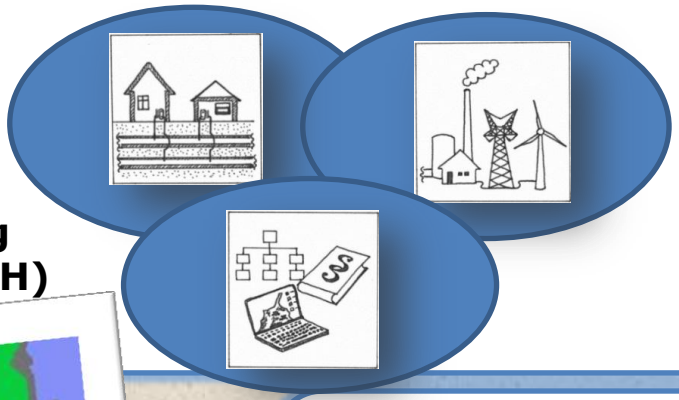
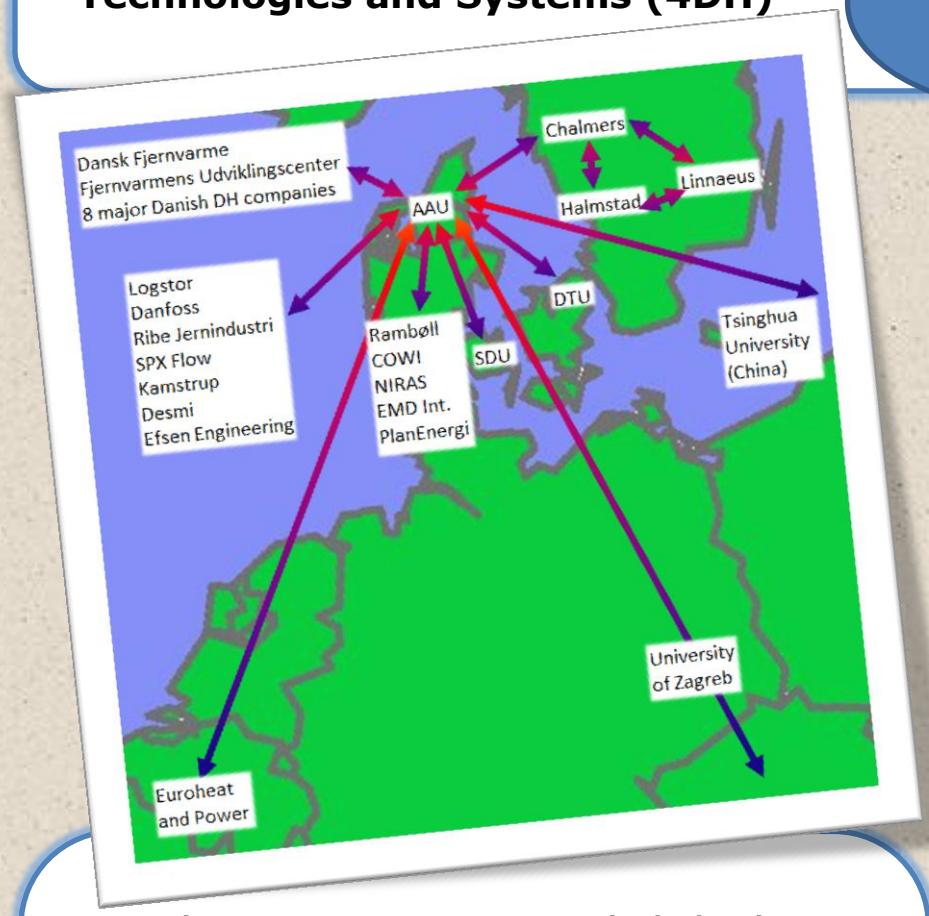
Appendix B: Project description

Strategic Research Centre for

4th Generation District Heating Technologies and Systems (4DH)





University partners

AALBORG UNIVERSITET

DTU

SYDDANSK UNIVERSITET

Tsinghua University

CHALMERS

Linnæus University

HÖGSKOLAN HALMSTAD

SVEUČILIŠTE U ZAGREBU

Private partners

RAMBØLL

COWI

NIRAS
-råd du kan regne med

EMD International A/S

PlanEnergi

District heating companies

VEKS

AALBORG KOMMUNE
FORSYNINGSVIRKSOMHEDERNE

københavns E

AFFALDVARME AARHUS

Ringkøbing-Skjern Kommune

VESTFORBRÆNDING

Fjernvarme Fyn

CTR – Centralkommunernes Transmissionsselskab I/S

Industrial partners

LOGSTOR

Danfoss

Aktieselskabet Ribe Jernindustri

SPX

Kamstrup
- metering solutions

THE DESMI GROUP

EFSEN ENGINEERING A-S

Dissemination partners

Fjernvarmens Udviklingscenter

Dansk Fjernvarme

EUROHEAT & POWER

Appendix B - Project description

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

1. Summary

The ***aim*** of the Strategic Research Centre is to assist in the development of 4th Generation District Heating Technologies and Systems (4GDH). Such development is fundamental to the implementation of the Danish objective of being fossil fuel-free by 2050 as well as the European 2020 goals. Moreover, the sector has a significant green growth potential. Currently, district heat is delivered to millions of end-consumers in more than 5,000 European systems. Denmark is one of the front runners with a district heating share of approx. 50 per cent and substantial exports of technology. At present, the Danish district heating industry employs more than 9,000 people and generates a turnover of approx. 20 billion DKK per year [1].

Recent studies conclude that district heating has the potential for playing an important role in the future in terms of utilising essential resources such as CHP, geothermal energy, industrial surplus heat, waste and biomass. On the other hand, district heating must co-exist with substantial energy savings and conservation measures in the heat demand. Consequently, district heating faces a significant challenge in terms of its ability to optimise, re-design and further develop the technological concept in order to decrease losses and, by the use of low temperatures, create a synergy between conservation and higher efficiencies in production.

The 4DH Centre will generate knowledge in, among others, the following areas: Design of future district heating network technologies including the development of components and concepts; planning and management tools based on Geographical Information System (GIS); and tools for decision-making support of the involvement of production units in electricity markets.

2. Objective of the project

The **scientific objective** is to establish a platform for the coherent development of 4th Generation District Heating Technologies and Systems in which synergy is created between the development of grids and components, house installations, district heating production and system integration, as well as planning and implementation tools and methodologies.

The **societal objective** is to further the understanding of the role of district heating in the design of future national energy systems seen in the light of the Danish objective of being fossil fuel-free by 2050 as well as the European 2020 goals.

A **further perspective** of the centre is to facilitate the development of additional national and international research projects as well as demonstration projects. The constitution of the Centre is suitable for such activities, since the participants include industry and universities as well as district heating companies.

3. The main results of the project

The anticipated result from which society will benefit is the creation of knowledge related to the development and implementation of future district heating technologies. Such knowledge is essential to society (at all levels of planning) due to the extensive time frame of district heating infrastructural investments. Moreover, such information is essential to the industry in terms of suitable innovation strategies, involving both individual components and network designs. It should be noted that the Centre will provide such information from different parts of the world. The anticipated scientific results are:

- better scientific understanding of the 4GDH concept based on technology theory,
- innovation of potential future district heating network technologies and designs,
- further development of combined coherent spatial databases, data infrastructures and energy planning tools based on GIS,
- strategies and software tools for decision-making support of local district heating supply companies with a focus on the integration into emerging electricity markets,
- the identification of future sustainable heating concepts seen from an energy system perspective,
- energy system analysis tools, methodologies and theories to conduct studies and scenarios of future sustainable energy systems in order to identify the role of district heating systems and technologies in various countries around the world, and
- theories and methodologies as well as the design of specific public regulation measures at the local, national and supranational levels to secure the implementation of these measures.

4. Background and hypothesis of the project

As an overall hypothesis, the Centre presupposes that district heating infrastructures have an important role to play in future sustainable energy systems, but the technology has to change. The official Danish goal is to create an energy system free of fossil fuels by 2050. A number of recent studies, including the IDA Climate Plan [2], The Climate Commission's report [3], Heat Plan Denmark [4], Efficient District Heating in the future energy system [5], and the CEESA project, financed by The Danish Council for Strategic Research [6], all come to the conclusion that district heating plays an important role in the implementation of such goal. However, the same reports also emphasise that the present district heating system must undergo a radical change into low-temperature district heating networks interacting with low-energy buildings as well as electricity smart 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). In recent state-of-the-art papers [8-10] and discussions [11-13], such future district heating technologies are defined as 4th Generation District Heating Technologies and Systems (4GDH).

The *first generation* of district heating systems [14] using steam as a heat carrier was introduced in the USA in the 1880s, and almost all district heating systems established until 1930 used this technology. Today, steam-based district heating is an outdated technology due to high losses and safety reasons. The technology is still used in, e.g., Manhattan, Paris, and partly in Copenhagen, but replacement programmes have been successful in Hamburg and Munich.

The *second generation* used pressurised hot water as a heat carrier, with temperatures typically above 100ºC. These systems emerged in the 1930s and dominated all new systems until the 1970s. Remains of this technology can still be found in the older parts of the current water-based district heating systems.

The *third generation* of systems was introduced in the 1970s and gained a major share of all extensions in the 1980s. Pressurised water is still the heat carrier, but supply temperatures are

usually below 100ºC. This technology is used for all replacements in Central and Eastern Europe and the former USSR. All extensions and all new systems in China, Korea, Europe, the USA and Canada use this third generation technology.

The development of these three generations has been directed at lower distribution temperatures, the creation of components requiring less material, and prefabrication resulting in lower man power involvement at the construction sites. Following these identified directions, a future fourth generation of district heating technologies should embrace lower distribution temperatures, assembly-oriented components, and more flexible materials.

The concept of 4GDH has been described in, among others, [8]. As opposed to the first three generations, the development of 4GDH involves meeting the challenge of more energy efficient buildings as well as the operation of electricity smart grids. The *4th Generation District Heating (4GDH)* system is defined as a coherent technological and institutional system. By use of *district heating smart grids,* the system implements sustainable energy systems in a suitable way; thus, providing heat supply to low-energy buildings with low grid losses by integrating low-temperature heat sources. The concept involves the development of an institutional and organisational framework for suitable cost and motivation structures [15].

Recent studies have investigated the feasibility of district heating in terms of implementing a sustainable energy system based on renewable energy and including substantial reductions in the space heating demand [6,16,17]. The studies conclude that the role of district heating is significant, but that district heating technologies must be further developed to decrease grid losses, exploit synergies, and thereby increase the efficiencies of low-temperature production units in the system. Renewable energy, together with energy conservation and combined heat and power production (CHP), is an essential factor in the climate change response in Europe as well as in many other regions [18-22].

Denmark is one of the leading countries in terms of implementing the combination of CHP, energy conservation and renewable energy [23]. The country's primary energy supply has been kept nearly constant for almost 40 years, and today, 50 per cent of the Danish electricity demand is met by CHP and approx. 20 per cent is produced from wind power. Moreover, a further expansion is intended. Important measures to further reduce the combustion of fossil fuels are to improve the energy efficiency in end-use and supply; to introduce or expand CHP; to include heat pumps; to utilise industrial waste heat, and/or to replace fossil fuels with residual resources such as waste or various biomass fuels [6]. However, all such policies involve the existence and further development of a district heating system.

The development of future district heating systems and technologies involves energy savings and conservation measures. The design and perspective of low-energy buildings have been analysed and described in many recent papers [24,25], including concepts like zero emission buildings and plus energy houses [26]. However, such papers mostly deal with future buildings and not the existing building stock which, due to the long lifetime of buildings, is expected to constitute the major part of the heat demand for many decades to come. Some papers address the reduction of heat demands in existing buildings and conclude that such effort involves a significant investment cost. The share of currently existing buildings in the building stock is expected to remain high for many years; i.e., 85-90 per cent of the stock in Denmark in the year 2030. No study has been found which identifies how to completely eliminate the heat demand in existing buildings within a reasonable time horizon. The first step towards the next generation of district heating systems is to change all existing district heating networks to low-temperature operation (50-60°C and higher temperatures in winter periods), and this may be implemented over a relatively short period of time (10 years). The second step includes the introduction of energy savings in the renovation of buildings and the replacement of fossil fuel-based heat supply with renewable energy systems. The creation and implementation of the new technologies are the focus of the 4DH Research Centre.

5. Innovative value, impact and relevance of the project

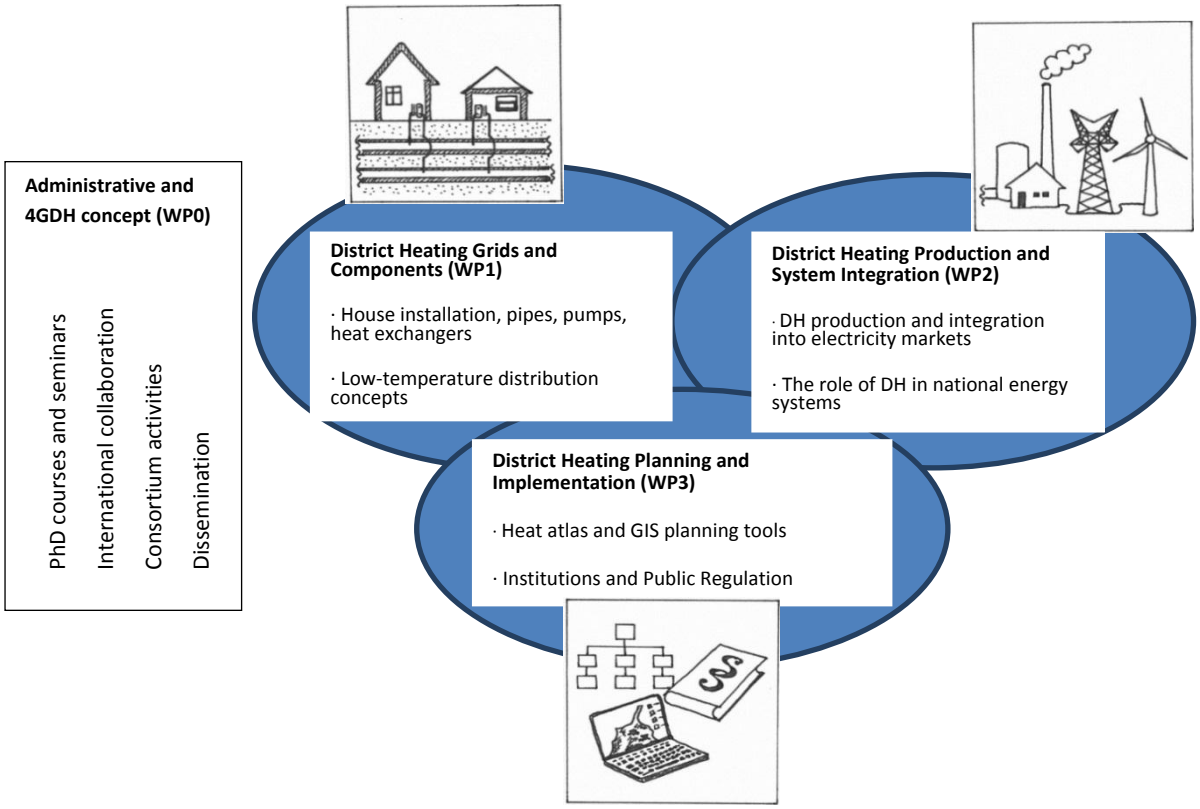
The research has high relevance and is by nature interdisciplinary and strategic: High **relevance,** since the research is fundamental to the implementation of the Danish objective of being fossil fuel-free by 2050 as well as the implementation of the European 2020 goals; **strategic,** because it concerns the implementation of long-term infrastructures of essential importance; and **interdisciplinary,** since such infrastructure cannot be implemented without the coordinated action in the development of technology itself as well as in the organisation involving ownership, tariffs and public planning. The **innovative values** of the project are:

- The establishment of an **interdisciplinary platform** on which different skills will create a synergy, such as, e.g., the synergy between energy conservation in houses, low-temperature district heating, and more efficient use of district heating production; or the synergy between the development of technical solutions and public planning and implementation measures.
- The establishment of a **multi-organisational collaboration** between industry and universities as well as district heating companies and consultancies. Such collaboration furthers the important link between, on the one hand, the development of new components and system integration and, on the other, testing, demonstration and implementation.
- The establishment of **international networks** between universities and institutions to strengthen research such as, e.g., when coordinating the Danish experience with district heating relations to electricity smart grids and the Swedish experience with interactions between transport biofuels and district heating.

Denmark is a world-leading country with respect to market intelligence, equipment supply and planning methods concerning the third generation of district heating systems. In many foreign cities, new district heating systems are initiated and developed by Danish consultants in the planning phase. Danish manufacturers also supply the corresponding equipment, especially distribution pipes and customer substations. Hereby, Denmark should take a strong interest in defending its unique number one world market position, when the fourth generation of district heating systems shall be developed. This project application for the fourth generation is written in the light of the current well-known, strong, and unique Danish market position within the world district heating sector.

6. Project's methodology and results

The research centre will provide a platform for the interdisciplinary approach to the development of 4DH organised as shown in the diagram below. Research will be carried out in three WPs (WP1-WP3), each including 4-5 PhD projects and 1 postdoc project in a collaboration between industrial and university partners. Additionally, a WP (WP0) is allocated for administrative as well as centre activities such as PhD courses, international collaboration, and dissemination. Moreover, WP0 includes the joint activities in the scientific and theoretical development of the 4GDH concept. All PhD fellows will be employed at the participating universities, while one third of the financing (a total of approx. 8 million DKK) will be transferred from the industrial partners to the universities.



The projects will emphasise the following areas:

Work package 0: Administrative and 4GDH concept

In addition to administration, international collaboration and dissemination, WP0 includes the further development of the theoretical definition and understanding of the 4GDH concept. Such effort will be headed by Prof. Henrik Lund and Prof. Sven Werner, but will naturally include inputs and contributions from all participants in the centre, including international partners, and relations outside the centre, e.g., in the European platforms for DHC (District Heating and Cooling).

The joint discussions on the 4GDH concepts and the understanding of these will serve as an important platform for the exchange of information and further collaboration between the different WPs. The platform will promote the understanding of the relationship between the individual efforts and the coherency of the research centre among the individual projects and participants. In addition, WP0 is responsible for the conduction of PhD courses and exchange programmes between the partners.

Work package 1: District Heating Grids and Components

This WP will focus on the research, development and evaluation of low-temperature district heating systems based on renewable energy. The research will basically provide new knowledge on the hardware and software technologies of the new generation of district heating systems supplying heat to existing buildings, that gradually become extensively energy renovated, and new low-energy buildings. The hypothesis is that low-temperature district heating, with a general supply and return temperature of 50°C and 20°C, can be used in existing district heating systems, if minor modifications are implemented in the systems for room heating and domestic hot water supply of the existing buildings. The immediate implementation of the low-temperature technology (10 years) in existing and new district heating systems and buildings makes it possible to use low-temperature renewable heat from geothermal plants and central solar heating plants as well as waste heat from industrial processes directly and thereby replace fossil fuels and imported biomass in the district heating systems. The results of WP1 are used in the other WPs to identify the overall optimal way of realising the energy system without the use of fossil fuels. The WP includes the following sub-projects:

WP 1.1. Heating of existing buildings by low-temperature district heating

The hypothesis of this project is that it is possible to heat all types of existing buildings with a hydronic heating system by use of low-temperature district heating with a supply temperature of 50°C, except for short periods with very cold weather when a higher temperature is supplied. By use of detailed simulation calculations of the typical buildings, the realistic dynamic heating load is calculated and compared to the heating power of the existing heating elements with a low supply temperature. The conversion of the heating system to low-temperature operation should be the first step of a specific plan for a thorough energy renovation of the typical buildings.

WP 1.2. Supply of domestic hot water at comfort temperatures without Legionella

The hypothesis of this project is that it is possible to change the operation of existing domestic hot water systems (DHW) in all types of buildings to a comfort temperature of 40°C without risk of Legionella. Two types of solutions are investigated: (1) Local production of DHW in highly efficient compact heat exchangers with a very small volume of DHW in the pipes to the tap; and (2) UV-sterilisation of the water entering and circulating in the DHW system of buildings with a circulation loop for DHW supply.

WP 1.3. Conversion of existing district heating grids to low-temperature operation and extension to new areas of buildings

The hypothesis of this project is that it is possible to convert/extend the existing DH grid to the low-temperature DH concept with typical supply/return temperatures of 50/20°C to the areas with low-energy demand buildings. Thereby it becomes possible to supply renewable heat to new and renovated buildings in city areas at a competitive price compared to alternative decentralised renewable energy supply systems. This project's focus is on the extension of district heating grids to areas where the existing buildings will be energy renovated over the next decades or newly built areas with low-energy demand buildings.

WP 1.4 Minimising losses in the DH distribution grid

The losses in DH grids are a major obstacle to the utilisation of renewable heat sources and waste heat. A significant reduction in the distribution heat losses is gained by the introduction of low-temperature DH. The hypothesis of this project is that it is possible to develop and utilise technical solutions by which the total thermal, temperature and electrical losses in DH distribution systems can be further reduced. Modelling and simulation of the total distribution grid, including modelling of the individual components, will be carried out. The model will be able to identify and eliminate potential component sub-optimisation and point out other potential critical focus areas in the DH grid. The project will include a review of innovative designs and concepts of distribution pipes and other components.

Work package 2: District Heating Production and System Integration

The hypothesis of this WP is that 4DH has an important role to play in efficient future energy systems. The WP will develop energy systems analysis tools, methodologies and theories for the study and scenario-building of future sustainable energy systems with the aim of identifying the role of district heating systems and technologies in various countries. The European project partners will engage in the development of EU policies and strategies to define the role of district heating, and similar activities will be carried out by the Chinese partner. This includes an investigation of the balance between heat savings and heat supply as well as the balance between the supply of individual houses through collective or individual systems, respectively. Moreover, the WP focuses on the development of strategies and software tools for decision-making support to local DH companies and energy planners. This involves a change in the operation as well as the step-by-step investment, from fossil fuel-based CHP plants mainly on the spot market to plants based on renewable energy resources at all levels of the electricity markets. The work package includes the following parts:

WP2.1: The role of 4DH in energy systems with focus on Denmark, Europe and China

The hypothesis is that 4DH and low-energy buildings will contribute to the creation of thermal comfort in the future. The research will be based on knowledge from Heat Plan Denmark and the strategic research centre NZEB, but will also reach further into the future with an aim of investigating scenarios for Danish heating sectors. Of particular focus is a) the balancing between, on the one hand, individual heating technologies and, on the other hand, communal solutions, and b) the borderline between heating and energy savings. Hence, the work will develop methodologies and investigate the extent to which DH is favourable compared to individual heating, and the extent to which energy savings are favourable compared to heating supply and, hence, also concepts like passive and active houses seen in an energy system perspective. Similarly, the role of 4DH on a European scale as well as in China will be targeted.

WP2.2: Integration of energy systems

The hypothesis is that storage will be a necessity in future energy systems based on fluctuating renewable energy sources. WP2 will develop methodologies of analysis and investigate the means of adding system flexibility through geothermal storage for steam and hot water as well as other storage options. Steam and heat storages enable the temporal separation of electricity and heat production from waste incineration. Conventional distributed CHP mainly assists the energy system by means of its high efficiency, but 4DH will assist the energy system additionally through its flexibility. Research will develop tools and focus on investigating the investment and daily operation strategies for distributed CHP, when these plants are participating across more wholesale markets and balancing markets. Furthermore, it will focus on the needed interaction between the plants when optimising market participation.

WP2.3: Energy resources for district heating systems

The hypothesis is that electricity and heat productions are moving away from storable fossil fuels and that combustible biomass and waste resources are being limited in quantity. Therefore, future heating systems will, to a higher degree, be based on absorption or compression heat pumps exploiting heat resources at modest temperatures. This work will investigate various sources of low-temperature heat, their applicability to national energy systems as well as their potential for energy savings. This includes geothermal energy and heat from industrial processes, waste heat from cooling systems in retail and foodstuff, and even air conditioning. Waste plays an important role in the Danish energy system and will be given particular attention. A model for determining the waste available for district heating plants, seen in company, macro-economic, and European perspectives, will be developed.

Work package 3: District Heating Planning and Implementation

This WP focuses on the further development of the planning and management systems based on spatial analysis and geographical information systems (GIS) as a tool for planners and decision-makers. This includes the further advancement of theories and methodologies as well as the design of specific public regulation measures. The latter will focus on how to manage the conflict between implementing energy conservation in buildings and, at the same time, utilising available low-temperature heat sources in district heating, seen from planning, organisational and legal perspectives. The work package includes the following sub-projects:

WP 3.1: Strategic energy planning in a legal perspective

Hypothesizing that heat planning is challenged by outdated and obsolete plans, emerging low-energy buildings, increased waste incineration and surplus wind energy, this part focuses on the legal aspects of future strategic energy planning. The commitment to heat plans jointly made by municipalities, supply companies and other parties has weakened since 1990, when written plans became optional. Planning is challenged by renewable energy and energy efficiency. Energy price change, technology development and land use change affect the zoning of heat supply, further confronted by the complaint system and legislation. The legal obligations of district councils are considered and a comparison is made of the obligations and the actual behaviour of councils.

WP 3.2: Innovative strategic energy planning and socio-economic development

The hypothesis here is that new technologies will not appear automatically and they do not by design result in a strong socio-economic development. Innovative strategic energy planning is aimed at technological solutions within renewable energy and energy conservation at the consumer level, which may have a larger part of their value added close to the consumers than fossil technologies; thus, generating vital socio-economic development. Research relates to the ability to invest subject to demographic changes and urbanisation; location in the country; support and organisation of financial institutions, consultancies and businesses; ownership models; and the promotion of regional socio-economies. A systematic innovative planning methodology will be developed to support the reaping of potential socio-economic benefits.

WP 3.3: Energy atlases to support planning

The premise is that energy demand and supply, energy savings and new supply, renewable energy resources, as well as associated costs can be mapped in spatial databases called Energy atlases. Looking back on a long tradition in Denmark, heat atlases mapped the heat supply and delivered consistent geographical energy data until the early 2000s. Theories, methods and tools are to be developed and tested in participating utilities and municipalities, combining technical data with demographic and socio-economic data to facilitate strategic energy planning. As a product, an energy atlas for Denmark will locate and quantify the current energy system, the potential, and the associated costs of energy efficiency, validated by using real demand for any scale and unit.

WP 3.4: Price regulation, tariff models and sector ownership

The hypothesis here is that incentives can promote rational and efficient behaviour to the benefit of consumers and society. District heating is a monopoly, strictly regulated in terms of prices and tariff models. Price regulating mechanisms have developed over time, leaving a heterogeneous sector with many individual companies. Ownership has changed in recent years, from consumer and municipal to commercial ownership, but leaving the price regulating mechanism unchanged. This part will propose price regulation modes including elements such as benchmarking and income brackets, a split between fixed and variable tariffs, pricing of supply to DH networks, differentiated prices, cross subsidisation, and entry into markets.

7. Project plan

The research in the 4DH research centre is implemented in four work packages each comprising several sub-topics and each with strong interrelations to one another, as described above. In principle, the research includes more than four areas. However, in order to further the interrelations, the sub-projects have been merged into three major WPs and one administrative WP, which also includes the research related to the development of the 4GDH concept itself. As part of such organisation, the centre introduces a chair/co-chair management structure in which four WPs will each be headed by a WP leader and a deputy. Moreover, a research leader will be allocated to each activity. All activities include the active involvement of the industrial partners in addition to the co-financing of PhD projects. Such activities are listed below and the size is indicated in "manpower months" below. (Several industrial partners participate in more than one WP but are here mentioned only once):

Work Package 0: Administration and development of overall concept
(WP leaders: Prof. Henrik Lund and Ass. Prof. Brian Vad Mathiesen)

- WP0.1: Scientific and theoretical development of the 4GDH concept
- WP0.2: PhD course activities and international collaboration
- WP0.3: Dissemination
- WP0.4: Centre administration

Work Package 1: District Heating Grids and Components
(WP leaders: Prof. Svend Svendsen and Ass. Prof. Carsten Bojesen, Industry: 25 Months)
(Industrial partners: Danfoss, Rio, Kamstrup, SPX, AffaldVarme Århus, Efsen/Wallenius, Desmi)

- WP1.1: Heating of existing buildings by low-temperature district heating
- WP1.2: Supply of domestic hot water at comfort temperatures without Legionella
- WP1.3: Conversion of existing district heating grids to low-temperature operation and extension to new areas of buildings
- WP1.4: Minimising losses in the DH distribution grid

Work Package 2: District Heating Production and System Integration
(WP leaders: Ass. Prof. Poul Østergaard and Head of Department Anders N. Andersen, Industry: 25 Months)
(Industrial partners: Logstor, EMD, Vestforbrænding, Aalborg Forsyningsvirksomhederne, Rambøll, PlanEnergi)

- WP2.1: The role of 4DH in energy systems with focus on Denmark, Europe and China
- WP2.2: Integration of energy systems
- WP2.3: Energy resources for district heating systems

Work package 3: District Heating Planning and Implementation
(WP leaders: Ass. Prof. Bernd Möller and Prof. Bent Ole Gram Mortensen, Industry: 25 Months)
(Industrial partners: VEKS, CTR, NIRAS, Fjernvarme Fyn, Ringkøbing-Skjern kommune, Københavns Energi)

- WP3.1: Strategic heat planning in a legal perspective
- WP3.2: Innovative strategic energy planning and socio-economic development.
- WP3.3: Energy atlases to support planning
- WP3.4: Price regulation, tariff models and sector ownership

13 PhDs and 3 postdocs will be hired in the centre. However, more will be expected to enrol as new companies may be involved and some of the activities may expand. Each of the three WPs (WP1-WP3) includes 4 PhD projects and 1 postdoc project in collaboration between industrial

and university partners. All PhD fellows will be employed at the participating universities, while one third of the financing (a total of approx. 8 million DKK) will be transferred from the industrial partners to the universities. Additional to the PhD financing, each company contributes with significant staffing (6 years in total) as well as material and components. Each of the universities already has a number of relevant activities within the field. Funding for salary and travel will be given from the centre to professors at the international universities.

Milestones and the distribution of work among the partners are shown in the table and the diagram below, including the distribution of PhDs and postdocs. However, as this is a large centre activity, changes may occur during operation.

Work Package		**Milestone**	**Due Date**
No	**Title**		
0	Administration and development of overall concept	Steering Committee meetings	1/year in March
		Advisory Board meetings	1/year with centre meetings
		Homepage	June 2012
		Newsletter	2/year in February and September
		PhD courses	1/year
		Centre workshop, seminar or conference	1/year in March
		Dissemination seminars	1/year (maybe together with centre conference)
1	District Heating Grids and Components	Start of PhD projects in WP1.1, WP1.2, and WP1.4	July 2012
		Preliminary Results from WP 1.1 and WP1.2. Input to WP1.3	December 2013
		Start of PhD in WP1.3	January 2014
		End of PhD projects in WP1.1 and WP1.2 and WP1.4	January 2014
		End of PhD project in WP1.3	December 2017
2	District heating Production and System Integration	Energy scenarios for Denmark	Summer 2016
		Thermal storage in DH systems	Summer 2015
		Distributed CHP plants optimized across more electricity markets	Summer 2015
		Low temperature energy sources for DH	Summer 2016
3	District Heating Planning and Implementation	Centre workshop "Energy Atlases"	October 2012
		Working Energy Atlas available	December 2013
		Road map for strategic municipal energy planning	May 2014
		Innovative energy planning guidelines to support the harvesting of potential socio-economic benefits	May 2016
		Dissemination conference "Strengthening the information basis for strategic energy planning"	January 2017

WP no.	Name	WP leaders / responsibles	2012	2013	2014	2015	2016	2017	Participants
0	**Administration and development of overall concept**	Henrik Lund and Brian V. Mathiesen							
	0.1 Scientific and theoretical development of the 4DGH concept	Henrik Lund and Sven Werner							HL, SW and all
	0.2 PhD course activities and international collaboration	Henrik Lund and Brian V. Mathiesen							HL, BVM and all
	0.3 Dissemination	Henrik Lund and Brian V. Mathiesen							HL, BVM and FjvU, Da Fjv, Euro Heat and Power
	0.4 Centre administration	Henrik Lund and Brian V. Mathiesen							HL, BVM, MRS/PSA and WP-l.
1	**District Heating Grids and Components**	Svend Svendsen and Carsten Bojesen							
	1.1 Heating of existing buildings by low-temperature district heating	Svend Svendsen							SS (PhD Stud), Kamstrup, Rio, Danfoss
	1.2 Supply of domestic hot water at comfort temperatures without Legionella	Svend Svendsen							SS (PhD Stud), Efsen, Danfoss
	1.3 Conversion of existing district heating grids to low-temperature operation and extension to new areas of buildings.	Carsten Bojesen							CB (PhD Stud), SPX, COWI
	1.4 Minimising losses in the DH distribution grid	Carsten Bojesen							CB (PhD Stud), Desmi, Logstor
2	**District Heating Production and System Integration**	Poul A. Østergaard and Anders N. Andersen							
	2.1 The role of 4DH in energy systems with focus on Denmark, Europe and China	Brian Vad Mathiesen							DC, BVM, NN (PhD stud), Lostor
	2.2 Integration of Energy Systems	Anders N. Andersen							ANA, PAØ, HL, NN (2 PhD stud), EMD, Vestforbr.
	2.3 Energy resources for district heating systems	Poul Østergaard							SW, NN (PhD stud), Aalborg, Rambøll
3	**District Heating Planning and Implementation**	Bernd Möller and Bent Ole G. Mortensen							
	3.1 Strategic energy planning in a municipal and legal perspective	Bent Ole Gram Mortensen							BOGM (PhD stud), Fjv Fyn
	3.2 Innovative strategic energy planning and socio-economic development	Frede Hvelplund							FH, BOGM (PhD stud), NIRAS
	3.3 Energy atlases to support planning	Bernd Möller							BM, KK (2 PhD stud), CTR etc.
	3.4 Price regulation, tariff models and sector ownership	Bent Ole G. Mortensen and Frede Hvelplund							BOGM, FH, KE, VEKS

Time schedule and allocation of resources

8. Project's international dimension

The international dimension of the centre has a two-fold purpose. Firstly, the centre involves the expertise of countries in areas in which they, in terms of both development and research, are ahead of Denmark. Secondly, the centre involves the international development and understanding of 4GDH future district heating markets with a focus on China and Europe including the East European market. The centre includes the following key experts and world-leading universities:

- Tsinghua University (rated no. 1 in China), representing the huge and emerging markets of China. Formal agreements between AAU and Tsinghua have already been made at the university presidents' level. As part of such agreement, world-leading researcher Prof. Xiliang Zhang has committed his department to a close collaboration on energy systems of future sustainable energy solutions.
- Chalmers Technical University (Deputy Head of Department Erik Ahlgren) represents the Swedish world-leading expertise within the area of interactions between transport biofuels and district heating as well as other relevant issues. Such knowledge will be included in WP2 and add to - and interact with - the Danish stronghold within electricity smart grid interaction. The participation of Chalmers will include PhD student mobility between the participating universities.
- Halmstad University, Sweden (Professor Sven Werner) represents world-leading expertise in the development and understanding of existing district heating technologies at the international level and has been the first to formulate and advocate the 4GDH concept. Halmstad will host a PhD and be involved in the further development of the 4GDH concept in WP0 as well as tools, data and methodologies to establish the foundation for, among others, a European road map for district heating as part of the fulfilment of the European 2020 goals.
- Linnaeus University (Professor Leif Gustavsson) represents the Swedish world-leading expertise within the area of interactions between district heating systems and improved energy efficiency in the built environment in a life-cycle perspective, in particular for biomass-based polygeneration of district heat and other energy carriers, to minimise primary energy use and greenhouse gas emissions.
- Euroheat and Power will use already established platforms and further seek to raise a European research project by which the tools and methodologies mentioned above will be made active to influence the European market.
- University of Zagreb – Faculty of the Mechanical Engineering and Naval Architecture in Croatia, representing the many East European district heating networks. An informal collaboration between Zagreb and AAU (including exchange of staff) has already been conducted for several years with world-leading scientist Prof. Neven Duic as a key person. The centre will establish a joint postdoc position in the field of energy systems analysis with a focus on the role of district heating including 4GDH in the East European context.

The international dimension of the centre thus gives a lift to Danish research as well as the establishment of international networks to further the development and implementation of suitable technologies to fulfil the political goals.

9. Legal and ethical aspects, etc.

At present, no legal or ethical aspects are foreseen in terms of research, innovation or testing.

10. Publication and promotional strategy and exploitation of results

The centre will lead an active publication, promotional and exploitation strategy with four focus areas:

Interaction with the **international research society** will be carried out via the publication of research results in peer-reviewed journals and by the participation in important conferences. The international dimension of the centre facilitates such publication and promotion strategy, since the participants include the editor-in-chief of Elsevier International Journal ENERGY as well as associate editor and/or editorial board positions of a number of other relevant journals (Applied Energy, Renewable Energy, International Journal of Energy Technology and Policy). A special issue of one of these journals will be proposed during the period to strengthen the attention to the topic. Moreover, the participants include principle organisers and scientific committee members of important conferences within the field. Special sessions on one or more conferences will be proposed during the period.

Dissemination of knowledge via **Master educational and PhD programmes** is an important part of the centre. In itself, the centre contains 3 postdoc and 12 PhD projects and, as part of WP0, the centre will establish new PhD courses as well as update the curricula of existing Master and PhD courses at the participating universities. Moreover, the centre will organise PhD student mobility between the participating universities as well as additional relevant universities and institutions.

The centre focuses on the potential for innovation and commercialisation. Consequently, a key element in the centre is the interaction with **industrial partners as well as commercial organisations and public authorities**. Such activity is a two-way communication. Additional to the dissemination of results from the centre, such interaction will also provide a forum for valuable input from the sector to the research activities within the centre. To highlight the implementation of such activities, the centre will include the Danish District Heating Association and Euroheat & Power together with the Danish District Energy Development Centre (Fjernvarmens Udviklingscenter). These organisations represent the district heating sector and will be in charge of facilitating seminars, etc., to secure such interaction. Such activities will have a focus on the potential for innovation and commercialisation with relevant public and private sector actors, which may then lead to the involvement of further participants in the research centre.

A further perspective of the research centre is to influence the **international agenda primarily in Europe and China**. The international dimension of the centre facilitates such strategy and will be assisted by the involvement of Euroheat & Power. One of the first concrete activities will be to establish a European platform (research project) for the development of a European road map for district heating and cooling. Such activity will be supported by the tools, data and methodologies included as part of the centre activities.

The developed tools to map, analyse and plan future district heating systems will be disseminated in **relevant European networks** and will form a basis for participation in the EU FP7 project "**Transitioning Urban Resilience and Sustainability**", beginning in November 2011 with AAU as a partner, as well as the European Energy Research Alliance (EERA) project "**Smart Cities**" with DTU-Risø and AAU as partners.

11. The participating parties, project management and - if relevant - a description of the centre function or alliance function

The centre focuses on the potential for innovation and commercialisation. Thus, the participants include three Danish universities in collaboration with key international partners as well as some of the most important industries within the sector, i.e., Logstor, Danfoss, Kamstrup, DESMI and SPX Flow Technology (APV), together with the major consultants and software developers, i.e., EMD International, Rambøll, COWI, NIRAS and PlanEnergi. Moreover, the major district heating companies in Aalborg, Aarhus, Odense and Copenhagen participate including two major DH production companies, i.e. Vestforbrænding and AffaldVarme Aarhus.

The three Danish university partners are Aalborg University (AAU), University of Southern Denmark (SDU) and the Technical University of Denmark (DTU). The participating researchers include Prof. Henrik Lund from the Department of Development and Planning, Aalborg University (AAU), Prof. Svend Svendsen from the Department of Civil Engineering, Technical University of Denmark (DTU), Prof. Bent Ole Gram Mortensen from University of Southern Denmark (SDU), and Prof. Poul Erik Morthorst from Risø National Laboratory for Sustainable Energy (DTU-Risø). Moreover, the Centre involves collaboration with key experts in the field of energy systems analysis from the following world-leading universities: Tsinghua University (Prof. Xiliang Zhang), China; Chalmers Technical University (Deputy Head Eric Ahlgren) in collaboration with Halmstad University (Prof. Sven Werner), Sweden, Linnaeus University (Prof. Leif Gustavson), Sweden and Zagreb University (Prof. Neven Duic), Croatia.

The management objective is: Efficient, flexible, and proactive centre management with a clear distribution of responsibilities that is transparent to all partners. The plan is to closely coordinate the work on the different relevant projects carried out by the centre's researchers at their individual institutions or companies, so that the activities supplement each other and pull in the same direction.

Professor M.Sc.Eng. PhD. Dr.Techn. Henrik Lund, Aalborg University, will be the ***Head of Centre***. Henrik Lund has experience as the project leader of several research projects including the EU project DESIRE (2005-2007) involving various European partners. For six years, he held the position as the Head of the Department of Development and Planning at Aalborg University, with a staff of about 200 employees. At present, Henrik Lund is the coordinator of the strategic research project CEESA, which will be finalised in 2011. Consequently, Henrik Lund will be able to put his efforts into the work of the new research centre.

The project will introduce a chair/co-chair management structure. Consequently, the Head of Centre will have a Deputy Head, Ass. Prof. Brian Vad Mathiesen, and the three WPs will each be headed by a WP leader and a deputy:

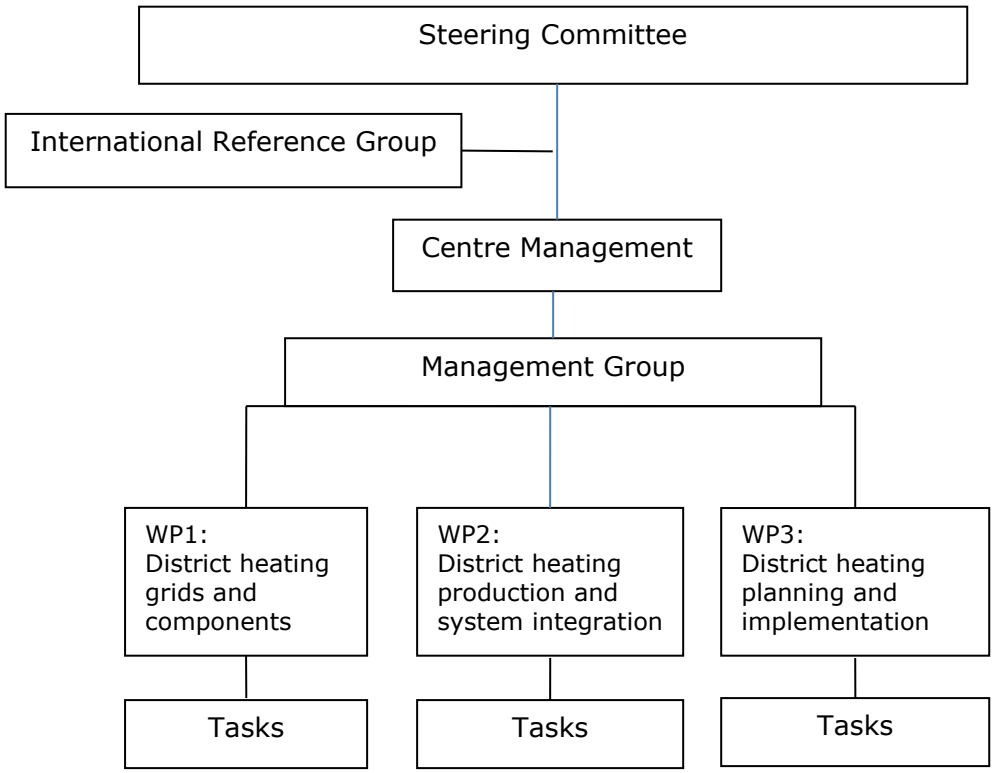
WP1: Prof. Sven Svendsen and Ass. Prof. Carsten Bojesen
WP2: Ass. Prof. Poul Østergaard and Head of Department Anders N. Andersen
WP3: Prof. Bent Ole Gram Mortensen and Ass. Prof. Bernd Möller

The idea of this structure is two-fold. It involves the different partners in a solid management structure. It also provides the framework for the "education" of future research project managers.

The project is organised as follows:

- ***The Steering Committee*** has the overall responsibility for the management of resources and progress. The Committee is an assembly consisting of the head of centre, the deputy and research managers from each partner. The committee meets **once or twice a year** to make decisions on the progress of the activities and the allocation of resources based on research performance and directions, perspectives and strategies seen from both academic and industrial viewpoints and in terms of the objective of the centre.

- ***The International Reference Group*** consists of selected recognised researchers from the involved universities (national and international). The International Reference Group will meet preferably **once a year** in connection with relevant international activities.
- ***Centre Management*** is responsible for the daily technical and administrative management of the research centre and consists of the head of centre together with the deputy, the administrative and financial manager. **They meet on a daily basis**.
- ***The Management Group*** is responsible for the daily technical and administrative management of the research centre and the coordination between WPs, and consists of the head of centre together with the WP leaders and/or deputies and the administrative and financial manager. **They meet on a monthly basis.**
- ***Technical Groups*** for each WP (WP1-WP3) consists of the leader, the deputy and the leading researchers for each of the sub-tasks in the WP. The technical groups are formed to ensure the close coordination of the work on the different projects carried out by the centre researchers at their individual institutions or companies. All partners will have access to participate in the working groups. **They meet on a weekly or monthly basis**.



All legal aspects related to rights and patents are handled by the involved institutions. A collaboration agreement is drafted and signed before the project starts. To ensure scientific excellence, break-through findings, the efficient use and allocation of resources, leading research education, international status as well as industrial interaction, an external mid-term review of the centre will be organised with international referees.

Centre activities

In order to facilitate internal cooperation and the exchange of knowledge between researchers at the different participating institutions and companies and to disseminate results, exchange

information and receive feedback from the international reference group, a 2-day workshop/conference will be arranged every year. The first day will focus on open presentations and discussions of results between researchers within and across the different WPs. This part will also be open to relevant national and/or international researchers as well as industries and companies in order to promote exchange and get feedback. The second day will concentrate on research workshops and PhD seminars to report and discuss in detail the progress. This workshop will serve as input to the steering committee as well as the management group and the WP leaders. It is the vision of the centre to facilitate the development of additional national and international research projects as well as demonstration projects. The constitution of the centre is suitable for such activities, since the participants include industry and universities as well as district heating companies.

Danish university participants

From the *Department of Development and Planning, Aalborg University (AAU-DDP),* a group of researchers will participate with many years of experience in the interdisciplinary interaction between energy system analysis, feasibility studies and the design of public regulation measures. Dating back to 1976 and up until now, the researchers have been actively involved in the development of theories, methodologies and tools for the design of alternative energy plans and strategies. Recently, the research team has been involved in the design of "Heat Plan Denmark", the Future Climate Plan of the Danish Society of Engineers, as well as energy plans for the towns of Frederikshavn and Aalborg. The team has a long record of publications within the subject and holds the editor-in-chief position of the international Elsevier journal Energy.

From the *Department of Energy Technology, Aalborg University (AAU-IET),* a group of researchers from the thermal section will participate. The thermal section is specialised in heating and cooling technologies such as heat exchanging equipment and systems and heat pumps ranging from household units to large-scale CHP plants.

From the *Department of Civil Engineering, The Technical University of Denmark (DTU-BYG),* Prof. Svend Svendsen's group specialising in building energy will participate. The group is very active within the research of low-energy buildings and low-temperature district heating. The research activities of the group are focused on the development and optimization of the new or improved technical solutions that will eliminate the use of fossil fuels in buildings based on an optimal combination of extensive energy savings and renewable energy supply. The new low-temperature district heating technology is investigated in relation to both new and existing buildings and district heating networks.

From the *Department of Energy Systems, The National Laboratory for Sustainable Energy at Risø (DTU-Risø),* a group of researchers including Prof. Poul Erik Morthorst with years of experience within energy system analysis, heat savings and economics will participate. The researchers have been involved in several relevant research projects, recently in the Future Climate Plan of the Danish Society of Engineers, the research project Efficient District Heating in the Future Energy System and are still active in the Centre for Energy Environment and Health (www.ceeh.dk) and as consultants for the Danish Commission on Climate Change.

From *University of Southern Denmark (SDU),* Prof. Bent Ole Gram Mortensen will participate. Gram Mortensen is professor in Commercial Law, a chair including especially Environmental and Energy Law, and, for a number of years, he has been engaged in the legal aspects of the grid-bound energy services. Gram Mortensen is, among others, member of the Danish Energy Board of Appeal and Chairman of the Valuation Authorities in the Region of Southern Denmark in compliance with the "VE-lov" [Renewable Energy Act]. He has worked with districting heating law for a number of years and is the author of *Municipality Planning of District Heating* [Kommunal varmeplanlægning i retlig belysning] and *A commentary to the Danish Heat Supply Act* [Varmeforsyningsloven med kommentarer].

International university participants
The research centre includes the *active* participation of world leading experts within the subject, i.e. from *Chalmers, Halmstad and Linnaeus universities in Sweden,* Profs. Sven Werner, Leif Gustavsson and Erik Ahlgren; from *Tsinghua University* in Beijing, China, Prof. Xiliang Zhang; and from *Zagreb University* in Croatia, Prof. Neven Duic. These participants are all included in the budget, of which the partner typically contributes with 50%, and play an active and important role. For further details, please consult section 8 Project's international dimension.

District heating production, transmission and distribution companies
The centre includes the major district heating production, transmission and distribution companies described in the following. *VEKS* – also known as Vestegnens Kraftvarmeselskab I/S - is a district heating transmission company supplying heat to 19 local district heating companies in the western suburban area of Copenhagen. *AffaldVarme Aarhus*, with an annual turnover of approx. DKK 2.8 bn. and approx. 280 employees, supplies almost 95% of the citizens of Aarhus with district heating and is responsible for the operation of the waste incineration CHP plant in Lisbjerg. *Fjernvarme Fyn* is a district heating company supplying heat and 'hot water' to 200,000 residents of Odense and Otterup on the island of Funen. Fjernvarme Fyn obtains heat from many sources: coal-fired CHP, straw and waste incineration, heat recovery from the paper industry and biogas. *Copenhagen Energy* supplies town gas (0.25 million residents), district heating (0.5 million), district cooling, water (1 million) and sewerage (0.5 million) to the Danish capital. The company has 700 employees and a turnover of DKK 4.5 bn. The Public Utility Companies, Aalborg Municipality, are Aalborg's supplier of gas, district heating, water, sewerage and waste disposal. The Public Utility Companies supply approx. 125,000 of the municipality's approx. 200,000 citizens with district heating. Approx. 60 % of the heat is produced by cogeneration at Nordjyllandsværket and approx. 40 % is surplus heat primarily from the cement production at Aalborg Portland and waste incineration at Reno-Nord.

District heating software and consultancy companies
The following two SMEs and three major consultancy companies are included: *PlanEnergi,* a Danish consultancy SME with 25 employees specialising in renewable energy, environment, sustainable systems, energy planning and technology transfer; *EMD,* a software SME, specialising in tools for wind energy and the integration of CHP into district heating as well as electricity smart grids; *Ramboll*, founded in Denmark in 1945, today with close to 10,000 experts and more than 200 offices in 23 countries; *NIRAS* with more than 1200 employees located in offices in Europe, Asia and Africa; and *COWI,* a leading international consultancy firm, which provides state-of-the-art services within the fields of engineering, environmental science and economics. District heating has, for many years, been a core competence of all these companies and together they represent many years of world-wide experience within the sector, including the participation in various research and development projects.

District heating component manufacturers
The following major district heating component manufacturers are included: *Danfoss A/S – Danfoss District Energy,* an international group and leader in the research into and development and production of mechanical and electronic components and solutions. *LOGSTOR*, the world's leading manufacturer of pre-insulated pipes for energy-efficient transport of gases and liquids for district energy (district heating and cooling, solar, marine and industrial purposes) and oil and gas. *Kamstrup*, world leading manufacturer of district heating meters; *SPX/APV,* Kolding Denmark, has produced plate type heat exchangers for

district heating since 1985. Most of the installed base of heat exchangers in the district heating segment in Denmark is produced by SPX/APV. The range of SPX/APV plate heat exchangers covers applications from large power plants through district heating distribution stations and down to individual household units. The *DESMI* group with head office is in Aalborg, Denmark, which develops, manufactures, sells and provides service of pumps and pumping systems, environmental equipment, and special products related to these areas. DESMI A/S operates globally in the sale and sourcing of components. Sales are affected both directly and through wholly or partly owned companies, agents, and distributors. *Efsen Engineering* is a Danish SME engineering and trading company founded in 1986 with focus on radiation technology within the fields of UltraViolet radiation curing, Electron Beam applications, and Water Disinfection by means of UV-light. Efsen Engineering is working in cooperation with Wallenius Water AB, who is at the leading edge of sustainable water purification. Years of research and experience have gone into the development of their patented product Wallenius AOT. In the research centre, Efsen engineering supported by Wallenius participates in the research related to ultraviolet radiation of low temperature hot water supply.

Network and Dissemination partners

Additional to the partners mentioned above, the research centre will include the Danish District Heating Association and Euroheat & Power together with the newly established Danish District Energy Development Centre (Fjernvarmens Udviklingscenter). These organisations represent the district heating sector and will be actively involved in the centre to secure an efficient dissemination of knowledge.

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