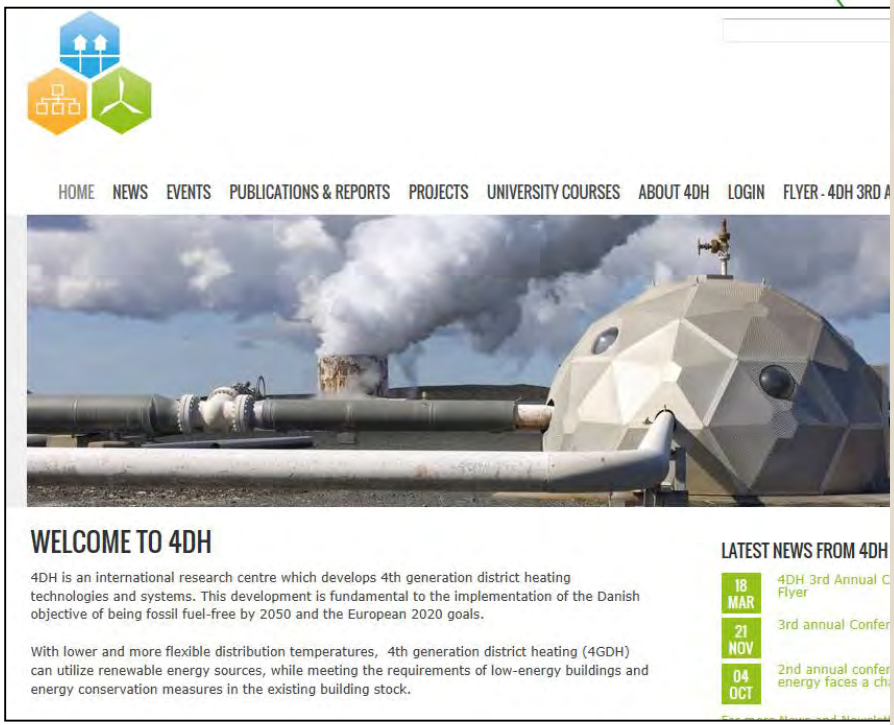
# www. 4DH. dk

# 4DH

**4th Generation District Heating Technologies and Systems**

4DH

第四代区域供暖技术及系统





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#SmartEnergySystems & #4DH

4DH

4th Generation District Heating Technologies and Systems

4DH

第四代区域供暖技术及系统

# Three pillars三大支柱

## Supply供应:

Low temperature District heating

低温供暖

## Production生产:

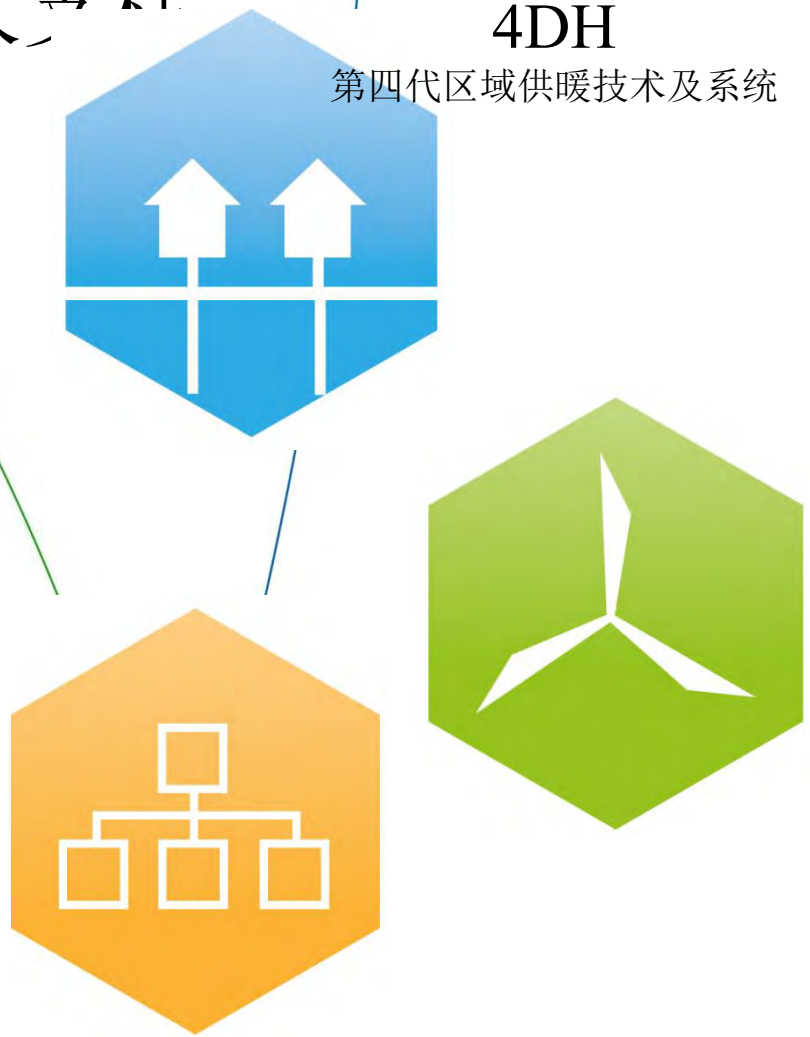
Renewable Systems Integration

可再生能源体系整合

## Organisation组织:

Planning and Implementation

规划和实施



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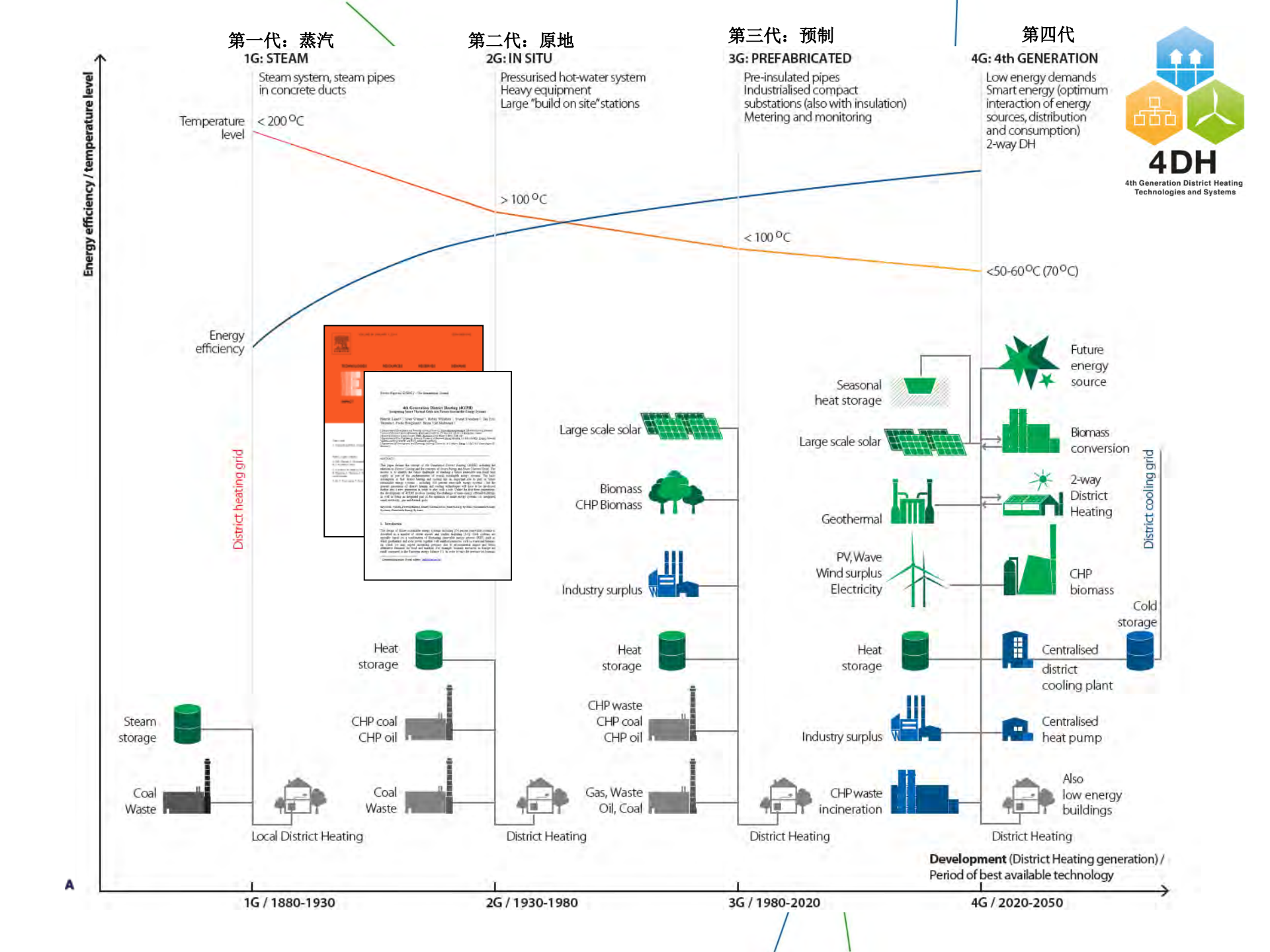
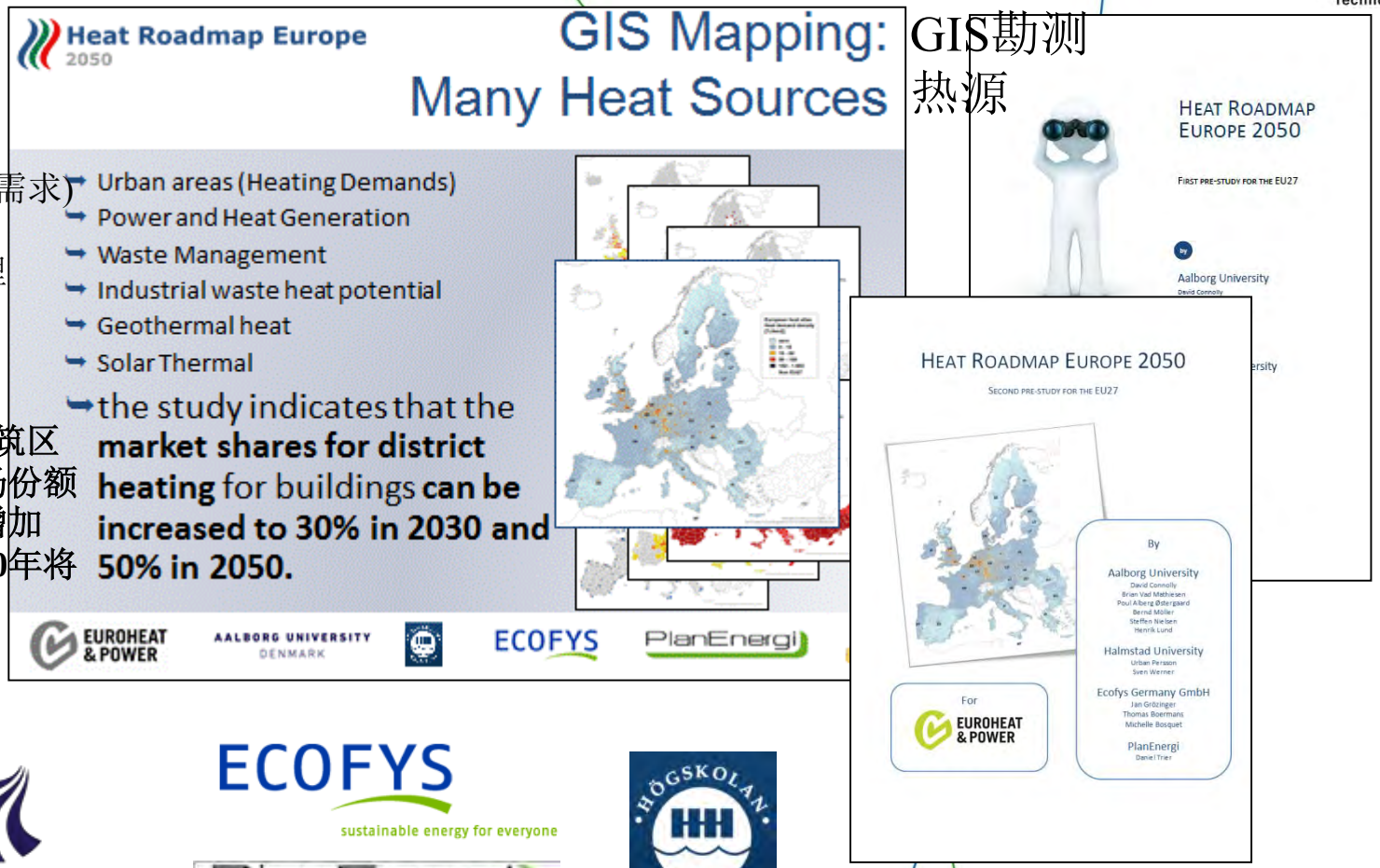

第一代：蒸汽
1G: STEAM
Steam system, steam pipes in concrete ducts
第二代：原地
2G: IN SITU
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
第三代：预制
3G: PREFABRICATED
Pre-insulated pipes
Industrialised compact substations (also with insulation)
Metering and monitoring
Energy efficiency / temperature level
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
Industry surplus
Heat storage
CHP waste incineration
District Heating
第四代
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
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
A
1G / 1880-1930
2G / 1930-1980
3G / 1980-2020
4G / 2020-2050

# Heat Roadmap Europe
# 欧洲供暖路线图

4DH
4th Generation District Heating Technologies and Systems




GIS勘测热源

- 城区 (供暖需求)
- 热电联产
- 废弃物管理
- 工业余热
- 地热
- 太阳能

**研究指出建筑区域供暖市场份额2030年将增加30%，2050年将增加50%**

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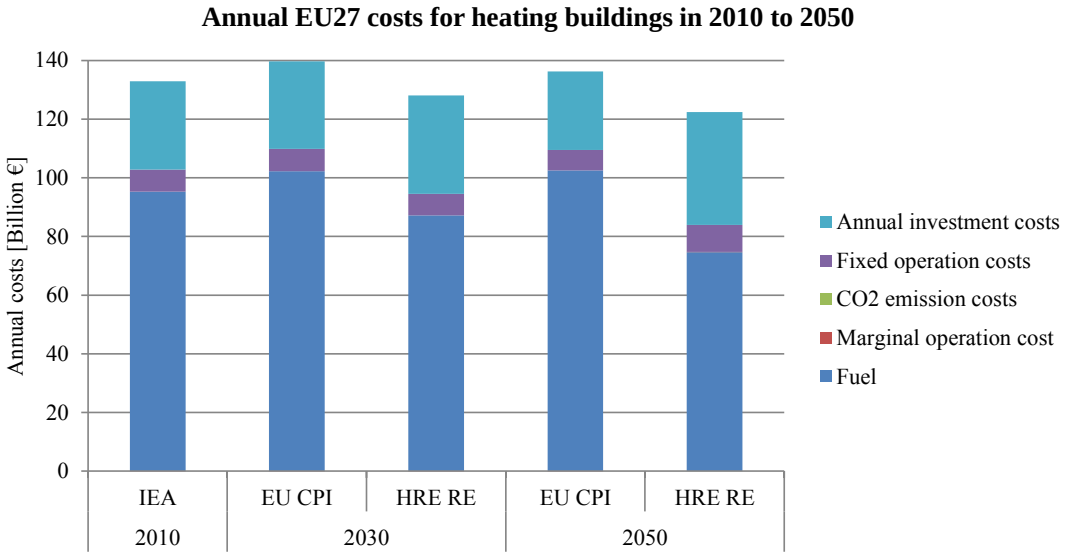
ECOFYS
sustainable energy for everyone

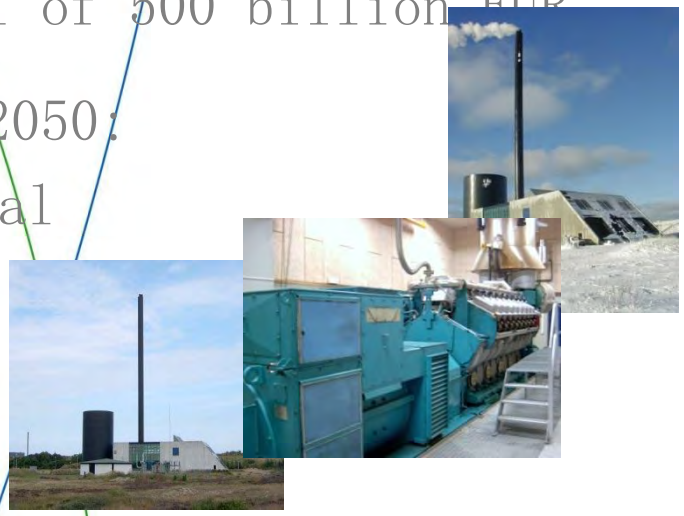
PlanEnergi

HÖGSKOLAN HALMSTAD

# Cost and Jobs:




- Saved fuel costs of annual approx. 30 Billion EUR in 2050
- In total cost are reduced by 14 Billion EUR in 2050
- Additional investments of a total of 500 billion EUR
- Additional jobs from to 2013 to 2050:
  8-9 million man-year in total
  Approx. 220,000 jobs.



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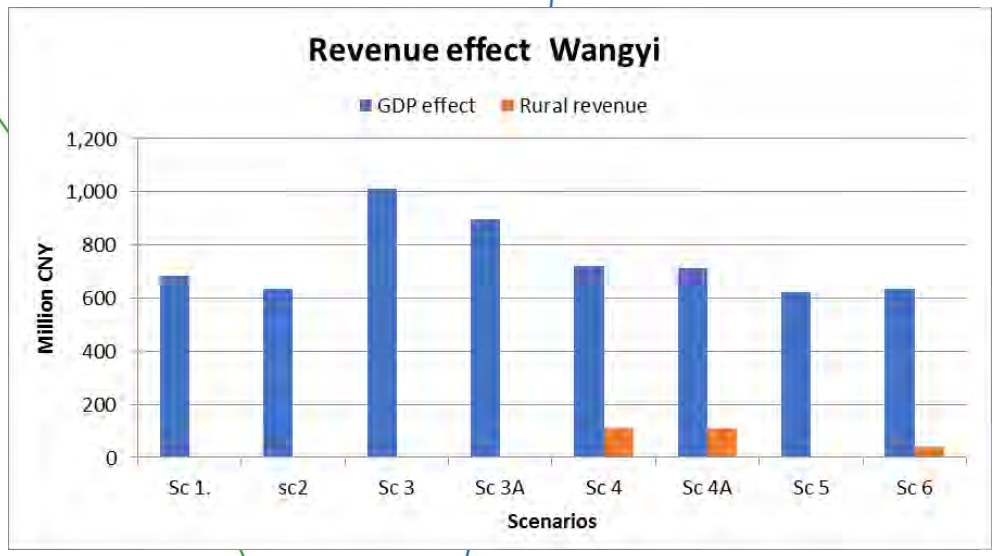
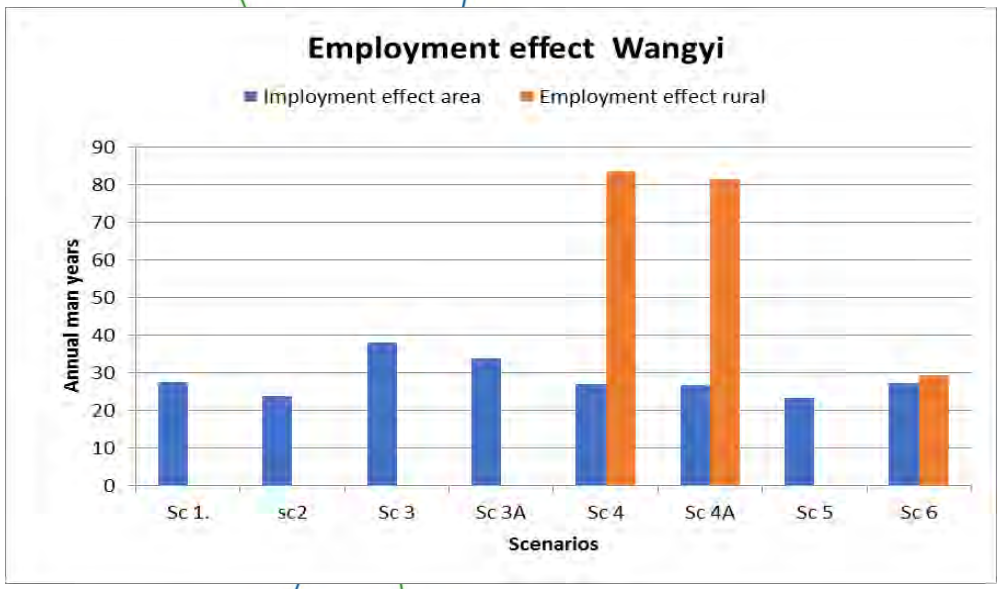
# GDP, Revenue and employment

- GDP calculated on the basis of reductions in import to the area
- Employment calculated on the assumption of 15 man year per one million CNY

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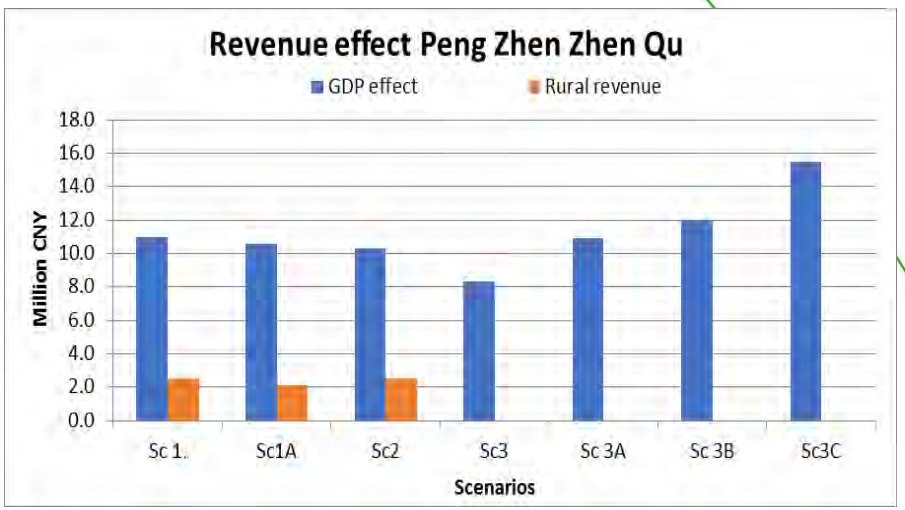
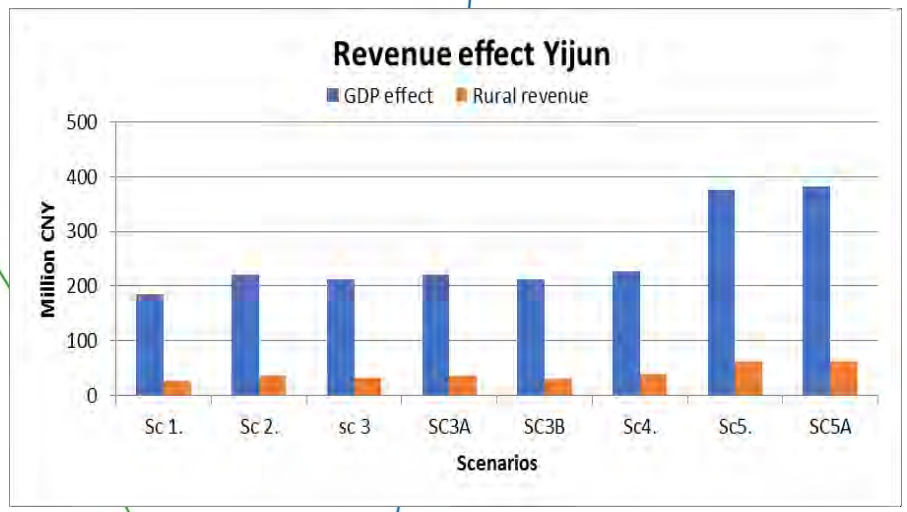
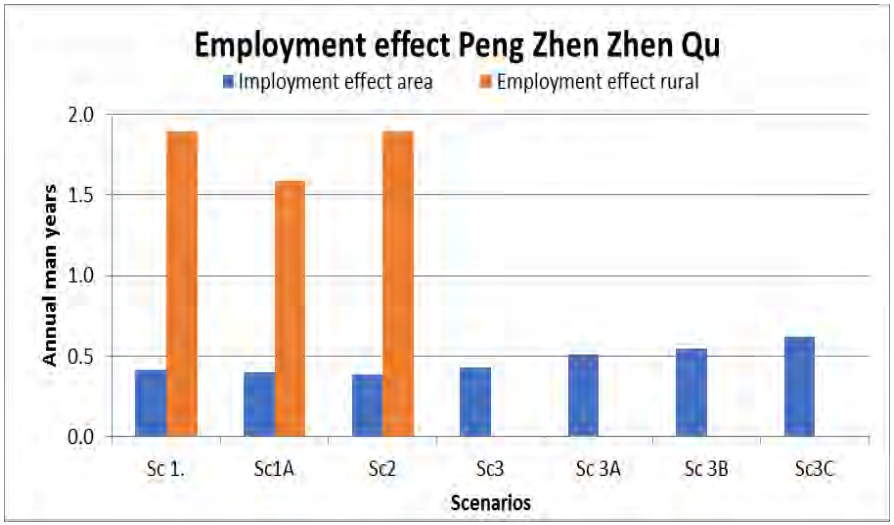
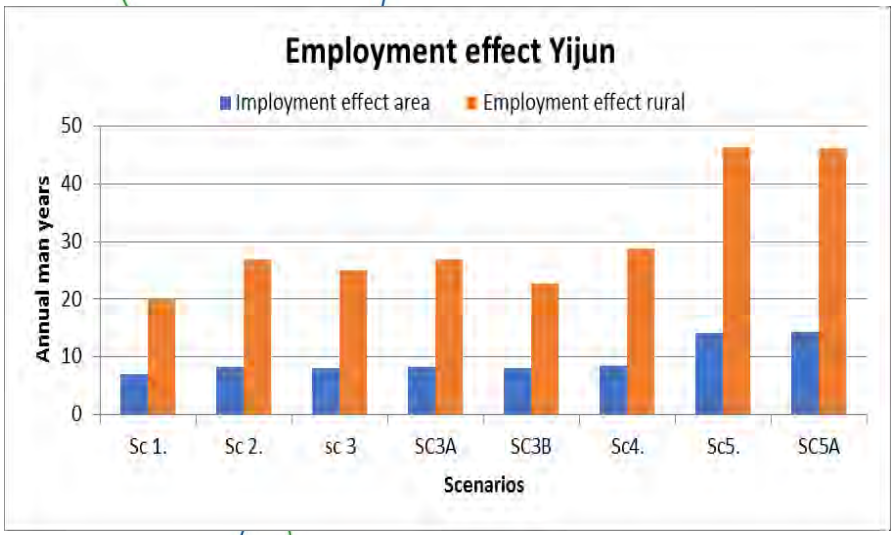
# GDP, Revenue and employment

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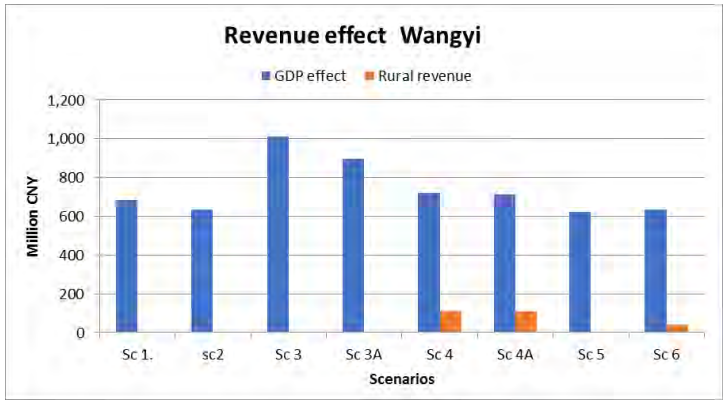
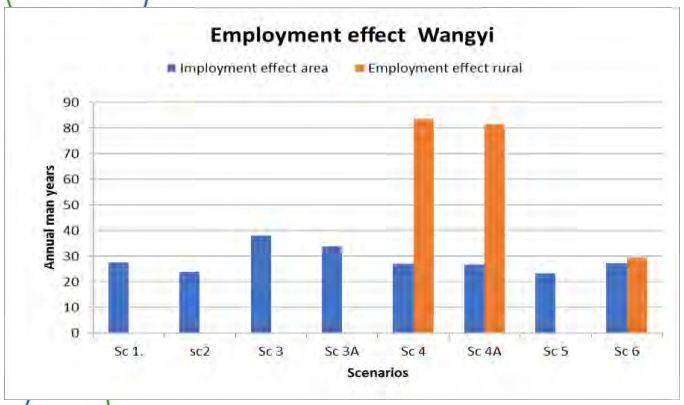
# Conclusion

District heating in Wangyi, Yijun and Peng Zhen Zhen Qu will

- decrease imports to the areas and
- increase economic activities and
- generate local jobs

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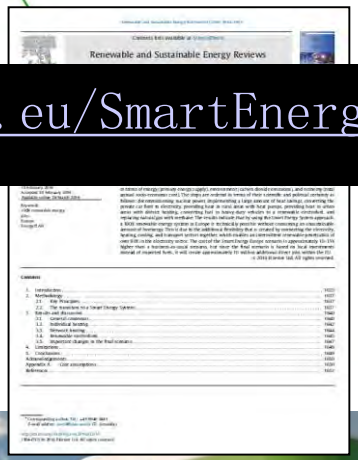
www.henriklund.eu

www.4DH.dk

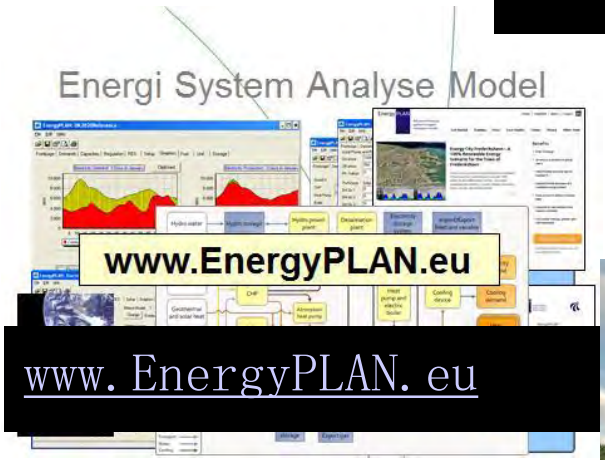
ore information更多信息:


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




www.energyplan.eu/SmartEnergyEurope


www.heatroadmap.eu




www.EnergyPLAN.eu


www.energyplan.eu/smartenergysystems/

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