4th Generation District Heating Technologies and Systems
Second PhD Seminar, 13 March 2014

Welcome

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DENMARK

4DH
4th Generation District Heating
Technologies and Systems

Agenda…

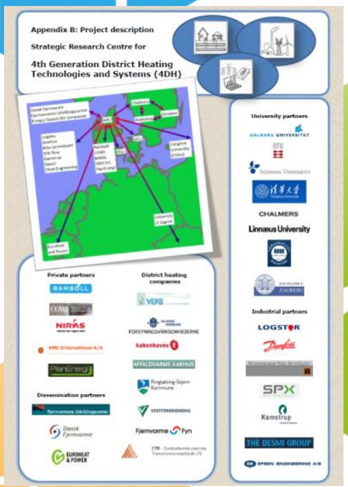
Main point of today:

Present results at the coming

4DH Consortium meeting ..?

Recent development:

- Smart energy definitions
- 4DH definition paper..



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4DH
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Main point today

Next consortium meeting
Is allocated for presenting
research results

Among others:

- Heat Roadmap Europe
- Heat savings (ZEB project)
- …..

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4DH
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13 PhD projects

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

4DH
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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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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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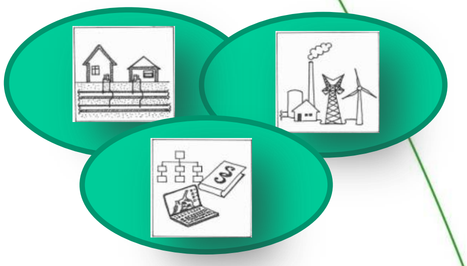
Aim and Objectives

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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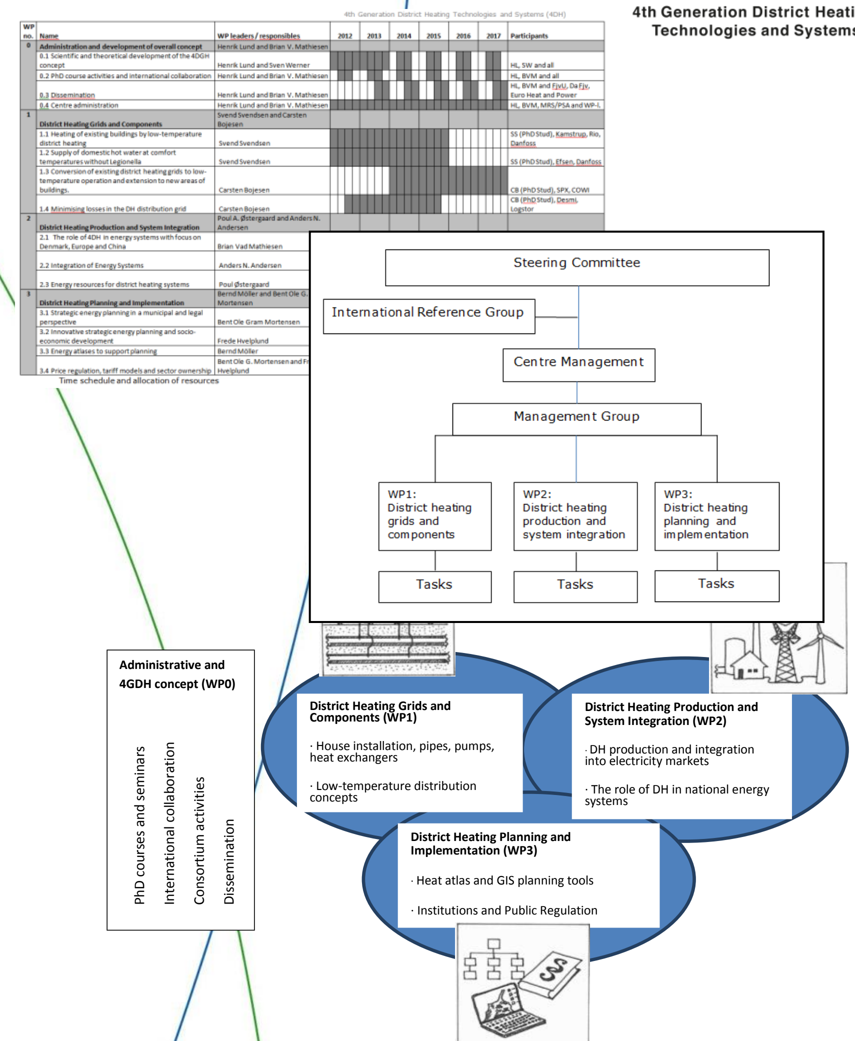
Consortium meetings

- 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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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…

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Review

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

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Keywords:
Smart grid
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Large-scale integration of wind and solar
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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.

1. Introduction

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- 4DH definition paper..

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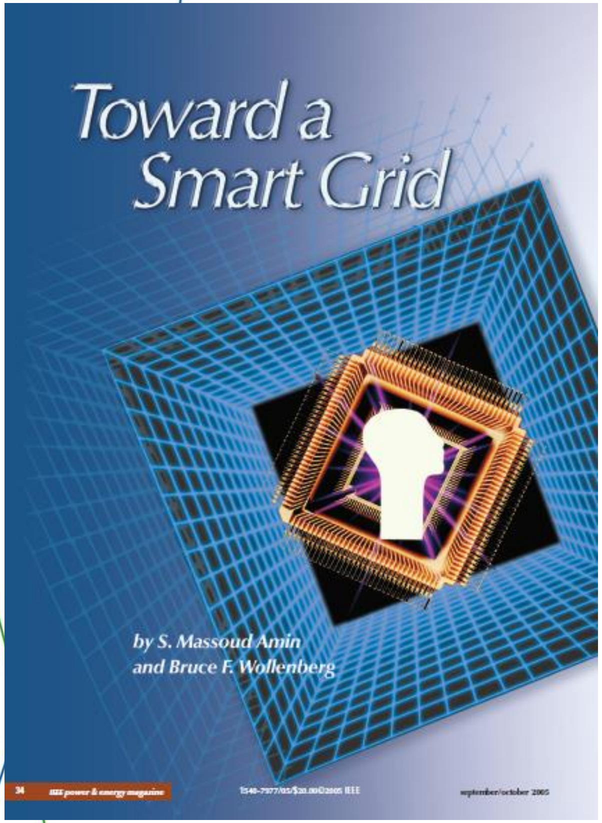
Smart Grid (2005)

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).

U.S. DEPARTMENT OF ENERGY

European SmartGrids Technology Platform

EUROPEAN COMMISSION

International Energy Agency

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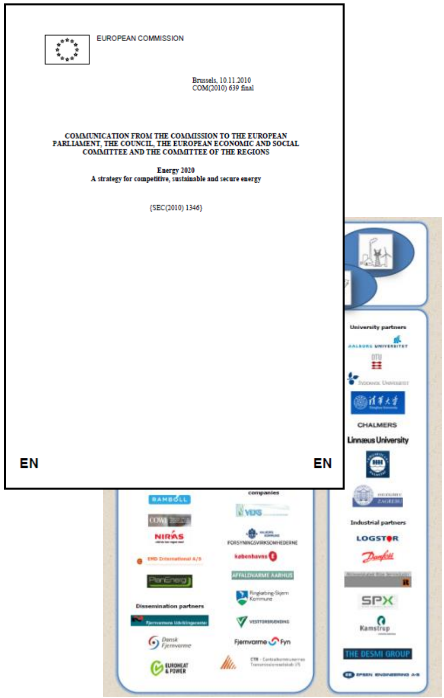
Smart heating and cooling grids

- 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}

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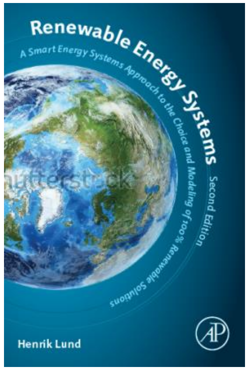
Smart Energy Systems



- **Smart Electricity Grids** are 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

Smart Energy System is defined as an approach in which smart Electricity, Thermal and Gas 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.

- **Smart Gas Grids** are 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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1

Review Paper for ENERGY – The International Journal.

4th Generation District Heating (4GDH)

Integrating Smart Thermal Grids into Future Sustainable Energy Systems

Henrik Lund [a,*], Sven Werner [b], Robin Wiltshire [c], Svend Svendsen [d], Jan Eric Thorsen [e], Frede Hvelplund [a], Brian Vad Mathiesen [f]

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ABSTRACT

This paper defines the concept of *4th Generation District Heating* (4GDH) including the relations to *District Cooling* and the concepts of *Smart Energy* and *Smart Thermal Grids*. The motive is to identify the future challenges of reaching a future renewable non-fossil heat supply as part of the implementation of overall sustainable energy systems. The basic assumption is that district heating and cooling has an important role to play in future sustainable energy systems - including 100 percent renewable energy systems - but the present generation of district heating and cooling technologies will have to be developed further into a new generation in order to play such a role. Unlike the first three generations, the development of 4GDH involves meeting the challenge of more energy efficient buildings as well as being an integrated part of the operation of smart energy systems, i.e. integrated smart electricity, gas and thermal grids.

Keywords: 4GDH, District Heating, Smart Thermal Grids, Smart Energy Systems, Sustainable Energy Systems, Renewable Energy Systems.

1. Introduction

The design of future sustainable energy systems including 100 percent renewable systems is described in a number of recent reports and studies including [1-6]. Such systems are typically based on a combination of fluctuating renewable energy sources (RES) such as wind, geothermal and solar power together with residual resources such as waste and biomass on which we may expect increasing pressure due to environmental impact and future alternative demands for food and material. For example, biomass resources in Europe are small compared to the European energy balance [7]. In order to ease the pressure on biomass

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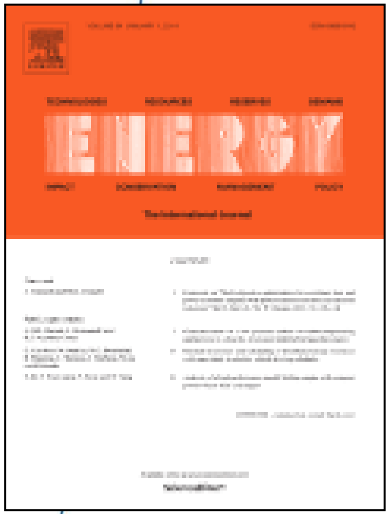

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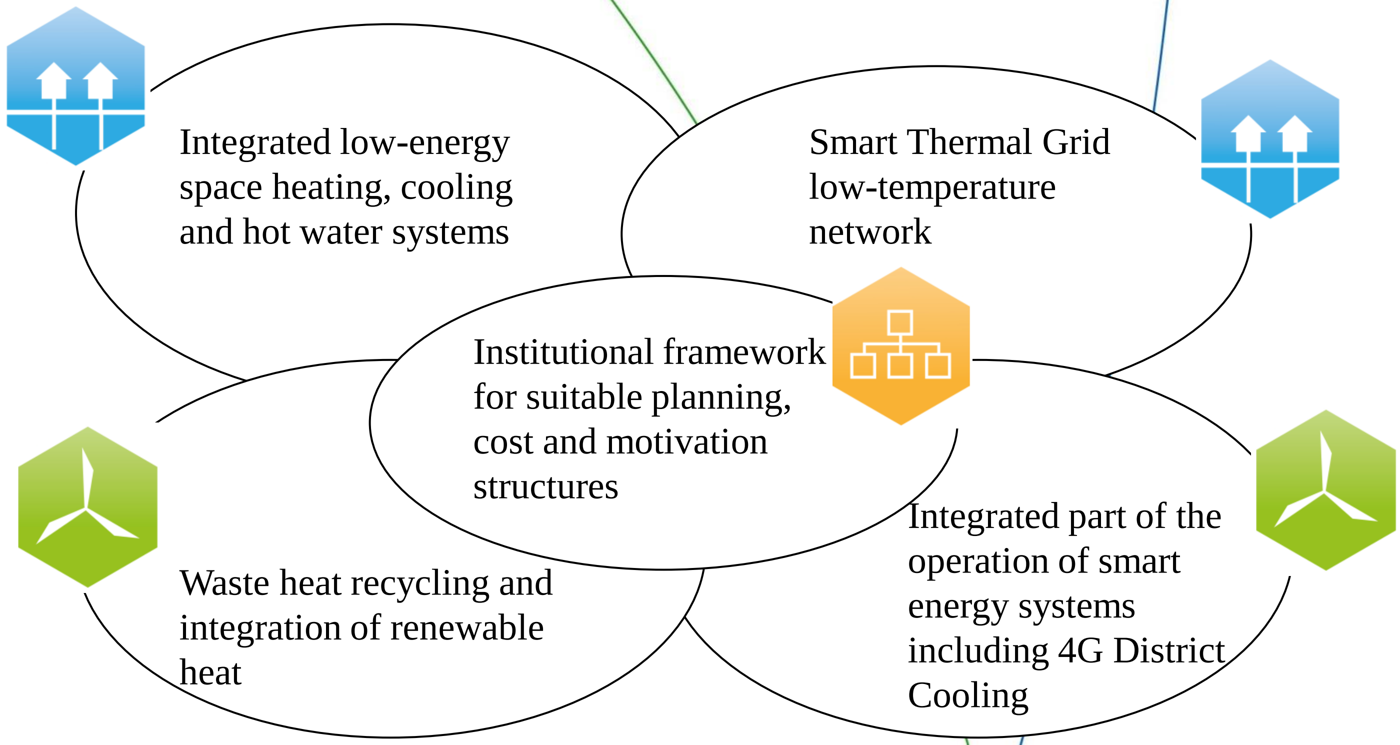
Figure 1: Illustration of the concept of 4th Generation District Heating



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4th Generation District Heating Technologies and Systems

Three pillars

Supply:

Low temperature District heating

Production:

Renewable Systems Integration

Organisation:

Planning and Implementation

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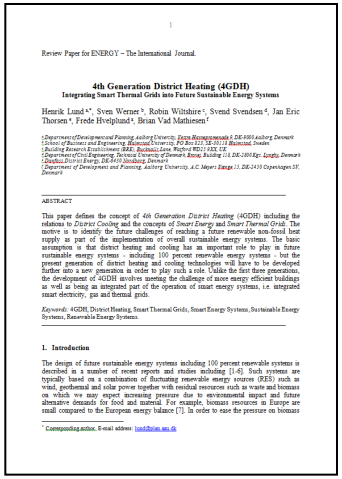
Supply:

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.


Review Paper for ENERGY – The International Journal

4th Generation District Heating (4GDH)
Integrating Smart Thermal Grids into Future Sustainable Energy Systems

Table 1	1st generation	2nd generation	3rd generation	4th generation
Label	Steam	In situ	Prefabricated	4GDH
Period of best available technology	1880-1930	1930-1980	1980-2020	2020-2050
	Distribution and Demand			
Heat carrier	Steam	Pressurised hot water mostly over 100ºC	Pressurised hot water often below 100ºC	Low-temperature water 30-70ºC
Pipes	In situ insulated steel pipes	In situ insulated steel pipes	Pre-insulated steel pipes	Pre-insulated flexible (possible twin) pipes
Circulation systems	Steam pressure	Central pumps	Central pumps	Central and decentralised pumps
Substations Heat exchanger	No	Tube and shell heat exchangers	Without or with plate heat exchangers	Probably mostly with plate heat exchangers Introduction of flat-stations. (decentralised supply of hot water in new buildings)
Buildings	Apartment and service sector buildings in the city	Apartment and service sector buildings 200-300 kWh/m²	Apartment and service sector buildings (and some single-family houses) 100-200 kWh/m²	New buildings: < 25 kWh/m² Existing buildings: 50-150 kWh/m²
Metering	Condensate meters in order to measure the amount of steam used.	Initially only flow meters in substations, later replaced by heat meters. Annual or monthly readings. Sometimes use of allocation meters on radiators for internal distribution of heat costs.	Heat meters and sometimes additional metering of flow in order to compensate for high return temperatures. Wireless readings introduced for more frequent readings.	As earlier but continuous reading used for continuous commissioning of customer heating system.
Radiators	High-temperature radiators (+90°C) using steam or water.	High-temperature radiator (90°C) using district heating water directly or indirectly.	Medium-temperature radiators (70°C) using district heating water directly or indirectly. Floor heating.	Floor heating. Low-temperature radiators (50°C). Indirect system.
Hot water	Hot water tanks heated directly with steam or	DHW tank heated to 60°C. Circulation at	Heat exchanger heating DHW to 50°C. Domestic	Very efficient local heat exchanger heating DHW to

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Production:

Renewable Systems Integration

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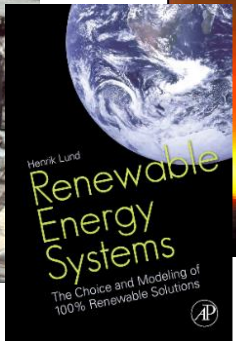
Production and system integration:

- 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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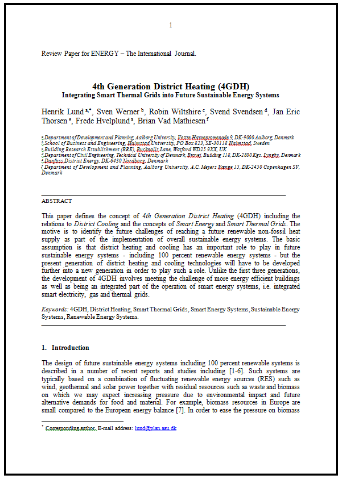

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ABSTRACT

This paper defines the concept of *4th Generation District Heating* (4GDH) including the relations to *District Cooling* and the concepts of *Smart Energy* and *Smart Thermal Grids*. The motive is to identify the future challenges of reaching a future renewable non-fossil heat supply as part of the implementation of overall sustainable energy systems. The basic assumption is that district heating and cooling has an important role to play in future sustainable energy systems - including 100 percent renewable energy systems - but the present generation of district heating and cooling technologies will have to be developed further into a new generation in order to play such a role. Unlike the first three generations, the development of 4GDH involves meeting the challenge of more energy efficient buildings as well as being an integrated part of the operation of smart energy systems, i.e. integrated smart electricity, gas and thermal grids.

Keywords: 4GDH, District Heating, Smart Thermal Grids, Smart Energy Systems, Sustainable Energy Systems, Renewable Energy Systems.

1. Introduction

The design of future sustainable energy systems including 100 percent renewable systems is described in a number of recent reports and studies including [1-6]. Such systems are typically based on a combination of fluctuating renewable energy sources (RES) such as wind, geothermal and solar power together with residual resources such as waste and biomass on which we may expect increasing pressure due to environmental impact and future alternative demands for food and material. For example, biomass resources in Europe are small compared to the European energy balance [7]. In order to ease the pressure on biomass

[*] Corresponding author. E-mail address: lund@plan.aau.dk

Table 2 Label Period of best available technology	1st generation Steam 1880-1930	2nd generation In situ 1930-1980	3rd generation Prefabricated 1980-2020	4th generation 4GDH 2020-2050
	Production and System Integration			
Heat Production	Coal steam boilers and some CHP plants	Coal and oil based CHP and some heat-only boilers	Large-scale CHP, distributed CHP, biomass and waste, or fossil fuel boilers	Low-temperature heat recycling and renewable sources
Integration with electricity supply	CHP as heat source	CHP as heat source	CHP as heat source, and some large electric boilers and heat pumps in countries with temporary electricity surpluses. Some very few CHP plants on spot market as exception	CHP systems integrated with heat pumps and operated on regulating and reserve power markets as well as spot markets

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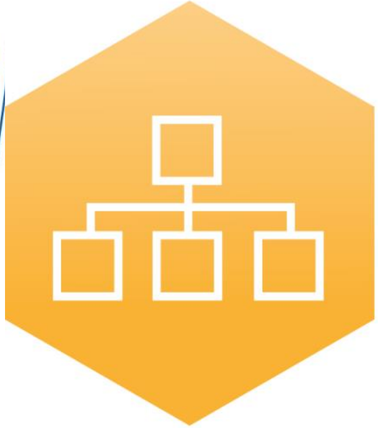
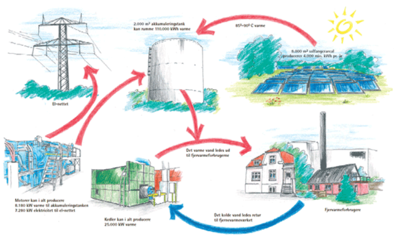
Organisation:

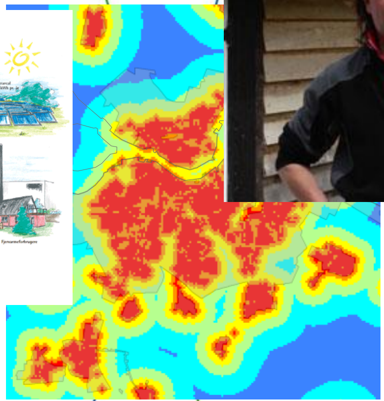
Planning and Implementation

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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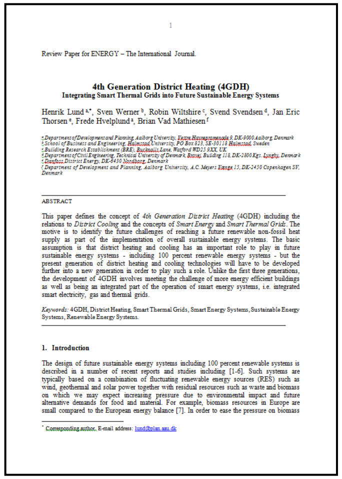

1

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Henrik Lund [a,*], Sven Werner [b], Robin Wiltshire [c], Svend Svendsen [d], Jan Eric Thorsen [e], Frede Hvelplund [a], Brian Vad Mathiesen [f]

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	Planning and Implementation			
Primary motivation in society (why to have DH)	Comfort and reduced risk	Fuel savings and reduced costs	Security of supply	Transformation to a sustainable energy system
Infrastructure planning (where to have DH)	Governing competing district heating infrastructures	Developing and expanding DH suitable for cost efficient use of CHP	Identifying and implementing suitable DH infrastructures in fossil based energy systems	Identifying and implementing suitable DH infrastructures in fossil free energy systems
Cost principles for investments (DH supply versus savings in demand)	Minimising the per unit supply costs. Few concerns regarding savings because space is more important.	Minimising the per unit supply costs. Few concerns regarding savings because CHP is cheap and plenty.	Dilemma between short- and long-term marginal costs with short-term marginal costs winning based on existing investments (sunk costs)	Dilemma between short- and long-term marginal costs with a need to integrate better long-term marginal costs (future investments). Incl. DSM costs
Motivation in operation (how to best operate given supply/demand system)	Consumers have to condensate steam. Further cooling is of minor concern.	Motivation of consumers' cooling is of less importance.	Motivation of consumers' cooling gradually becomes important.	Motivation of consumers' cooling is essential.
			Expansion of CHP and use of biomass and waste are important.	Motivation of the integration of fluctuating RES is essential.

4th Generation District Heating

4th Generation District Heating (4GDH) system is defined as a coherent technological and institutional concept, which by means of *smart thermal grids* assists the appropriate development of sustainable energy systems. 4GDH systems provide the heat supply of low-energy buildings with low grid losses in a way in which the use of low-temperature heat sources is integrated with the operation of smart energy systems. The concept involves the development of an institutional and organisational framework to facilitate suitable cost and motivation structures.

4DH
4th Generation District Heating
Technologies and Systems

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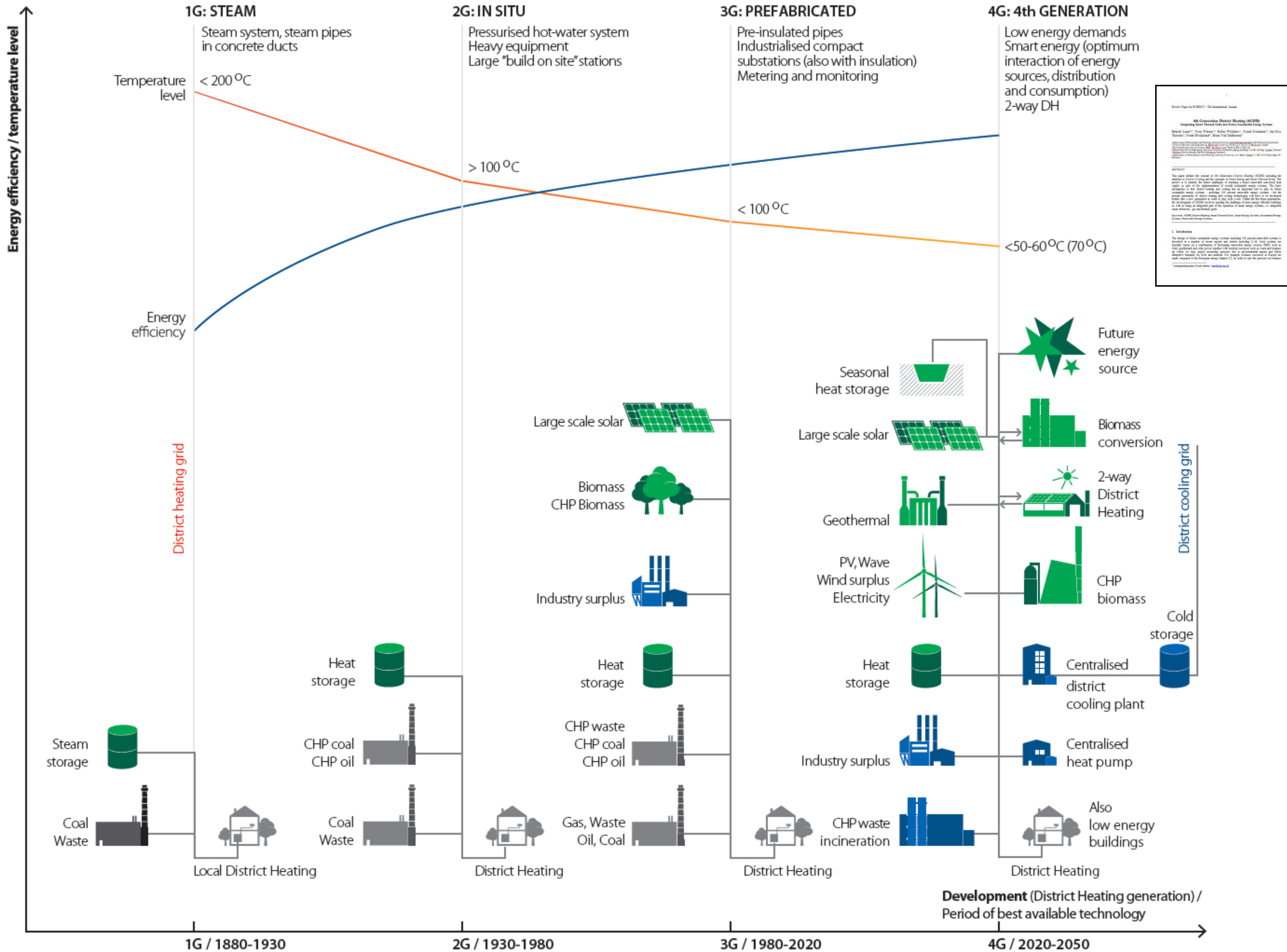
Energy efficiency / temperature level
1G: STEAM
Steam system, steam pipes
in concrete ducts
2G: IN SITU
Pressurised hot-water system
Heavy equipment
Large "build on site" stations
3G: PREFABRICATED
Pre-insulated pipes
Industrialised compact
substations (also with insulation)
Metering and monitoring
4G: 4th GENERATION
Low energy demands
Smart energy (optimum
interaction of energy
sources, distribution
and consumption)
2-way DH
Temperature level
< 200 °C
> 100 °C
< 100 °C
<50-60 °C (70 °C)
Energy efficiency
District heating grid
District cooling grid
Steam storage
Coal
Waste
Local District Heating
Heat storage
CHP coal
CHP oil
Coal
Waste
District Heating
Large scale solar
Biomass
CHP Biomass
Industry surplus
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
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

Main point today

Next consortium meeting
Is allocated for presenting
research results

Among others:

- Heat Roadmap Europe
- Heat savings (ZEB project)
- …..

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4th Generation District Heating Technologies and Systems

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4th Generation District Heating Technologies and Systems
Second PhD Seminar, 13 March 2014

Thank you

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