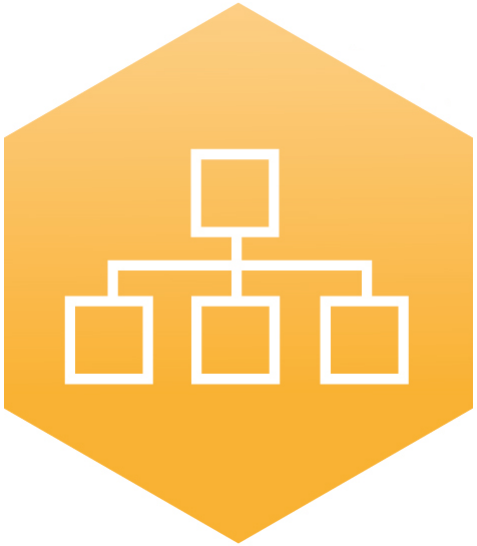
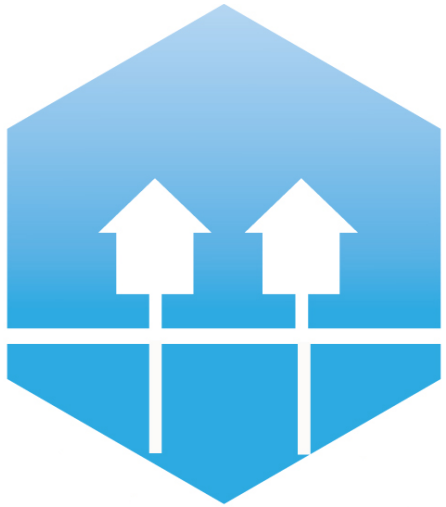
4th Generation District Heating Technologies and Systems
First PhD Seminar, 7 March 2013

Welcome





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4DH
4th Generation District Heating
Technologies and Systems

4DH

4th Generation District Heating Technologies and Systems

Introduction

The 4DH Research Centre:

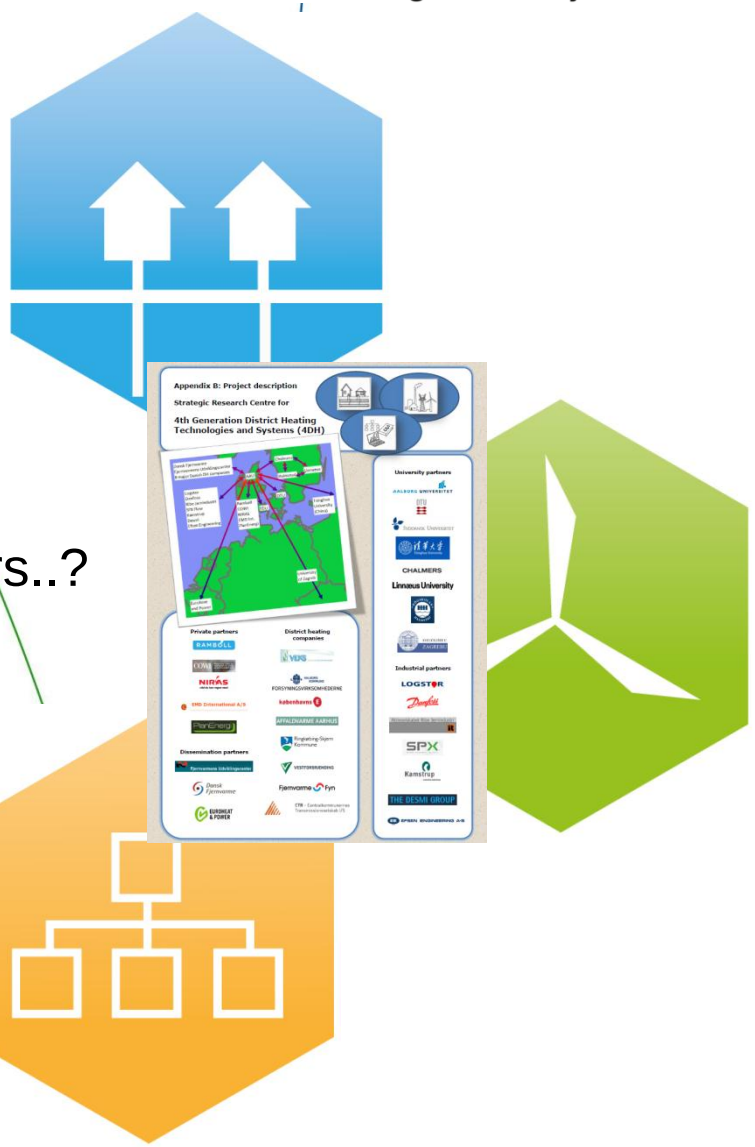
What and Who are 4DH ..?

4DH content and research:

What are we going to do in the next 6 years..?

4GDH concept:

First inputs for further discussions



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What and who are 4DH?

- Strategic Research Centre financed by the Danish Research Council and the partners
- Universities and Industry including manufactories, consultants and DH companies
- International partners

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The long-term Objective of Danish Energy Policy

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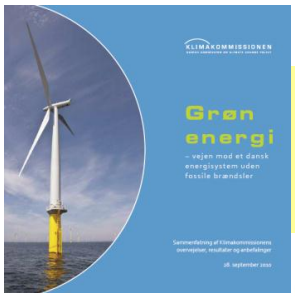
Expressed by former Prime Minister Anders Fogh Rasmussen in his opening speech to the Parliament in 2006 and in several political agreements since then:

To convert to 100% Renewable Energy

Prime minister 16 November 2008:
"We will free Denmark totally from fossil fuels like oil, coal and gas"



Prime minister 16 November 2008:
"… position Denmark in the heart of green growth"

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New Government September 2011

- 100% RES by 2050
- 100% RES for electricity and heating by 2035
- No coal on power plants and no oil for heating households by 2030
- 50% wind in electricity supply by 2020
- 40% CO2 reduction by 2020 compared to 1990

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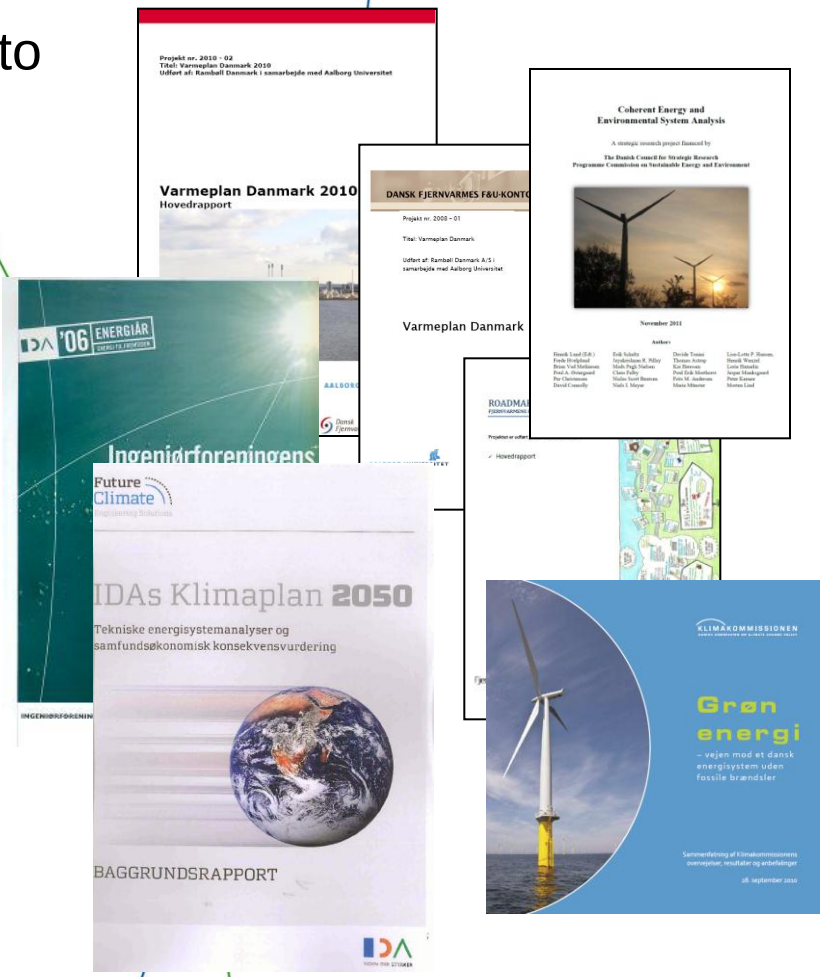
Background

District heating has an important role to play in future Sustainable Energy Systems:

- Energy efficiency
- Renewable energy and waste
- System integration of wind etc.

District heating technology has to be further developed (4GDH):

- Low energy buildings
- Low temperature sources
- Low Grid loses



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Aim and Objectives

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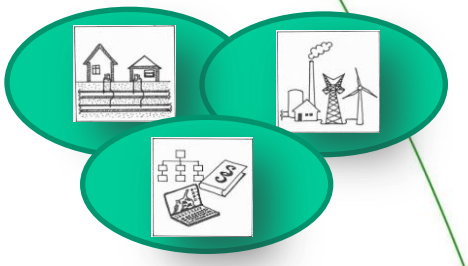
The **Aim** is to assist in the development of 4th Generation District Heating Technologies and Systems (4GDH).



Objectives:

- Scientific platform for research activities
- Societal understanding of the role of District Heating
- Further additional national and international projects

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Why 4th Generation ?

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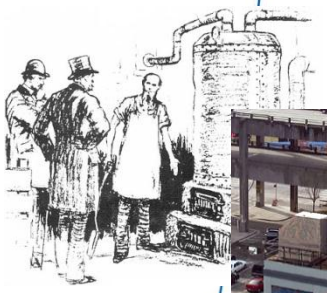

First Generation (1880-1930):

Steam as heat carrier. Is today in use in e.g. Manhattan, Paris and partly in Copenhagen.

Second Generation (1930-1970):

Pressurised hot water as heat carrier with temperature above 100 C.
Can be found today in older parts of current water-based systems.

Third Generation (1970-present):

Pressurised water with temperatures below 100 C.
Used in replacements in Central and Eastern Europe
and all extensions in China, Korea, Europe, USA and Canada.

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Three pillars

Supply:

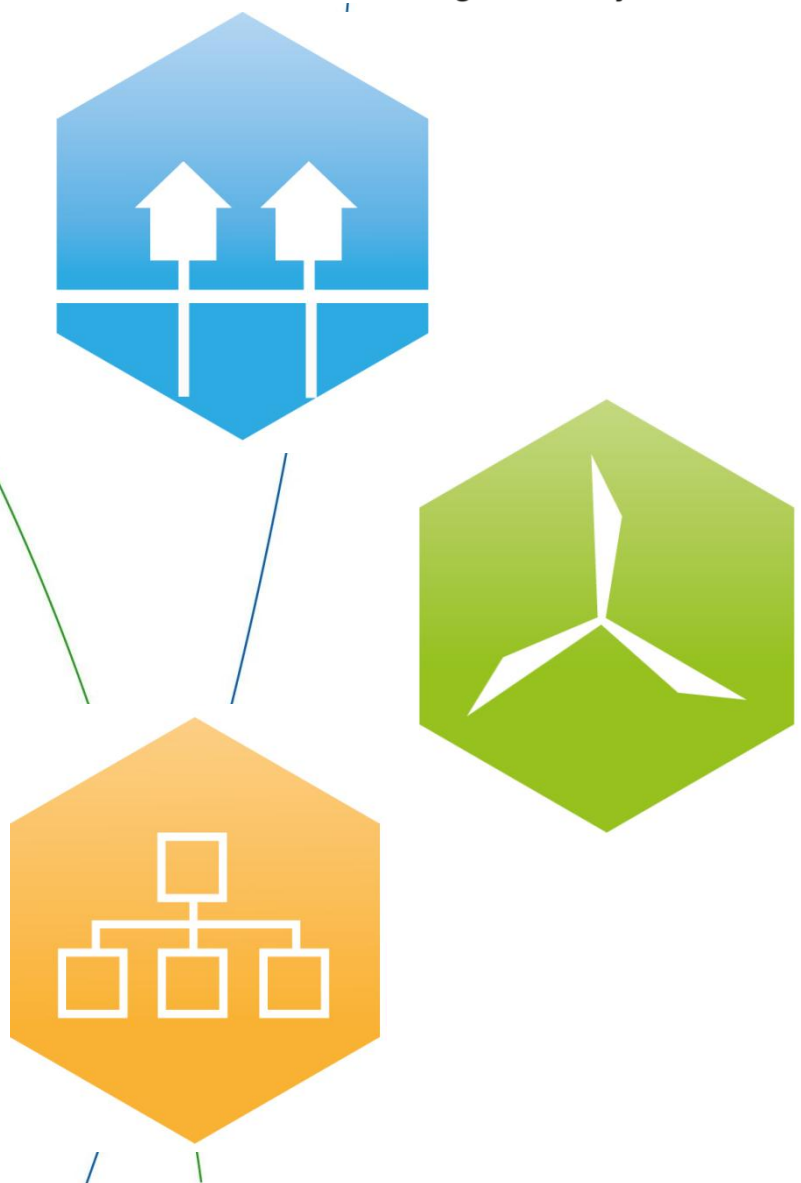
Low temperature District heating

Production:

Renewable Systems Integration

Organisation:

Planning and Implementation



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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.

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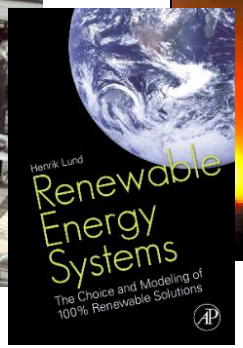
Production:

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



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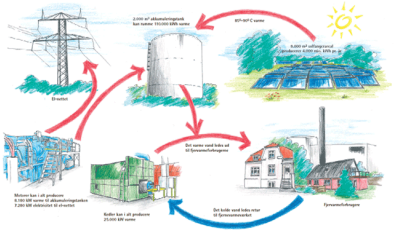
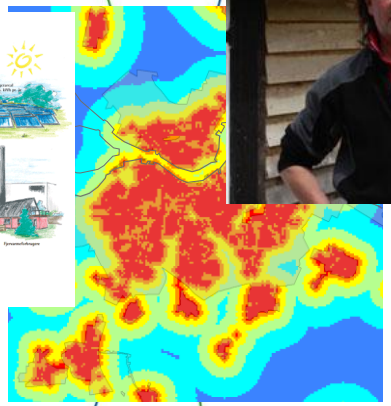
Organisation:

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.





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13 PhD projects

Strategic Research Centre for 4th Generation District Heating Technologies and Systems

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PhD 1.1. Heating of existing buildings by low-temperature district heating
PhD 1.2. Supply of domestic hot water at comfort temperatures without Legionella
PhD 1.3. Conversion of existing district heating grids to low-temperature operation and extension to new areas of buildings
PhD 1.4 Minimising losses in the DH distribution grid

Ph.D. 2.1: Energy Scenarios for Denmark
Ph.D. 2.2 Thermal storage in district heating systems
Ph.D. 2.3 Distributed CHP-plants optimized across more electricity markets
Ph.D. 2.4 Low-temperature energy sources for district heating
Ph.D. 2.5 The role of district heating in the Chinese energy system

PhD 3.1: Strategic energy planning in a municipal and legal perspective
PhD 3.2: Price regulation, tariff models and ownership as elements of strategic energy planning
PhD 3.3: Geographical representations of heat demand, efficiency and supply
PhD 3.4: Geographical representations of renewable energy systems

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International Dimension

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International Partners:

- Tsinghua University, China
- Chalmers, Halmstad and Linnaeus universities, Sweden
- Zagreb, Croatia
- Euro Heat and Power

First result:

Heat Road Map Europe

First pre-study

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Interdiciplinary

PhD courses

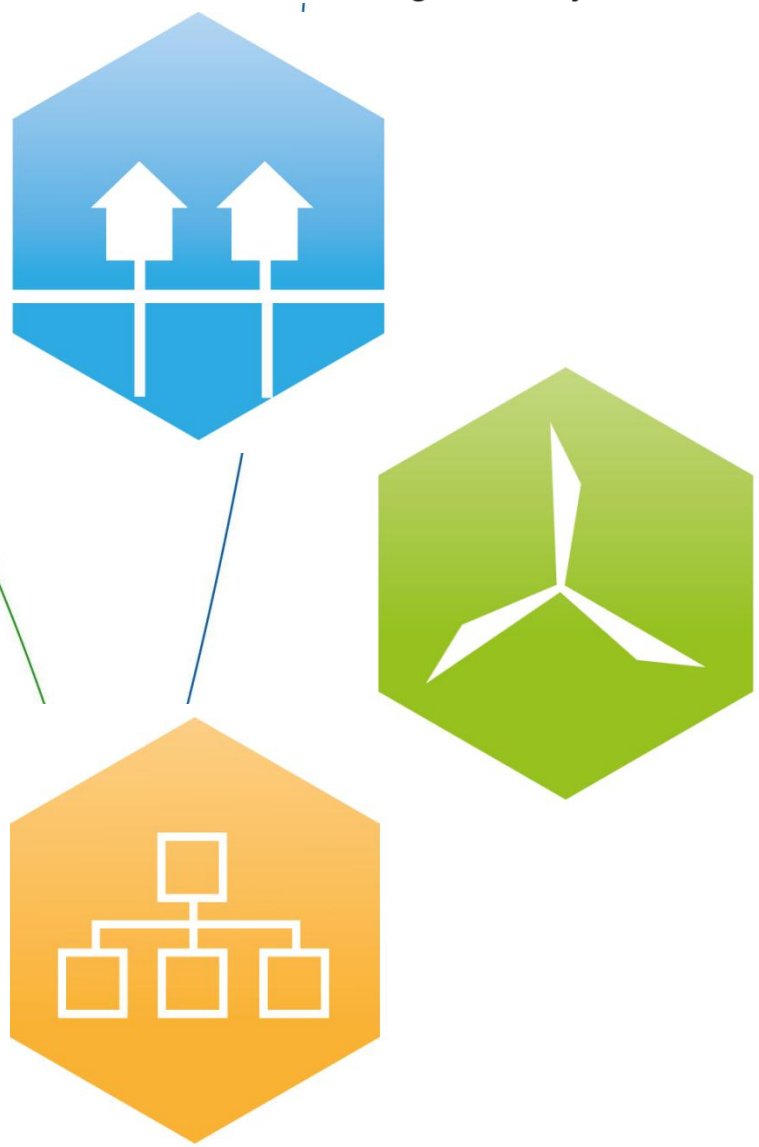
At the different participating universities

Management activities:

International collaboration, Consortium activities and dissemination

4GDH concept:

Further development of the concept.



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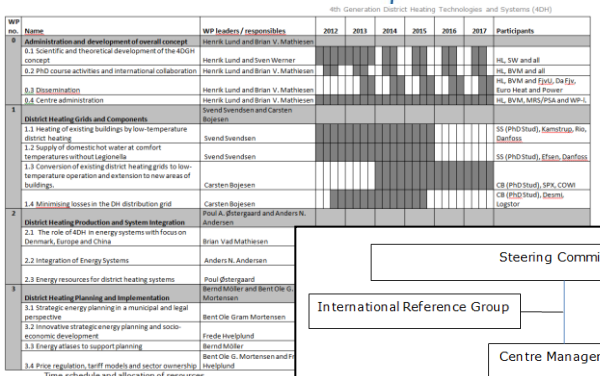
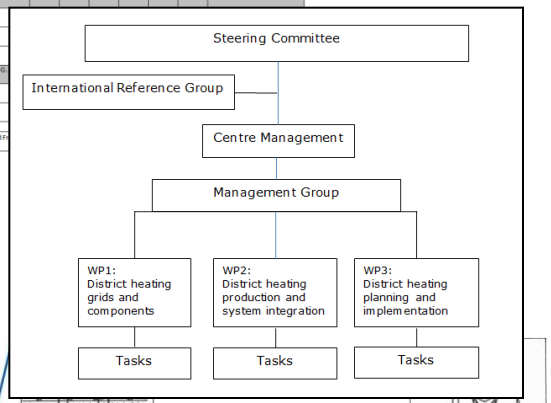
Consortium meetings

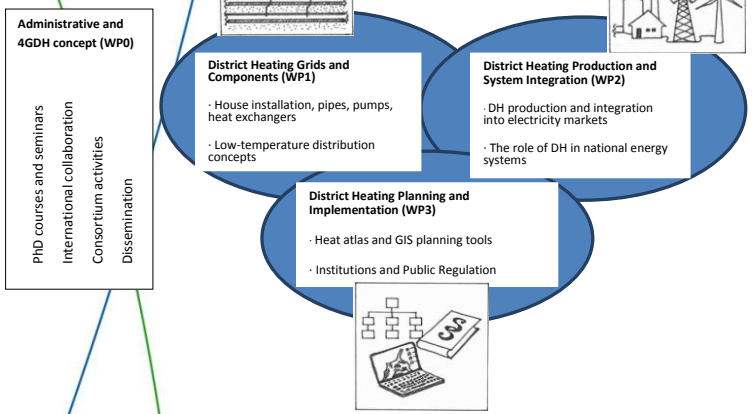
- Conference on 4GDH Technologies and Systems (Public)

- Status and administrative meetings (4DH Participants)

6-year project (2012-2017) with on-going dissemination.







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4th Generation District Heating - First Annual Conference, 3 October 2012

Venue: Utzon Center, Slotspladsen 4, Aalborg

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Programme

09.30-10.00 **Breakfast and registration**

10.00-10.30 **Introduction to the 4DH project and the agenda for the first annual 4DH conference**

Professor Henrik Lund, Aalborg University, Head of the 4DH Research Centre

10.30-12.00 **Previous research in Sweden and Denmark on the future of district heating systems**

Results of the Swedish sparse district heating project
Professor Sven Werner, Halmstad University

State-of-the-art of designing future sustainable energy systems - the role of district heating
Associate Professor Brian Vad Mathiesen, Aalborg University

Swedish experience of district heating, transportation and Biomass
Professor Leif Gustavsson, Linnaeus University

Panel debate: Which key knowledge from previous research can be brought into the 4DH project? Chairman: Technical Manager Per Wulff, Vestforbrænding.
Panel members: Speakers; Ass. Professor Erik Ahlgren, Chalmers University of Technology, Business Unit Director Lars Boye Mortensen, NIRAS; and Head of Energy Systems Department Anders N. Andersen, EMD.

12.00-13.00 **Lunch**

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13.00-14.30 Status and challenges to the development of the 4GDH Concept

The work on 4GDH within the IEA and the EU DHC platform
Dr Robin Wiltshire, Building Research Establishment Ltd., UK

The work on 4GDH in Denmark
Professor Svend Svendsen, Technical University of Denmark

Organisational and institutional challenges to the 4GDH Concept
Professor Bent Ole Gram Mortensen, University of Southern Denmark

Panel debate: Which role does the 4DH project have in the further development of the 4GDH Concept? Chairman: Professor Poul Erik Morthorst, Technical University of Denmark. Panel members: Speakers; Head of Division Per Alex Sørensen, PlanEnergi; Professor Sven Werner, Halmstad University; and Managing Director Astrid Birnbaum, Københavns Energi

14.30-15.00 Coffee break

15.00-16.30 International status and future perspectives of district heating and the 4GDH Concept

The case of China
Professor Xiliang Zhang, Tsinghua University

The case of Eastern Europe
Professor Neven Duic, University of Zagreb

EU and Heat Road Map Europe pre-study
Assistant Professor David Connolly, Aalborg University

Panel debate: Which international trends can be seen with regard to the development of district heating and how can the 4DH project contribute?
Chairman: Project Manager Torben Hermansen, COWI.
Panel members: Speakers; Project Manager Jan Eric Thorsen, Danfoss; Vice-President Birger Lauersen, Euro Heat and Power; and Dr Robin Wiltshire, Building Research Establishment Ltd.

16.30-17.00 Concluding remarks
Ass. Prof. Brian Vad Mathiesen, Aalborg University, Deputy Head of the 4DH Research Centre

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Publications

Bent Ole Gram Mortensen: *Fjernvarme – en monopolsektor i konkurrence*. Artikel i Festskrift til Jens Fejø, Jurist og Økonomforbundets Forlag, 2012, s. 299-310, ISBN 978-87-574-2573-4.

Bent Ole Gram Mortensen: *Status quo vedrørende forblivelsespligt*. Artikel i Tidsskrift for Miljø, Magnus Informatik, 4/2012, s. 102-105 (TfM 2012, 45), ISSN 1603-8398.

Bent Ole Gram Mortensen: *Fjernkøling* i Jan-Erik Helenelund, Ilpo Luoto, Niina Mäntylä og Kristian Siikavirta (red.): Offentlig – privat; i hurudana strukturer? Festskrift til Eija Mäkinen, Universitas Wasaensis (Finland), Acta Wasaensia No 265, s. 452-467, 2012, ISBN 978-952-476-408-7.

David Connolly, Brian Vad Mathiesen, Poul Alberg Østergaard, Bernd Möller, Steffen Nielsen, Henrik Lund, Daniel Trier, Urban Persson, Daniel Nilsson & Sven Werner: *Heat Roadmap Europe 2050. First pre-study for EU27*. Performed by Aalborg University and Halmstad University for Euroheat & Power, Brussels 2012. Link to report Link to further information: www.heatroadmap.eu

Lund, H. Andersen, A.N. Østergaa
SMART ENERGY SYSTEMS - A mar
96–102, June 2012

Bernd Möller, Steffen Nielsen an
PHOTOVOLTAIC ELECTRICITY RES
Dublin City University, Ireland

Bernd Möller: *A Danish Heat Atla*

Presentations

Frede Hvelplund: *From smart electricity systems to smart energy systems (The subsidiarity principle, local ownership and wind power integration)*. Presentation August 2012, Salzburg Austria.

Bernd Möller, Steffen Nielsen and Karl Sperling: *A SOLAR ATLAS FOR BUILDING-INTEGRATED PHOTOVOLTAIC ELECTRICITY RESOURCE ASSESSMENT*. Paper presented at the SEEP conference, June 5-8, 2012, Dublin City University, Ireland. This paper won the Award for Best Presentation.

Bernd Möller: *A Danish Heat Atlas, or how existing public databases can be used for energy planning*. Paper presented at the Climate change adaptation workshop, 20-21 March 2012, Aalborg.

Bent Ole Gram Mortensen: *Regulatoriske rammer for fjernkøling*. Præsentation den 8. marts 2012 på seminar om fjernkøling, Fjernvarmens Udviklingscenter. Afviklet over internettet

Bent Ole Gram Mortensen: *Den specielle konkurrenceret og forsyningsvirksomhed – fjernvarme som case*. Præsentation den 4. september 2012 på frokostseminar, Centre for European Studies (CESEL) ved Juridisk Fakultet ved Københavns Universitet.

Henrik Lund: *From Smart Electricity Grids to Smart Energy Systems*. Keynote at 3rd International Conference on Contemporary Problems of Thermal Engineering (CPOTE 2012), Institute of Thermal Technology, Gliwice, Silesia, Poland, 18-20 September 2012.

Henrik Lund: *Heat Roadmap Europe 2050*. Presentation and panel debate at the 13th International Symposium on District Heating and Cooling, Copenhagen 3-4 September 2012.

Henrik Lund: *Heat Roadmap Europe 2050*. Presentation at European Sustainable Energy Week. Euro Heat and Power and Cogen Europe, Charlemagne building 21. June 2012

Henrik Lund: *From Smart Electricity Grids to Smart Energy Systems*. Keynote at 5th International Conference on Sustainable Energy & Environmental Protection (SEEP 2012), Dublin City University, Dublin 5-8 June 2012.

Henrik Lund: *Heat Pump Integration in Energy Systems*. Keynote at Symposium on Advances in Refrigeration and Heat Pump Technology, DTU, 15-16 May 2012. Link to proceedings.

Henrik Lund: *Heat Roadmap Europe 2050*. Presentation and panel debate at the Euroheat and Power Conference TEAMING UP FOR RENEWABLE HEATING AND COOLING, Copenhagen 26-27 April 2012.

HEAT ROADMAP EUROPE 2050

FIRST PRE-STUDY FOR THE EU27

by

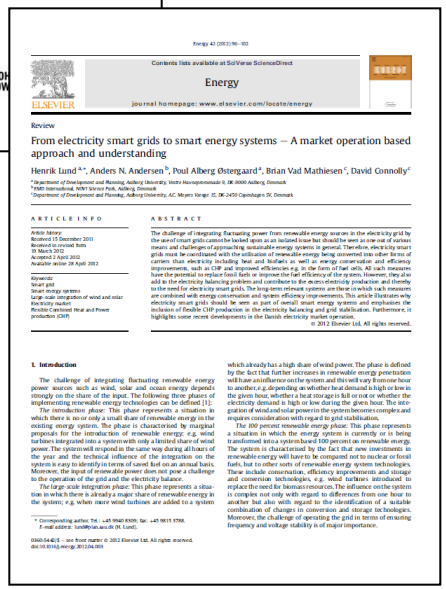
Aalborg University
David Connolly
Brian Vad Mathiesen
Poul Alberg Østergaard
Bernd Möller
Steffen Nielsen
Henrik Lund

Halmstad University
Urban Persson
Daniel Nilsson
Sven Werner

PlanEnergi
Daniel Trier

for

EUROH & POW



Energy 42 (2012) 96–102

Contents lists available at SciVerse ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Review

From electricity smart grids to smart energy systems – A market operation based approach and understanding

Henrik Lund [a,*], Anders N. Andersen [b], Poul Alberg Østergaard [a], Brian Vad Mathiesen [c], David Connolly [c]

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[b] EMD International, NOVI Science Park, Aalborg, Denmark
[c] Department of Development and Planning, Aalborg University, AC. Meyers Vænge 15, DK-2450 Copenhagen SV, Denmark

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Flexible Combined Heat and Power production (CHP)

ABSTRACT

The challenge of integrating fluctuating power from renewable energy sources in the electricity grid by the use of smart grids cannot be looked upon as an isolated issue but should be seen as one out of various means and challenges of approaching sustainable energy systems in general. Therefore, electricity smart grids must be coordinated with the utilisation of renewable energy being converted into other forms of carriers than electricity including heat and biofuels as well as energy conservation and efficiency improvements, such as CHP and improved efficiencies e.g. in the form of fuel cells. All such measures have the potential to replace fossil fuels or improve the fuel efficiency of the system. However, they also add to the electricity balancing problem and contribute to the excess electricity production and thereby to the need for electricity smart grids. The long-term relevant systems are those in which such measures are combined with energy conservation and system efficiency improvements. This article illustrates why electricity smart grids should be seen as part of overall smart energy systems and emphasises the inclusion of flexible CHP production in the electricity balancing and grid stabilisation. Furthermore, it highlights some recent developments in the Danish electricity market operation.

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1. Introduction

The challenge of integrating fluctuating renewable energy power sources such as wind, solar and ocean energy depends strongly on the share of the input. The following three phases of implementing renewable energy technologies can be defined [1]:

The introduction phase: This phase represents a situation in which there is no or only a small share of renewable energy in the existing energy system. The phase is characterised by marginal proposals for the introduction of renewable energy e.g. wind turbines integrated into a system with only a limited share of wind power. The system will respond in the same way during all hours of the year and the technical influence of the integration on the system is easy to identify in terms of saved fuel on an annual basis. Moreover, the input of renewable power does not pose a challenge to the operation of the grid and the electricity balance.

The large-scale integration phase: This phase represents a situation in which there is already a major share of renewable energy in the system; e.g. when more wind turbines are added to a system which already has a high share of wind power. The phase is defined by the fact that further increases in renewable energy penetration will have an influence on the system and this will vary from one hour to another, e.g. depending on whether heat demand is high or low in the given hour, whether a heat storage is full or not or whether the electricity demand is high or low during the given hour. The integration of wind and solar power in the system becomes complex and requires consideration with regard to grid stabilisation.

The 100 percent renewable energy phase: This phase represents a situation in which the energy system is currently or is being transformed into a system based 100 percent on renewable energy. The system is characterised by the fact that new investments in renewable energy will have to be compared not to nuclear or fossil fuels, but to other sorts of renewable energy system technologies. These include conservation, efficiency improvements and storage and conversion technologies, e.g. wind turbines introduced to replace the need for biomass resources. The influence on the system is complex not only with regard to differences from one hour to another but also with regard to the identification of a suitable combination of changes in conversion and storage technologies. Moreover, the challenge of operating the grid in terms of ensuring frequency and voltage stability is of major importance.

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Europe IEA 2010 and EU CPI scenario 2050

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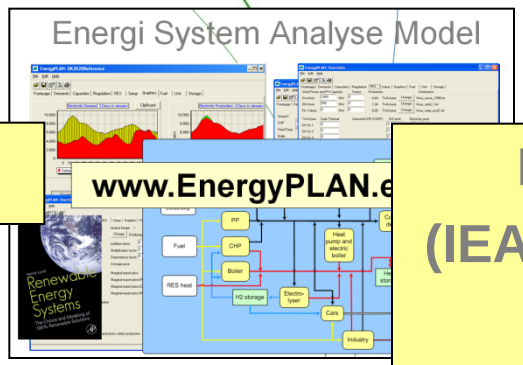
CPI = Current Policy Initiatives

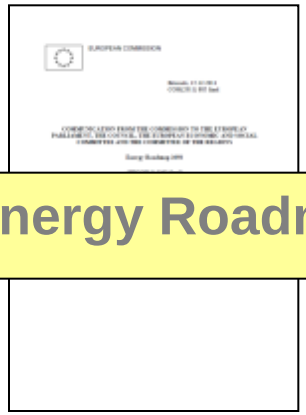
IEA Statistics 2009



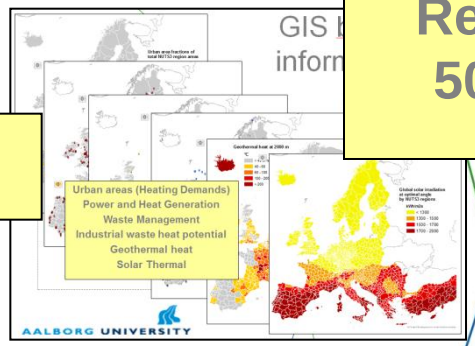
Reference (12% DH)
(IEA 2010 and EU CPI 2050)

Versus

Reference plus 30% and 50% DH (and CHP etc.)



EU Energy Roadmap 2050



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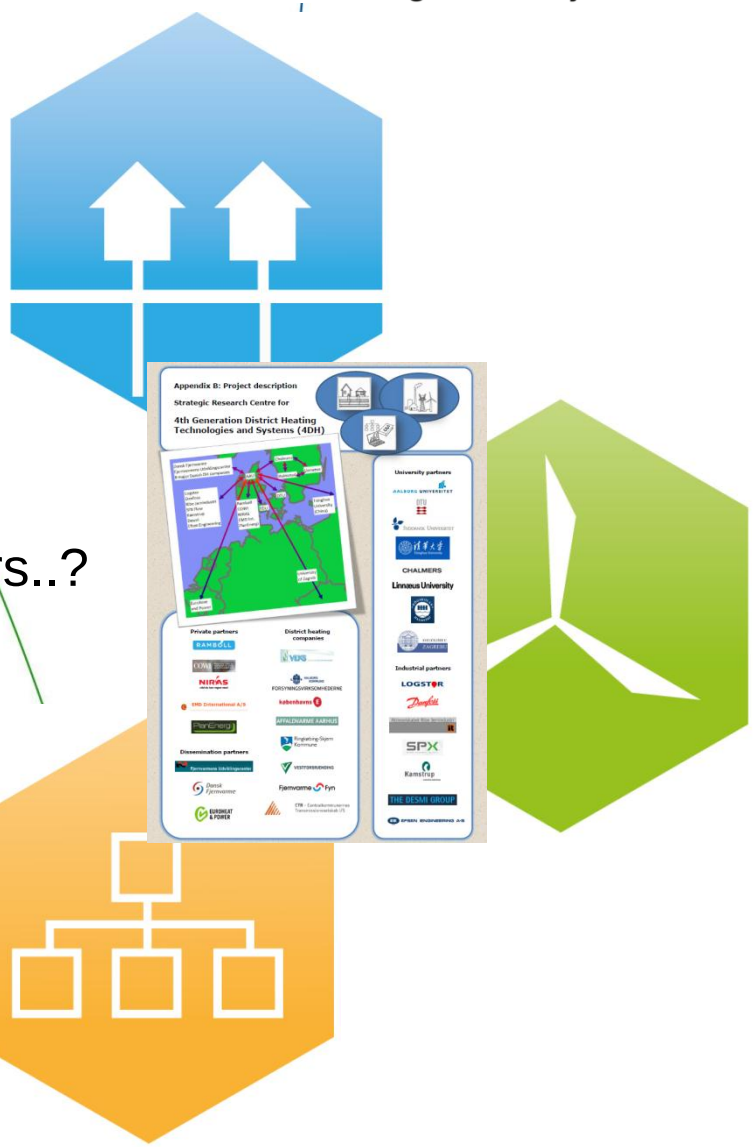

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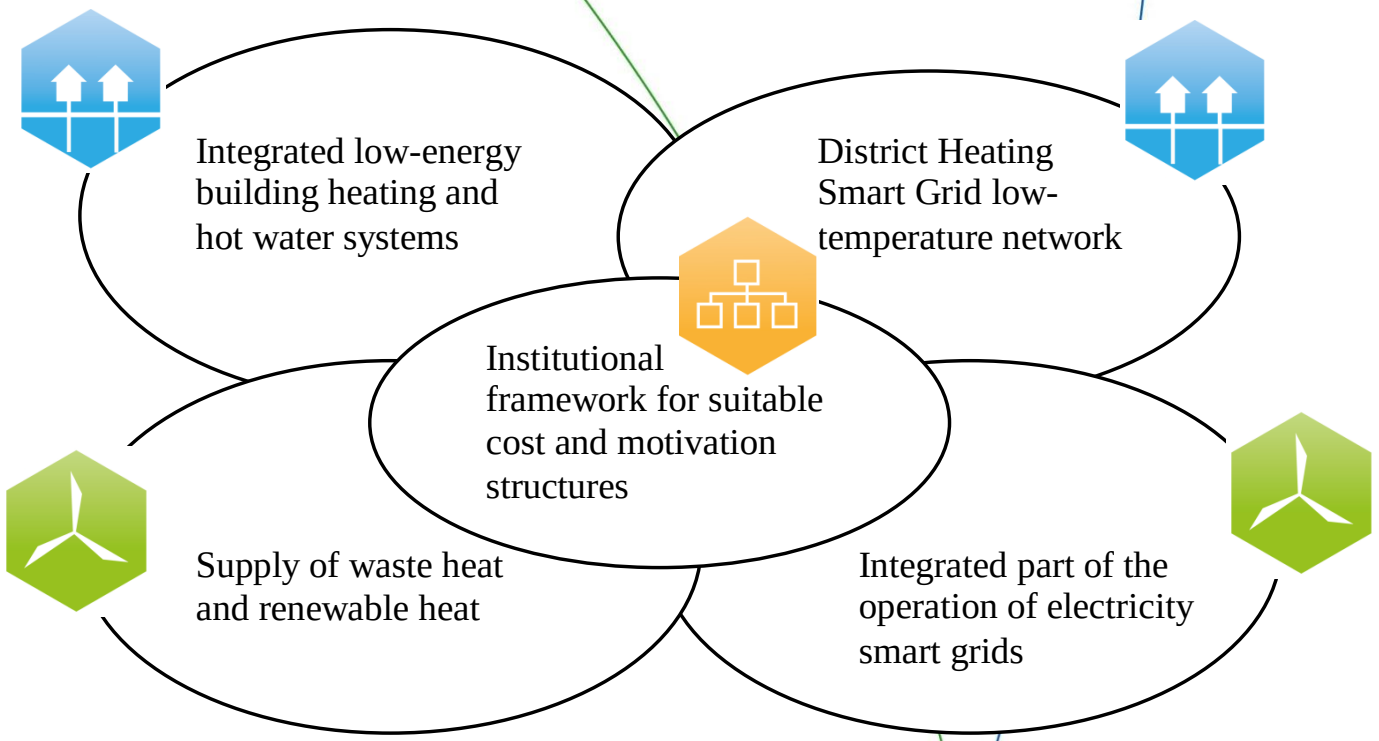
Figure 1: Illustration of the concept of 4th Generation District Heating



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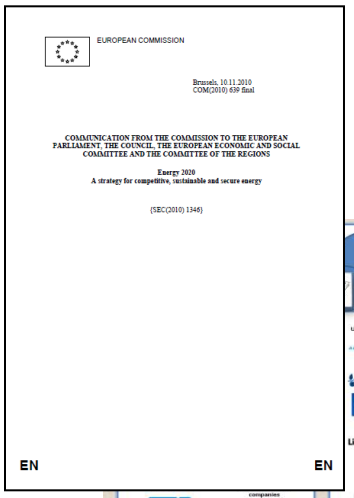
Smart heating and cooling grids

- In the European Commission's strategy [7] for a competitive, sustainable and secure "Energy 2020", the need for *"high efficiency cogeneration, district heating and cooling*" is highlighted (page 8). The paper launches projects to promote, among others, *"smart electricity grids*" along with *"smart heating and cooling grids*" (page 16).


EUROPEAN COMMISSION

Brussels, 10.11.2010
COM(2010) 639 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Energy 2020
A strategy for competitive, sustainable and secure energy

{SEC(2010) 1346}

EN EN

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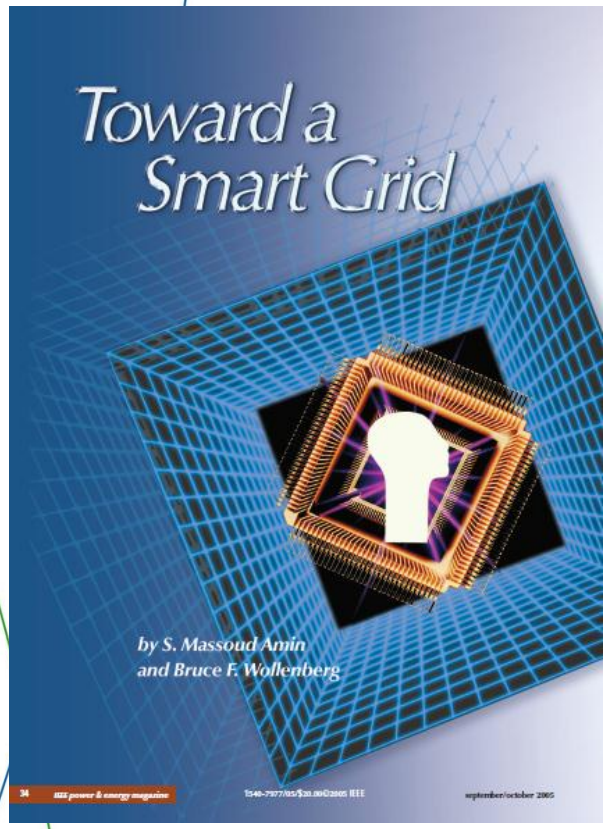
Smart Grid (2005)

No definition.

However it can be understood from the context that a *smart grid* is a power network using modern computer and communication technology to achieve a network which can better deal with potential failures.



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Smart Grid - definitions

"A *smart grid* is an electricity grid that uses information and communications technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity." (U.S. Department of Energy)

"*Smart Grids* … concerns an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies." (SmartGrids European Technology Platform, 2006).

"A *Smart Grid* is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety." (European Commission, 2011)

"*Smart grids* are networks that monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users" …. "The widespread deployment of smart grids is crucial to achieving a more secure and sustainable energy future." (International Energy Agency 2013).

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Smart Energy Systems

- *Electricity Smart Grids* are define as electricity infrastructures that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies.

Smart Energy Systems is define as an approach in which Electricity, District Heating and Cooling as well as Gas Smart Grids are combined and coordinated to identify synergies between them in order to achieve an optimal solution for each individual sector as well as for the overall energy system.

- *Gas Smart Grids* are define as gas infrastructures that can intelligently integrate the actions of all users connected to it - supplies, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure gas supplies and storage.

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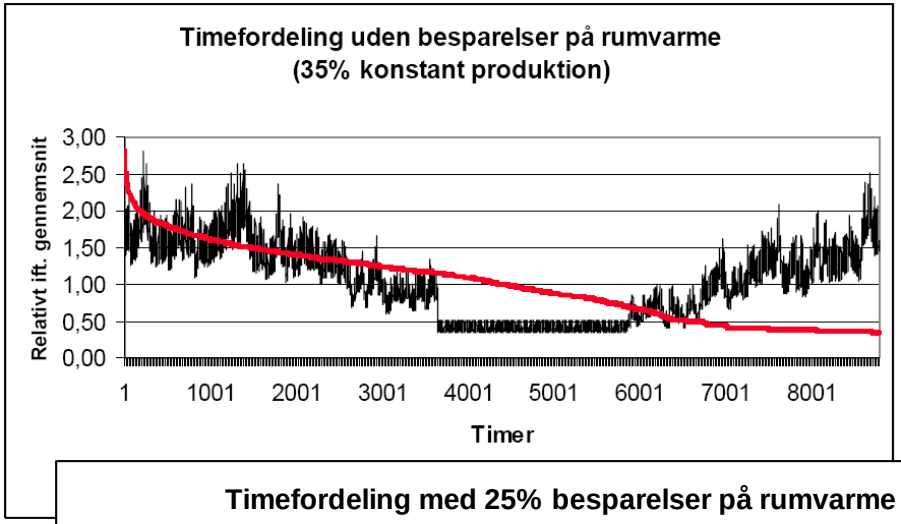
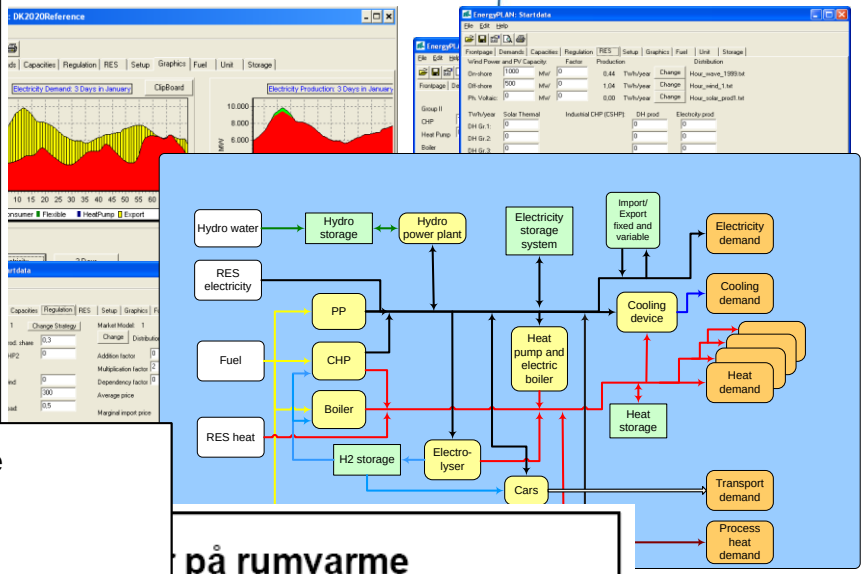
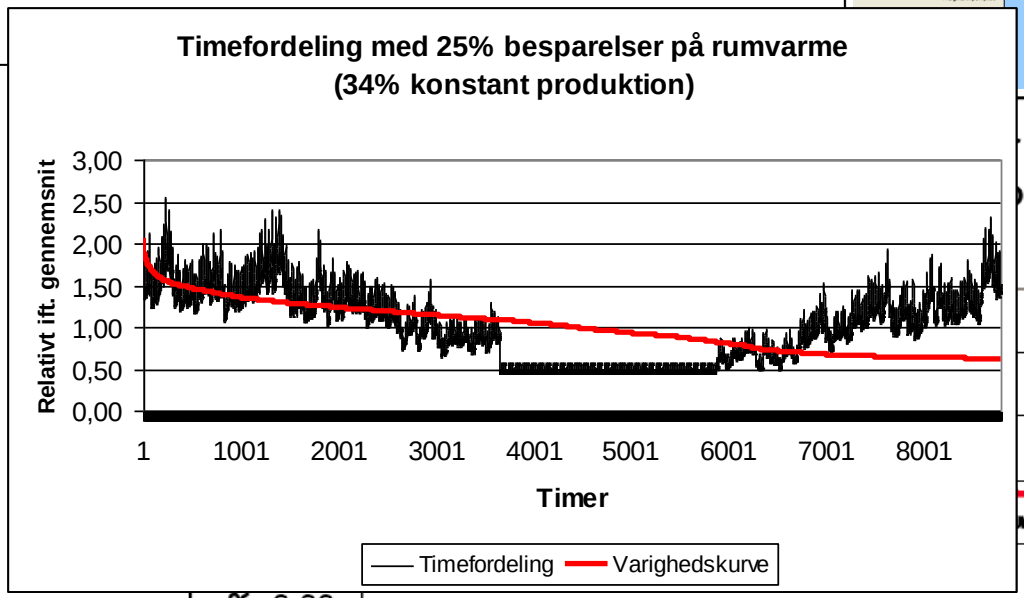
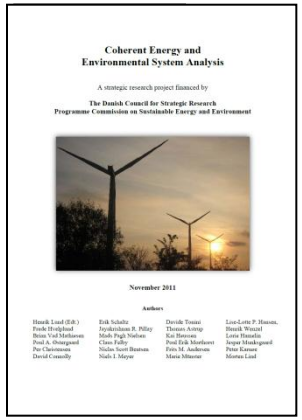

Timefordeling uden besparelser på rumvarme
(35% konstant produktion)
Relativt ift. gennemsnit
3,00
2,50
2,00
1,50
1,00
0,50
0,00
1
1001
2001
3001
4001
5001
6001
7001
8001
Timer


Hydro water
Hydro storage
Hydro power plant
Electricity storage system
Import/ Export fixed and variable
Electricity demand
RES electricity
PP
Cooling device
Cooling demand
Fuel
CHP
Heat pump and electric boiler
Heat demand
Boiler
Heat storage
RES heat
H2 storage
Electro-lyser
Cars
Transport demand
Process heat demand


Timefordeling med 25% besparelser på rumvarme
(34% konstant produktion)
Relativt ift. gennemsnit
3,00
2,50
2,00
1,50
1,00
0,50
0,00
1
1001
2001
3001
4001
5001
6001
7001
8001
Timer
Timefordeling
Varighedskurve

på rumvarme
n)
0,00
1
1001
2001
3001
4001
5001
6001
7001
8001
Timer
Timefordeling
Varighedskurve


Coherent Energy and
Environmental System Analysis
November 2011

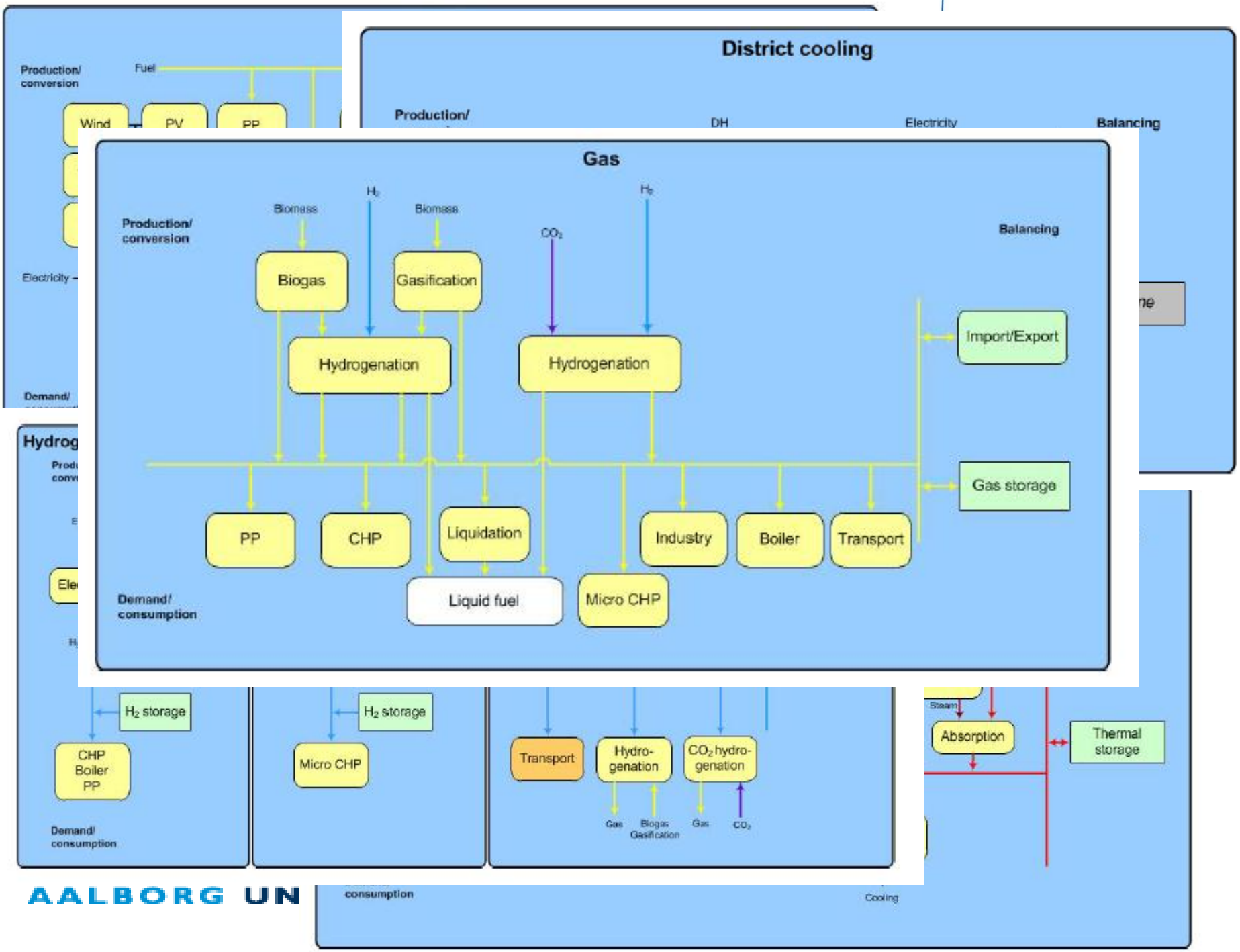
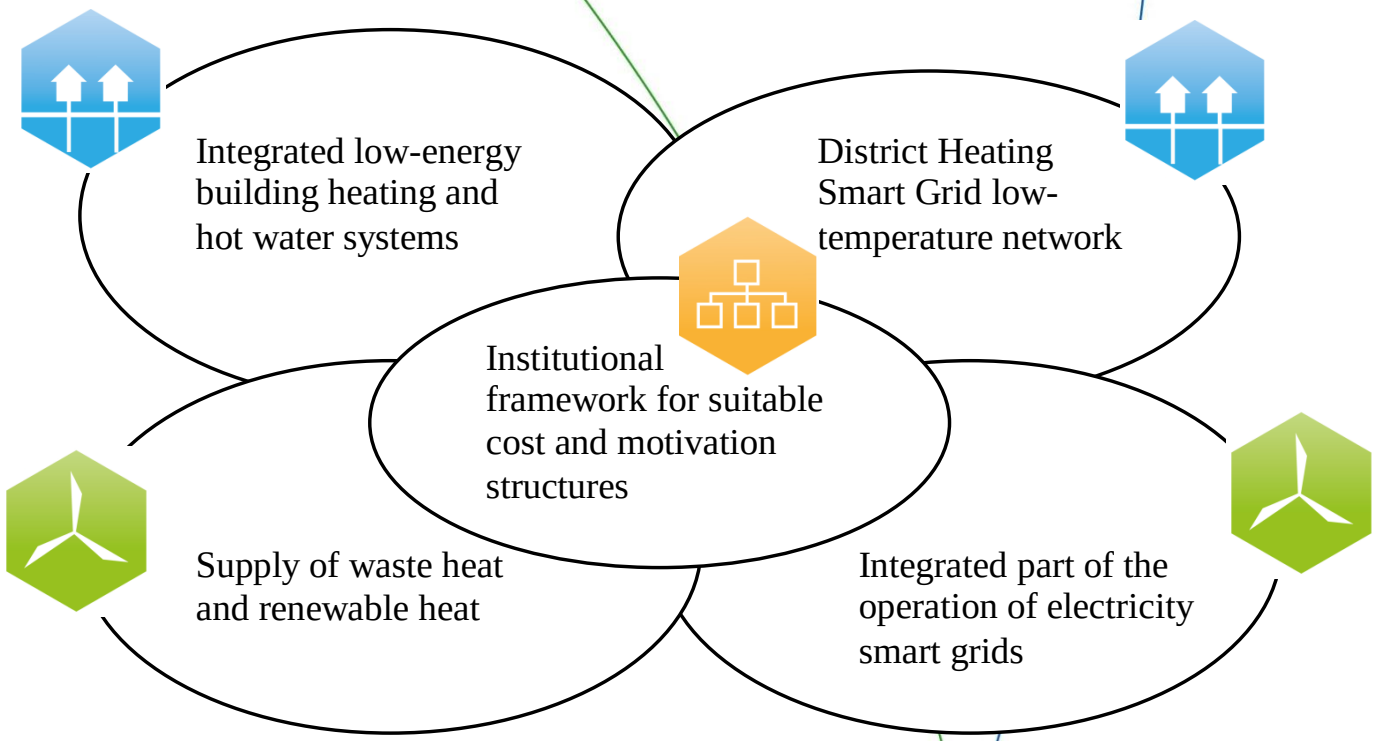

District cooling
Production/
conversion
Fuel
Wind
PV
PP
DH
Electricity
Balancing
Electricity
Demand/
Gas
Production/
conversion
Biomass
H_2
Biomass
CO_2
H_2
Balancing
Biogas
Gasification
Hydrogenation
Hydrogenation
Import/Export
Gas storage
PP
CHP
Liquidation
Industry
Boiler
Transport
Liquid fuel
Micro CHP
Demand/
consumption
H_2 storage
CHP
Boiler
PP
Demand/
consumption
H_2 storage
Micro CHP
Transport
Hydro-
genation
CO_2 hydro-
genation
Gas
Biogas
Gasification
Gas
CO_2
Steam
Absorption
Thermal
storage
consumption
Cooling

Figure 1: Illustration of the concept of 4th Generation District Heating



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4DH
4th Generation District Heating Technologies and Systems

4th Generation District Heating

4th Generation District Heating technological Systems are defined as a coherent technological and institutional system, which by use of *district heating smart grids* helps a suitable implementation of renewable energy systems by providing for heat supply of low-energy-buildings with low grid losses in a way in which the use of low-temperature heat sources are integrated with the operation of electricity and gas smart grids. The concept involves the development of an institutional and organisational framework to facilitate suitable cost and motivation structures.

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3 generations of DH in use

	1st generation	2nd generation	3rd generation
Period of best available technology	1880-1930	1930-1980	1980-
Heat carrier	Steam	Pressurised hot water, mostly over 100°C	Pressurised hot water, often below 100°C
Labels	STEAM	A. SOVIET DH TECHNOLOGY B. MARKET-BASED DH SYSTEMS	SCANDINAVIAN DH TECHNOLOGY
Typical components	• Steam pipes in concrete ducts • Often no condensate return • Steam traps • Compensators	• Pipes in concrete ducts • Large shell- and tube heat exchangers • Extensive substations • Heavy, material intensive components	• Prefabricated, preinsulated pipes directly buried into the ground. • Compact substations using brazed plate heat exchangers • Material lean components
Quality	Outdated technology	Low quality for the Soviet DH technology and high to medium quality for other systems	High quality
Current use	New York and Paris. Replacement in Hamburg and Munich	Older parts of all early district heating systems	All replacements in CEE and former USSR countries and all extensions and new systems in China, Korea, Europe, USA and Canada.

	1st generation	2nd generation	3rd generation	4th generation
Period of best available technology	1880-1930	1930-1980	1980-20xx	**20xx-2050**
Heat carrier	Steam	Pressurised hot water mostly over 100oC	Pressurised hot water often below 100oC	**Low-temperature water 50-60 oC**
Label	Steam	A. Soviet systems B. Market-based systems	Scandinavian	**4GDH**
Typical components				
Quality				
Current use				
Heat Production			Large-scale CHP, distributed CHP, Biomass or fossil fuel boilers	**Low-temp. RES CHP integrated with heat pumps Waste-heat**
Buildings	Apartment buildings Xx kWh/m2		Apartment and attached houses Yy kWh/m2	**Low-energy and plus energy buidings: < 100 kWh/m2**
Integration with electricity supply			CHP on Spot-market	**CHP-systems integrated with heat pumps and operated on regulating and reserve power markets as well as spot markets.**
Use of Renewable Energy				

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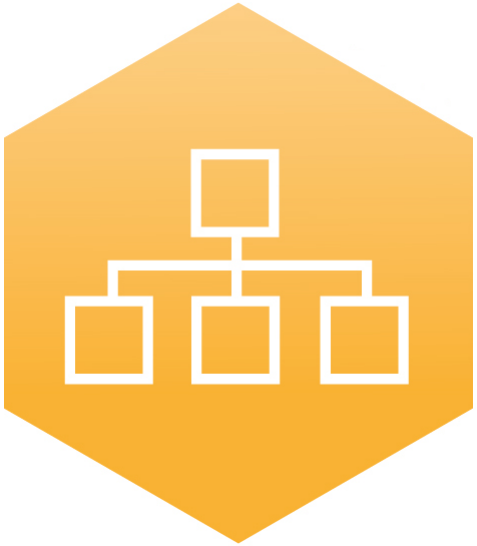
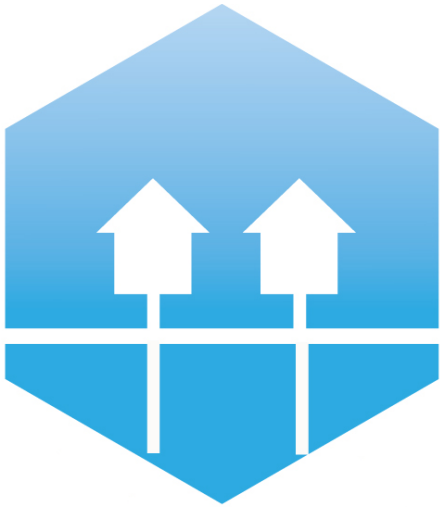
4th Generation District Heating Technologies and Systems
First PhD Seminar, 7 March 2013

Thank you





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4DH
4th Generation District Heating
Technologies and Systems