The Smart Energy System

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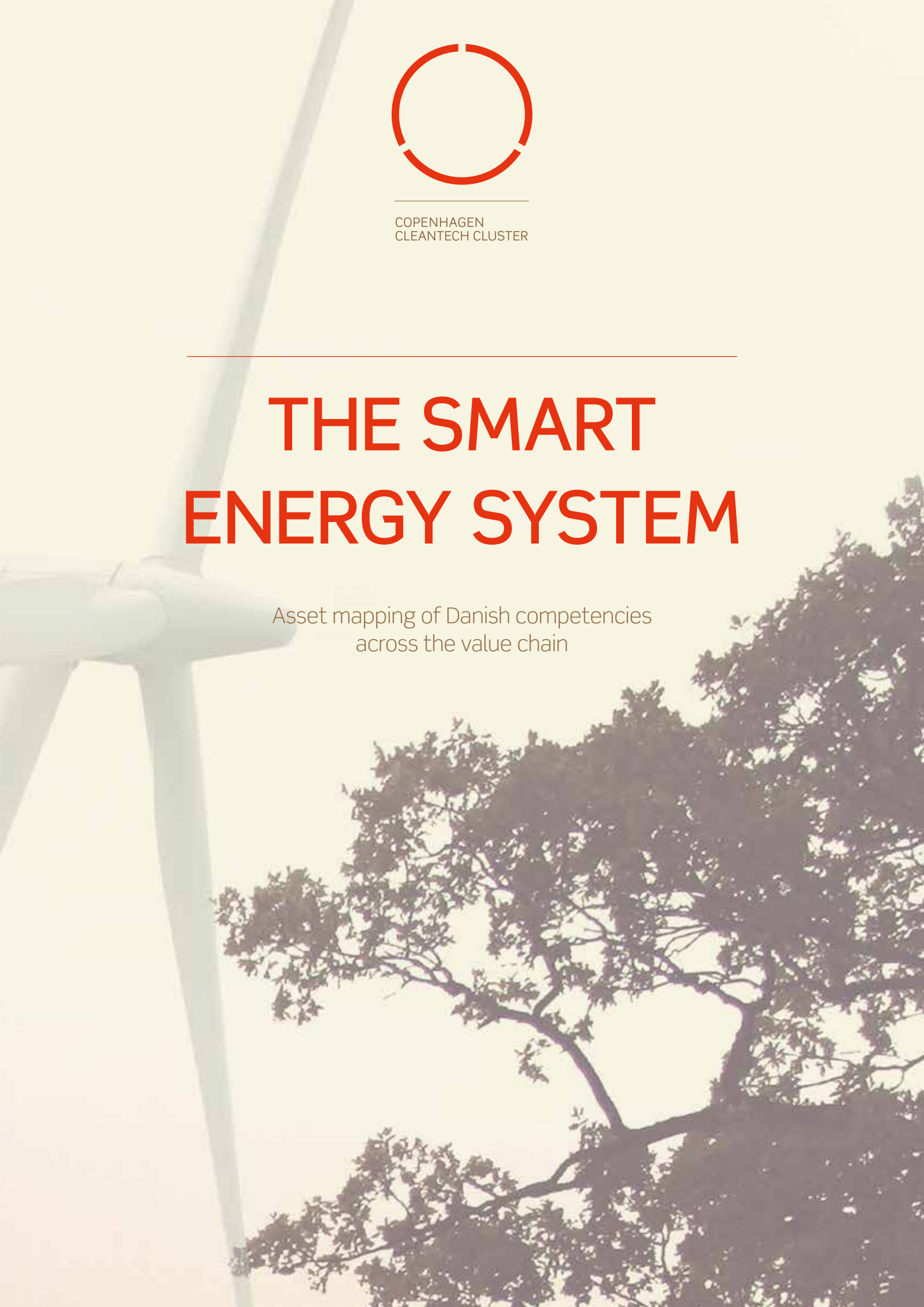
THE SMART ENERGY SYSTEM

Asset mapping of Danish competencies across the value chain



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1. Foreword

This report presents an overview of the smart energy system in Denmark as well as the technology providers and consultancy companies who contribute to its development.

It is important to note that this report's focus on smart energy extends beyond just dealing with electricity production and consumption. Rather, the report includes technology companies and consultancy companies working within all of the energy domains, including electricity, gas, and district heating and cooling. The aim of the report is to highlight the synergies and flexibility which are enabled through the integration of the gas, district heating & cooling, and the electricity grids into a single energy system using ICTs, production, conversion, storage, and end-use technologies. This is what we term "the smart energy system".

Besides presenting the state-of-play of the Danish smart energy system, the report presents some of the developments in Denmark, which can be expected in the years to come. The content of the report is meant as an inspiration and as a helpful tool for a) international stakeholders who wish to get an overview of the Danish smart energy system and/or are looking for Danish business partners, and b) national stakeholders wishing to know the extent of Danish competencies relating to the smart energy system.

The content of the report is the result of a questionnaire providing quantitative data from 178 Danish technology companies and consultancies. Furthermore, a number of expert interviews have been conducted in order to provide input into the report as well as qualify the findings of the survey. The experts who have contributed to the report include Anders Dyrelund, Rambøll, Roman Jurowetzki, Aalborg University, Leif Sønderberg Petersen, DTU National Laboratory for Sustainable Energy and World Energy Council, Allan Schrøder Pedersen, DTU Energy Conversion, Lea L. Lohse, DTU PowerLabDK, Brian Elmegaard, DTU Mechanical Engineering, Lars Hummelmose, DBDH, Preben Birr-Pedersen, Lean Energy Cluster, and Sune Thorvildsen, DI Energy.

The report has been written and edited by Copenhagen Cleantech Cluster in collaboration with Roman Jurowetzki, Aalborg University, Rambøll, DI Energy, Lean Energy Cluster, and DBDH.

Please note that the editing team is solely responsible for the content of the report.

2. Introduction

The world's population and cities are growing and the climate is changing. We continue to be dependent on fossil fuels, and global energy demand is set to grow by more than one third from present levels over the period up to 2035.

There is no doubt that putting the global energy system onto a more sustainable path presents a formidable challenge. In order to succeed, we have to reduce our consumption of fossil fuels, become more energy efficient, and make use of available renewable resources in a cost-effective manner.

Efforts are already being made. According to the World Energy Outlook 2012, renewables are already set to become the world's second largest source of power generation after coal by 2015, and by 2035 they will have become the largest, accounting for almost one-third of total electricity output[1]. Likewise, investment in other renewables outside of the electricity sector, such as solar hot water panels, biogas, biomass, and geothermal heat, is also on the rise[2].

In Europe, the 2020 targets set by the European Commission and the member states mean that renewable sources of energy will increasingly dominate the energy sector in the years to come, and some frontrunner countries, such as Germany and Denmark, are setting global standards for integrating renewable, fluctuating technologies into national energy grids. The question is whether the transformation towards renewables is happening fast enough.

Unfortunately, renewable energy sources in general are limited, expensive, of low quality, and fluctuating in comparison to more conventional energy sources. Moreover, the challenge of integrating renewables into the world's energy supply is not just a matter of replacing fossil fuels. More than one billion people around the world are not yet connected to the electricity grid. In order to be able to increase the general living standards of the world's population, the transformation away from fossil fuels has to happen in the most cost effective and affordable way.

In order for this to happen, the supply and demand side of the energy system must be kept as streamlined as possible. This means that end-users as well as the energy system itself have to be flexible and able to constantly take into account the quality of the energy and the influence of time fluctuations in order to minimize the overall cost.

In short, the need for smarter energy systems is becoming more and more apparent. But what exactly is a smart energy system?

1 World Energy Outlook 2012
2 Global Cleantech Report 2012

3. Four central characteristics of the Smart energy system

A smart energy system is a cost-effective energy system combining the efficient use of energy and the use of renewable sources. It is a system in which energy production, distribution, and consumption are linked together intelligently in an integrated and flexible way.

The smart energy system is therefore defined in this report as a flexible and intelligent system of integrated energy grids which ensures the most cost effective and sustainable energy supply, storage, and consumption while promoting cohesion between energy supply and demand.

In the following section, the smart energy system will be broken down into four core elements in order to describe its characteristics.

More than a power system

First of all, the smart energy system is more than an electricity power system. When talking about energy grids, we normally think about electricity, as the power grid is vital for modern society and most people have access to it. The power grid is relatively cheap in comparison to other energy grids and has been established in many rural areas. On top of this, electricity accounts for an increasing share of global primary energy use. However, in most regions it is expensive to store electricity[1] and to convert low-quality energy sources into electricity. A smart solution would therefore be to supplement the electricity grid with natural gas, district heating, and district cooling in the more densely populated areas in which these grids are cost effective and can benefit from economies of scale.

The backbone of the smart energy system and the key to optimizing the cost-effectiveness of the available renewable energy solutions is the combination of the energy grids for electricity, gas, district heating, and district cooling. Each of the four energy grids has specific qualities which enable certain energy-efficient solutions for the use of renewable energy see (Fig. 1 The electricity grid) on page 8.

Not only do the grids allow the utilization of the most cost-effective renewable energy sources a long distance away from consumers, such as large-scale hydro power, offshore wind power, and large-scale solar power, they also enable decentralized production. Special districts in industrial areas of the city (i.e. smart back yards) can be reserved for CHP plants, waste incinerators, biogas plants, and cooling plants, which can generate gas, heating, and cooling to the grids. Furthermore, businesses and households can invest in their own small-scale RE-production, such as heat pumps, wind turbines, micro CHPs, solar cells, and panels and be connected to the grids if it is profitable for them.

Enabling grid synergies through conversion and storage of energy

A second characteristic of the smart energy system is that it promotes synergistic effects between different renewable energy sources through the use of conversion and storage technologies. This also makes the smart energy system highly energy efficient.

Energy systems that depend largely on renewable energy sources are difficult to balance and regulate. Therefore, energy storage[2] and conversion technologies are vital for the smart energy system, as the available renew-

1 Electricity must be converted before it can be stored. The most widely used forms of "electricity storage" are through pumped hydro, compressed air, or batteries.

2 For an overview of the different energy storage options, see "Energy Storage Options for Future Sustainable Energy Systems", DTU International Energy Report 2013.

Figure 1 The energy grids
Source: CCC

able sources are unreliable and seldom match energy demand. Energy conversion and storage technologies can help balance the energy system and create coherence between supply and demand.

Renewable energy sources are dominated by electricity. The capacity of the available electricity hydro storage is limited and investment in additional storage capacity for electricity in more hydro, compressed air or batteries is currently very expensive. Gas, heat, and cold can be stored over longer periods of time and do not have to be used right away. The smart option is therefore to establish cheaper storage options in gas, hot water, and cold water whenever possible. However, it is important to remember that heat and cooling consumption vary during the year. This should be taken into consideration when selecting these technologies.

Many types of energy conversion and storage technologies exist which can help the smart energy system to absorb excess renewable electricity production. One example could be to convert surplus electricity into gas, which can be stored and used to produce electricity when needed. Another example is the use of electric heat pumps to generate heating via district heating grids combined with large hot water storage options. This is an integrated solution, which – compared to an individual heat pump without storage - has the same impact on the system as a form of electricity storage serving the same end-user demand. Likewise, electric chillers can be used to generate cooling via district cooling grids combined with large cold water storage systems, which also act as a type of virtual electricity storage.

Fuel cells are another interesting option for energy conversion and storage with the capacity to enable a range of different synergies between grids. One example is the combination of fuel cells with heat pumps and heat storage to increase energy efficiency. Another example is the use of fuel cells in micro CHP systems, which allows for decentralized production and can meet the energy needs of the individual household. Fuel cells can also be operated in reverse mode to enable energy storage or produce synthetic fuels for transport through electrolysis. Several different types of fuel cell exist. However, they still need further development before they are mature enough to enter into commercial use[1].

Naturally, the different storage and conversion technologies mentioned above are most suitable in urban areas where all the different energy grids are present and synergies between the grids can be promoted.

Using ICTs to enable intelligent energy management and control

A third central characteristic of a smart energy system is that it makes use of Information and Communication Technologies (ICTs) to promote cohesion between energy supply and demand.

In a decentralized energy system, which is connected to a large number of different production units, the integration of ICT-based technologies into energy grids is vital in order to enable constant ongoing monitoring, control, and regulation. Smart meters provide consumers with real-time data about their energy consumption, which can help spur changes in behaviour. Furthermore, they can help utility companies to get a better understanding of energy consumption patterns through automated reading.

Smart technologies can also be deployed in various consumer products in order to create a more dynamic energy demand, which reduces energy consumption at peak times. One example could be a smart refrigerator, which automatically adjusts its energy consumption to avoid peak times when energy is expensive. Such feedback processes between energy

1 DTU International Energy Report 2012, p. 95. Technical University of Denmark

production and consumption units might also allow the utilities to control certain consumption, e.g. the recharging of electric cars, to avoid overloading the grid locally.

In order to enable such two-way communication between utilities and customers in the energy grids, it is necessary to develop an integrated system of smart meters, communication networks, and data management software. Such a system is also referred to as an Advanced Metering Infrastructure (AMI). As an AMI consists of a range of different technologies which have to be able to communicate and interact, it is very much dependent on technology and communication standards.

"The real intelligent solution is to empower consumers to react according to energy fluctuations"

Anders Dyrelund, Rambøll

The creation of a so called ICT-enabled smart grid has been on the agenda for quite some time now. The lessons learned will constitute important building blocks in the development of the future smart energy system, which will be based on further integration between the different energy grids into a single, coherent system.

Empowering the consumer

Lastly, a fourth central characteristic of the smart energy system is its ability to empower consumers and give them the opportunity to have a positive impact on the overall energy system.

Historically, consumers have been "passive" users of energy, who have had more or less predictable consumption patterns. With the introduction of smart technologies into the energy system, this is starting to change as consumers are being enabled to interact with the energy system. Not only do they get the chance to manage their energy consumption, the use of smart home devices can also help them "shift" their consumption to periods when energy is cheaper. The smart energy system even enables private consumers to produce energy when it is cost effective and thereby act as resources for the energy system.

This type of interaction between the consumer and the energy system, which helps balance the overall energy supply and demand in an efficient and cost-effective way, can be termed "intelligent consumption". A primary prerequisite for this is that the consumers are well connected to the energy infrastructure and enabled to shift their consumption to the most cost-effective solutions.

Secondly, consumers should be actively motivated to invest in energy-saving measures, such as reducing temperatures for heating and optimizing the building envelope. By providing consumers with real-time data on their energy consumption and making their possible energy savings clear in economic terms, they can be motivated to manage their energy consumption in a more active way, e.g. shifting their electricity consumption from day to night when it is cheaper. Furthermore, consumers should be motivated to join forces and establish more cost-effective large-scale hot water and cold water storage tanks.

Lastly, when economically feasible, consumers can be motivated to invest in their own small-scale energy production, such as wind turbines, heat pumps and solar PVs. This turns them into "prosumers", who are able to deliver surplus energy back to the grids (e.g. surplus heat, biogas, and electricity).

4. Overview of the Danish smart energy sector

As is the case in many places around the world, the large-scale integration of fluctuating renewables into the national energy system is making the Danish electricity market increasingly volatile and fast changing.

This development places ever-increasing pressure on the energy system, which has to be able to respond rapidly to the fast-changing conditions of renewable energy production. In short, the smart energy system of the future requires a much greater level of flexibility and intelligent design.

In Denmark, the ambitious long-term political goals regarding the future use of renewable energy means that there is an increasing focus on the question of how to develop and organize the future Danish smart energy system. By 2020, half of Danish electricity consumption will be covered by wind turbines, and by 2050 Denmark aims to be completely carbon neutral. In order for these ambitious goals to be realized, it is not enough just to install more renewable energy production facilities. The energy infrastructure has to be upgraded and designed with intelligent control, integration, and flexibility in mind.

"The ambitious and long-term Danish energy policy is a fundamental driver for the smart energy sector"

Sune Thorvildsen, DI Energy

Although there are major financial costs associated with this development, reports show that the socio-economic costs of investing in a smart energy system outweigh the costs arising from conventional grid development[1]. Besides being the right thing to do in socio-economic terms, investing in the smart energy system brings with it significant environmental benefits and spurs innovation and local business development, which will support the future export of Danish energy technologies.

Turnover and employment

The 178 companies presented in this report have a combined turnover of more than € 1.4 billion. Some of the companies generate their entire turnover from activities relating to smart energy, while others only have smart energy technologies or consultancy services as part of their business portfolio. On average, the companies presented state that around half of their turnover can be directly linked to smart energy-related activities.

In terms of employment, the companies participating in the survey provide jobs for more than 20,000 people in Denmark. The green energy sector in general is a major contributor to Danish society as energy technologies constitute the biggest green business area in Denmark with an estimated total annual turnover of more than €14 billion[2].

1 Smart Grid i Danmark. Dansk Energi & Energinet.dk. P. 16.; IDAs Klimaplan 2050

2 Grøn produktion i Danmark – og dens betydning for dansk økonomi. Klima-, Energi- og Bygningsministeriet, Erhvervs- og Vækstministeriet og Miljøministeriet. 2012.

A new agenda for Denmark's energy policy

For almost four decades, Denmark has had one of the world's most ambitious energy policies. In 2012, the Danish Parliament reached a broad compromise on an energy policy agreement concerning the development of the Danish energy system over the period 2012 – 2020. At the same time, there is political consensus on the development extending to 2050, and the green changeover of Denmark's energy system is receiving wide support from Danish industry.

In fact, the initiatives in the energy agreement imply that in 2020 the Danish energy system will consist of 50 % wind in the electrical system, approximately 35 % sustainable energy in the energy system, nearly a 40 % reduction in greenhouse gas emissions, and a reduction in gross energy use of 7.6 % compared to 2010.

In a recent study by the World Economic Forum in December 2013, Denmark was ranked number one in the EU when it comes to access and security of delivery in terms of energy supply[1]. In particular, the Danish energy system is characterized by a well-developed electricity and district heating system and a well-functioning and flexible natural gas grid. This creates a number of possibilities for the utilization of synergies between the different forms of energy and the energy grid.

The Danish government wants increased integration and improved interaction between all parts of the energy system, such as electricity, gas, district heating and cooling, and biomass fuel. A precondition for this is a better method of predicting, controlling and optimizing integration by means of innovative IT systems. The objective of CITIES, a new, high-priority R&D project at DTU (Technical University of Denmark), is to conduct research into how to organize future cities with intelligent IT systems that can control the optimum flow of energy. Furthermore, Denmark is keenly focused on promoting the development of energy storage technologies and the smart grid.

As part of the energy agreement of March 2012, a decision was made to carry out a number of analyses of the functionality of the electricity grid, the gas infrastructure, the role of district heating, as well as an analysis of biomass fuel. The analyses help to demonstrate how the different energy forms and grids are interacting.

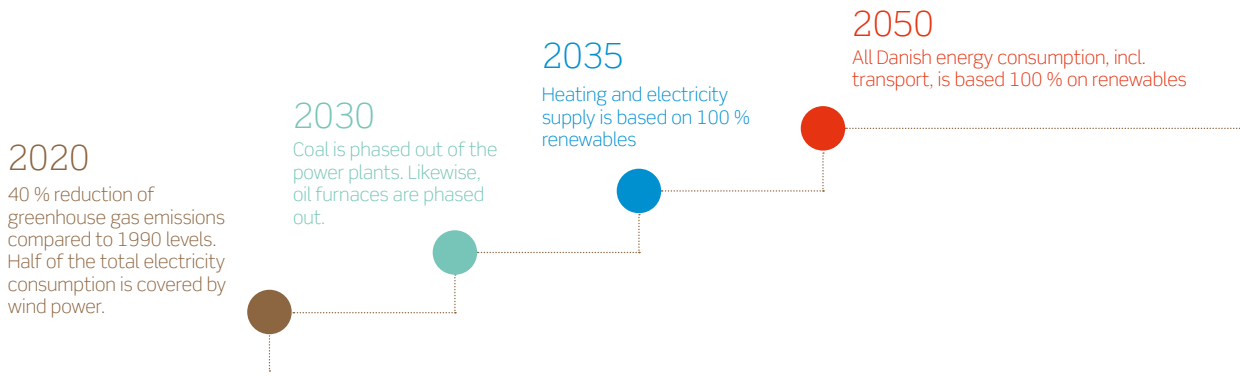
In 2013, the government launched a climate plan[2]. The climate plan consists of a general report on the government's principles and a catalogue of measures containing 78 measures for the reduction of greenhouse gas emissions in the energy, transport, agriculture, and waste sectors. The initiatives should contribute to the government reaching its objective of a 40 % reduction in greenhouse gas emissions by 2020. As a consequence of the climate plan, a climate act was adopted, resulting in the establishment of an independent climate council. The council will submit their recommendations on climate initiatives to the government at least once a year with due consideration being paid to cost effectiveness as well as growth and employment. The council has been tasked to evaluate the initiatives and present analyses of possible ways to achieve changeover.

The Danish government intends to reach the goals in the most cost-effective way for the society as a whole. Therefore, it has issued national guidelines on how to analyse cost effectiveness in a cost benefit analysis in which the costs to society of emissions of CO2 and harmful pollutants are included. This includes price forecasts for energy at the national level, a discount rate of 4 % (fixed prices) and the costs of emissions.

1 World Economic Forum: The Global Energy Architecture Performance Index Report 2014

2 The Danish Climate Policy Plan. Towards a low carbon society, 2013

Figure 2 Milestones in Denmark's energy policy
Source: CCC



Danish energy policy is of course linked to some extent to European energy policy. This is structured around a number of so-called "2020 goals", which have been adopted by the EU member states. These goals commit the member states to reaching a number of fixed energy targets before the year 2020. First of all, greenhouse gas emissions should be cut by 20 % in comparison to 1990 levels. Furthermore, each member state should have at least 20 % of its energy supply coming from renewables, such as wind, solar, and biomass. In addition to this, a voluntary agreement has been made to cut overall EU energy consumption by 20 %. Lastly, 10 % of energy consumed by the transport sector should derive from renewables by 2020[1].

1 Intelligent Energy Infrastructure for the future. DTU Risø Energy Report 8. 2009. P. 15.

CASE STUDY CITIES

Cities account for 80 % of global energy consumption and carbon emissions. By virtue of their population density and well-established energy networks, cities offer great scope for high levels of flexibility in the energy system. Linking energy systems together produces a number of advantages, e.g. the possibility of achieving lossless energy storage (virtual storage) lasting from minutes to several months.

The CITIES project will create IT solutions for the analysis, operation, and development of integrated energy systems (electricity, gas, district heating, and biomass) in cities. The focus of the research centre is on the opportunities provided by urban environments as well as the potential synergies with many existing green/smart cities projects. CITIES will conduct research into long-term planning models as well as operational solutions for the integration of increasing volumes of renewable energy.

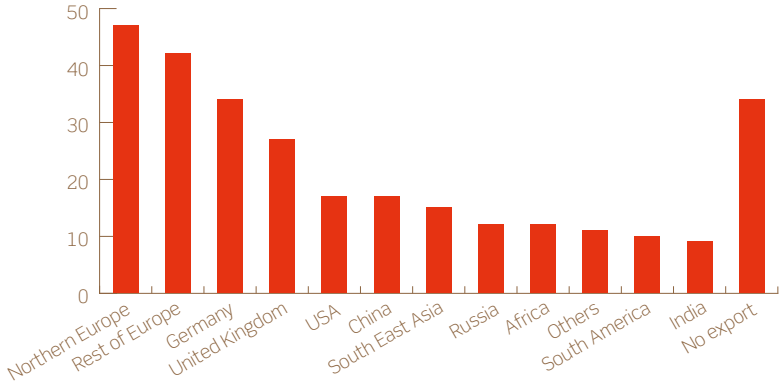
The centre will bring together researchers from the Technical University of Denmark, Aalborg University and a number of foreign universities (from Korea, the USA, Ireland, Austria, Spain and Germany). Besides this, the project will involve a large number of Danish and foreign companies and sector organizations.

www.energiforskning.dk/node/7731

Export

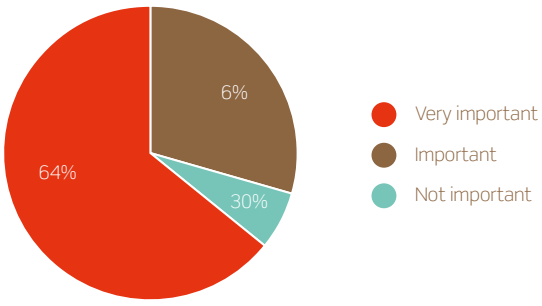
Figure 3 shows the primary export markets for the Danish smart energy companies which participated in the survey. As can be seen, most of the companies' export activities are within Europe, especially in the catchment areas of the northern European countries. The largest single European market is Germany followed by the U.K.. Looking outside of Europe, it is interesting to notice that there is an equal number of companies exporting to the US and China. This serves as a general indication of an export focus which is shifting east. 34 % of the companies participating in the survey have no exports.

Figure 3 Percentage of companies who export to specific markets (n=178)
Source: CCC survey



When comparing the main export markets of the companies participating in the survey with the more general picture drawn by the International Energy Agency (IEA) of the export markets of energy technology producers within the EU15, the picture is quite similar. The internal market of the EU is by far the biggest export market, generating more than 40 % of export turnover. Besides this, exports to China account for around 17 % of total export activities, while the figure for the US is 11 %. In this regard, the export activities of the companies participating in the survey are very similar to the export "norm" of the EU15. In 2012, total Danish exports of energy technologies generated around € 8.2 billion[1].

Figure 4 How important are R&D activities for your company? (n=142)
Source: CCC survey

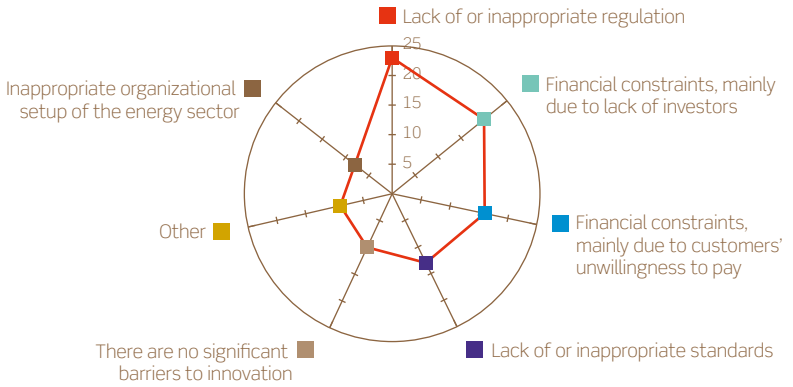


Innovation activities and barriers

The survey draws a general picture of a very innovative Danish smart energy sector. 53 % of the companies said that they have introduced a new or significantly altered product, solution, or technology to the market in 2013. Furthermore, around 70 % of the companies indicated that R&D activities are an important or very important part of their business (see Figure 4).

1 Danmark i Arbejde – Vækstplan for energy og klima. Regeringen 2013

Figure 5 Barriers to innovation: (n=174)
Source: CCC survey



In spite of this, the companies still experience a number of different barriers which prevent or seriously restrict further smart energy-related innovation. The main barrier is financial constraints, either from a lack of investors or customers' unwillingness to pay. Besides this, almost a quarter of the companies pointed to lack of or inappropriate regulation when identifying barriers to innovation activities. 10 % of the companies indicated that there are no significant barriers to innovation (see Fig. 5).

CASE STUDY INLEC – the national innovation network for smart energy

In order to accelerate the development of new solutions and technologies within the areas of energy efficiency and intelligent energy systems, the Danish Council for Technology and Innovation has established the INLEC innovation network. The main task of the network will be to establish a number of innovation platforms over the coming years in order to promote innovation and collaboration between the various Danish actors working with integrated energy solutions.

INLEC is rooted in the cleantech cluster organization, Lean Energy Cluster (LEC), which includes more than 250 active companies and organizations. LEC promotes efficient energy consumption through efficient partnerships, and the cluster has a project portfolio of more than €66 M.

www.leanenergy.dk/english/

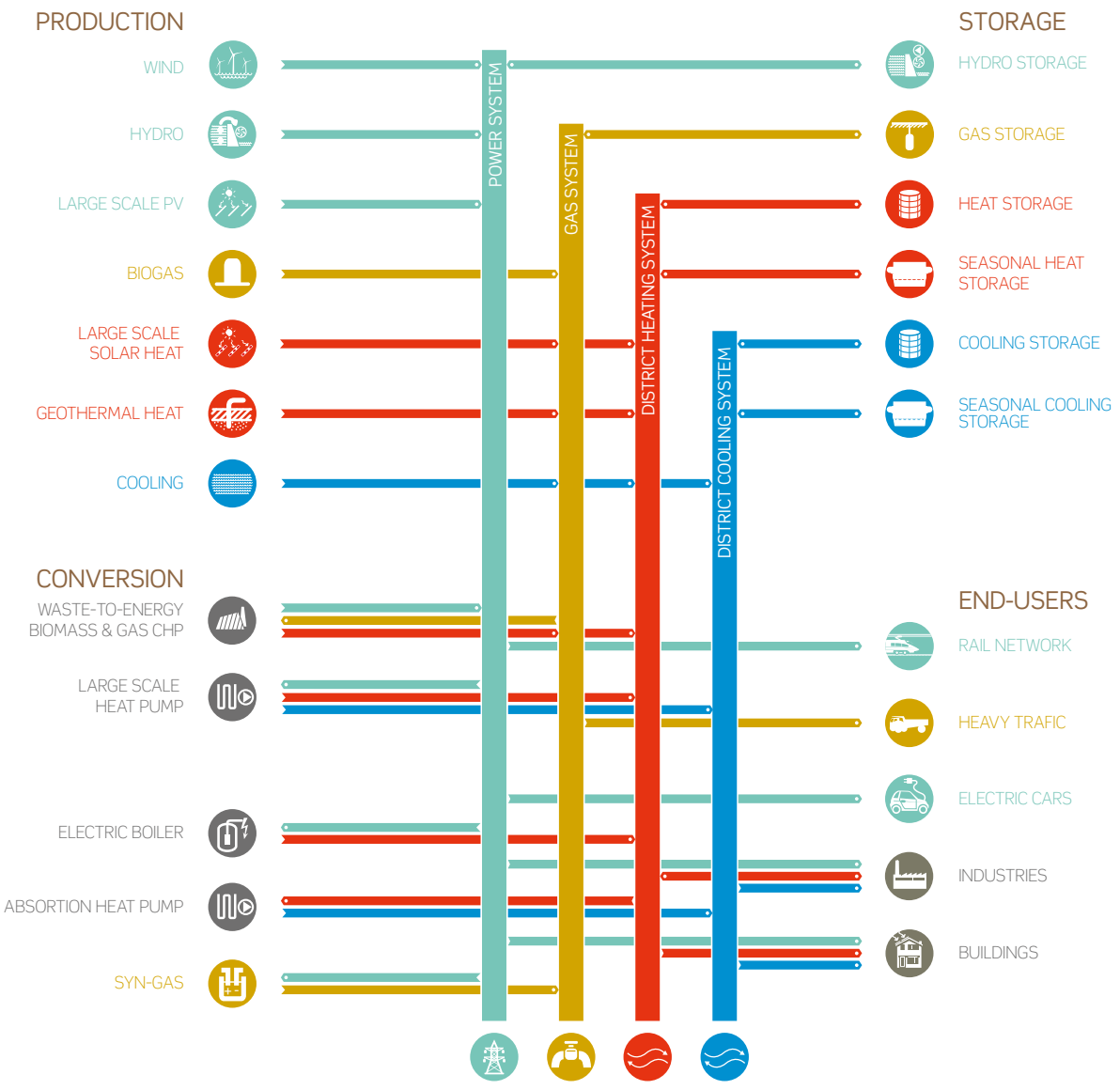
5. Danish competencies across the value chain

The value chain of the Danish smart energy system is presented in Figure 6, which also illustrates the interaction between the four energy grids in general with a focus on how the smart energy system can utilize renewable energy.

In addition, the diagram provides an overview of the competence areas across the value chain of the companies which participated in the survey. Information about the companies participating in the survey can be found in the matrices in the back of the report.

The value chain for each of the renewable energy sources consists of five main links: 1) Production, 2) Transmission & distribution, 3) Conversion, 4) Storage, and 5) Intelligent consumption. What makes the energy system smart is when the links work in unison in order to improve the overall performance of the energy system as a whole. Accordingly, the energy system should be considered as the whole value chain from the supply of renewable energy, through transmission & distribution, conversion and storage, to the demand for energy services, such as heating and air conditioning, mechanical energy, process energy and electricity for electronics.

Figure 6 The integrated energy system
Source: Rambøll



SURVEY

98
companies

~ € 694,5m
turnover

~ € 319,5m
average smart energy related turnover

~ 11.300
employees

~5.600
smart energy related employees

The renewable energy supply sector

The first step of the smart energy value chain is renewable energy supply. 55 % of the companies participating in the survey provide technologies relating to renewable energy supply.

Wind power

The survey shows that most of the combined revenue relating to renewable electricity production is generated in the wind power sector. In 2012, the combined revenue of the Danish wind power sector was just under €11 billion and the sector employed around 28,500 people, illustrating its importance in Denmark[1].

Wind power has long been a Danish core competence with leading global players, such as Vestas, LM Wind, and Siemens Wind Power, all having their head offices in Denmark. The country's leading position in wind power is supported by political decisions, which are among the most ambitious in the world when it comes to wind energy, stating that half of Danish electricity consumption should be covered by wind power by 2020. This means that there will be further investment in Danish wind power in the years to come. According to the Danish transmission grid manager, Energinet.dk, an extra 17 GW of wind power are needed to be produced in Denmark if the country is to achieve its ambition of becoming fossil-free by 2050[2].

Hydro power

For many countries around the world, hydro power is the main source of renewable energy. This is not the case in Denmark, where there is only very limited potential for hydro power generation due to the fact that the country is flat and has very few big rivers. In fact, there is only one single hydro-electric plant in Denmark, which generates around 0.1 % of Danish power production. Still, a number of Danish companies and consultants have developed considerable expertise within this area and are providing hydro power solutions to markets outside of Denmark. 6 % of the companies participating in the survey stated that they provide technologies or consultancy services relating to hydro power generation.

The fact that hydro power is not an abundant and available energy source in Denmark has forced the development of other renewable energy production technologies. One example of an upcoming technology area receiving attention in Denmark is wave energy. Five of the companies represented in this report have activities relating to this technology area.

Wave power

The development of wave energy is to some extent linked to developments within the offshore wind industry. Even though offshore wind turbines have become a recognized and

1 Danmark i Arbejde – Vækstplan for Energi og Klima. Regeringen 2013

2 Energi 2050 – Vindsporet, 2011, www.energinet.dk. For more information about the Danish wind energy market, please see the Danish Wind Industry Association, www.windpower.org/en

proven technology, the cost of establishing offshore wind farms is still a big obstacle to further development. Wave energy can help bring down the investment cost of offshore wind farms.

First of all, wave energy facilities can share some of the offshore wind farm installations (e.g. foundations, cables, service facilities). Secondly, wave energy works as a stabilizing factor in connection with wind power, as waves build up and level out more slowly than wind. The combination of wind and wave will therefore provide a more stable supply of energy than wind power alone. Lastly, there is a natural limit to the number of shallow areas where offshore wind farms can be established. In combination with wave energy, which only benefits from deeper water, offshore wind farms can be established further from shore and still be cost effective. In these ways, the wave energy and offshore wind industries complement each other well.

This link between the wind and wave energy industries, combined with the geographical location of Denmark, which is surrounded by water, means that wave energy – at least on paper – should be of great interest in Denmark. This is increasingly the case, and some of the best documented wave energy concepts in the world are now Danish[1].

1 For more information on wave energy in Denmark, please see the Danish Wave Energy Association, www.waveenergy.dk

CASE STUDY Wavestar

The oceans remain one of the few natural resources that have yet to be tapped for electricity production. However, since 2000 the Danish company Wavestar has been developing technology that can change this.

The key challenge is to provide a constant current, given the 5-10 second intervals between each wave. Wavestar's solution is a row of half-submerged buoys that rise and fall in turn as the wave passes along, allowing energy to be continually produced despite waves being periodic.

Commercial launch of the product is getting close. The half-scale, 600kW test-facility in Northern Jutland has in fact been feeding energy into the Danish grid since 2010. Once the technology is fully developed, the potential is huge. Among other forms of applications, Wavestar's products can be installed with offshore windmills, saving on setup and distribution costs.

www.wavestarenergy.com

Solar photovoltaic power

35 companies (14 %) have indicated that they provide technologies or consultancy services relating to solar photovoltaics. Especially within the last couple of years, photovoltaic technology has undergone rapid development in Denmark, which has resulted in increasing effectiveness and decreasing production costs. From January 2011 to August 2013 the price of a photovoltaic system decreased by 41 %[1]. This has made the technology more attractive for both private consumers and public and private institutions, and has resulted in an increased implementation of the technology. Even though the implementation of photovoltaic systems in Denmark lags behind European frontrunners such as Spain and Germany, Denmark still holds a relatively strong position in green energy conversion compared to the typical benchmark countries of Sweden, Norway, Finland etc.

The largest private photovoltaic system in Scandinavia is located on the Danish island of Møn. It consists of 6000 solar panels and is capable of delivering electricity to more than 350 households[2]. Furthermore, Denmark also hosts two of northern Europe's largest photovoltaic systems owned by corporate organizations. The first, Topdanmark, has installed a roof-based photovoltaic system of more than 3000 solar panels that are able to generate energy to more than 200 households[3], while the second, Danfoss, has installed a solar power plant with more than 9000 solar panels that can generate electricity to more than 400 households. Furthermore, the Danish military is planning to build photovoltaic solar power plants with a combined capacity of more than 1800kWp on their two airbases in Karup and Skrydstrup. The facility in Karup will become the largest solar power plant in northern Europe with a capacity of more than 1200kWp[4].

Lastly, it should be noted that the Technological University of Denmark is a leading global player when it comes to the development of the next generation of solar cells, which are based on ultrathin layers of plastic. Although currently not as efficient as conventional silicon-based solar cells, plastic solar cells require much less energy to produce[5].

Biogas and syngas

13 % of the companies presented in this report develop biogas technologies or provide consultancy relating to biogas, a few of them with export activities to global markets.

Denmark has quite a long tradition of biogas production dating all the way back to the

1 www.solcellepriser.dk/prissammenligning/prisudvikling-solceller
2 www.landbrugsavisen.dk
3 www.ing.dk
4 www.energiwatch.dk
5 Energy research at DTU. 2013. P. 9.

CASE STUDY Gaia Solar

Gaia Solar A/S is one of Scandinavia's leading suppliers of complete photovoltaic systems. The company has received awards for its commercial success, which has resulted in growth rates of more than 250% in revenue in 2013. Gaia Solar has been responsible for the development of the biggest solar power plant in Scandinavia commissioned by Danfoss. The plant is capable of producing 2.1MWp, equivalent to the consumption of 400 households. Gaia Solar is an innovative company with the ambition of being involved in 2-3 R&D projects per year.

www.gaiasolar.dk

1920s, which is largely due to the country's well-developed agricultural sector. At the beginning of 2014, there was a total of 154 biogas production units in operation in Denmark, the majority of these being agricultural and sewage sludge treatment plants[1]. This figure is set to increase in the coming years, as a new national waste management strategy has just been published in Denmark, which specifies that the organic fraction from household waste and from the service sector should be increasingly used as feedstock for biogas plants in combination with liquid manure in order to enhance energy output[2]. According to the European Biogas Association (EBA), Denmark is set to become the largest per capita producer of electricity and heat from biogas in European Biogas Association, www.biogasIn.org. The expected investment presents a market opportunity for Danish as well as foreign biogas technology producers.

In order to achieve the ambition of becoming fossil-free by 2050, Denmark will have to phase out the consumption of natural gas, which in 2012 constituted around 120 PJ[3]. Seeing that total Danish biogas potential has been estimated to be a maximum of around 40 PJ, Denmark will have to generate other types of green gases as well. In this regard, biomass gasification along with electrolysis technologies are set to play an increasingly important role in the future smart energy system. According to a research project undertaken by Risø DTU and the Danish Gas Technology Centre, the total potential for synthetic natural gas (Bio-SNG) from biomass resources in Denmark is between 100-150 PJ per annum without reducing food production. This means that the entire current consumption of natural gas could theoretically be replaced by Bio-SNG.

In general, the gas grid will play a crucial part in the future Danish energy system, as it has the capacity to balance the system and deliver the necessary energy in periods when wind and solar energy is scarce. Not only can biogas be upgraded to natural gas quality, gas produced through thermal gasification of biomass can be converted into synthetic natural gas through a methanization process.

> "The power-to-gas technologies have a great potential in the future energy system"
>
> Preben Birr-Pedersen, Lean Energy Cluster

1 In-depth analysis of the waste-to-energy field. "COOLSWEEP" project. 2014, www.Coolsweep.org

2 Denmark without waste – recycle more, incinerate less. The Danish Government, 2013

3 FiB. Vol. 46. 2013. www.biopress.dk

CASE STUDY **Haldor Topsøe – the energy supply of tomorrow**

Since it was founded in 1940, Haldor Topsoe has placed great emphasis on the link between fundamental research and technology development. This strong link with the research sector has helped the company become a first mover and global leader, providing catalysts and fuel cells with a wide variety of green applications. Among other things, Haldor Topsoe's catalysts are used to produce sustainable fuels, for cleaning flue gases, and reducing emissions from heavy transport. The catalytic processes enabled by Haldor Topsoe technologies can be used to institute flexibility into the smart energy system. The company's subsidiary, Topsoe Fuel Cell, develops and produces fuel cells, which are used among other things for micro CHP solutions.

www.topsoe.com and www.topsoefuelcell.com

This allows the gas to be injected into the national gas grid where it can be distributed over long distances and/or stored for later use. However, as it looks now, Danish gasification technologies in general are characterized by the fact that the producer gases are used in a boiler or an engine immediately after being generated instead of being upgraded.

A number of leading Danish companies exist within the field of thermal and catalytic gasification of biomass. One example is Haldor Topsoe and its subsidiary Topsoe Fuel Cell, which produce catalysts and fuel cells to be used in gasification processes.

"We are seeing a boom in the use of large-scale solar hot water panels on the ground, and we have only just started"

Anders Dyrelund, Rambøll

Solar thermal energy

A major contributor to Danish district heating is solar thermal energy. Already in the late 70s, private consumers were supported economically by government funds if they wanted to invest in a solar thermal energy system. The economic stimulus escalated the demand for the technology, which resulted in a widespread adoption of solar thermal energy systems and induced increased efforts in the research and development of solar thermal technology. The technology of solar thermal energy matured earlier than photovoltaic technology. Denmark has been very eager to implement this technology, which is why investment up until 2001 was targeted at the implementation of solar thermal energy systems. The district heating company Marstal Fjernvarme has been a pioneer in this development to benefit from the economy of scale and make large-scale solar heating on the ground competitive against oil at world market prices.

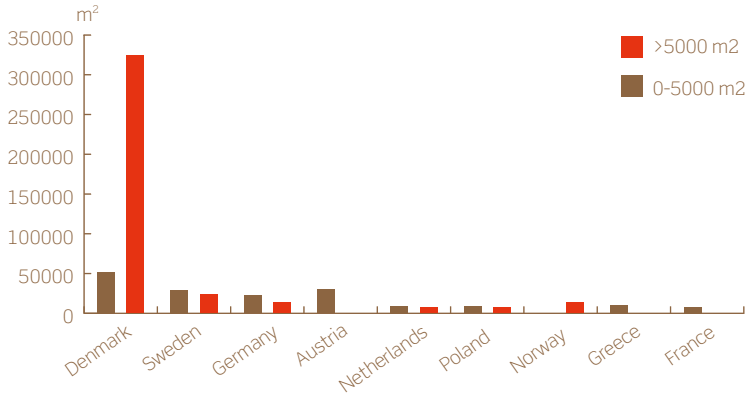
This development has made Denmark the country with the largest production capacity of solar heat for district heating by far in the EU see (Fig. 7 European solar thermal energy capacity) on page 23. According to data from Solar District Heating EU, 30 out of the 38 European large-scale (>5000 m2) solar heating plants are Danish. Danish companies like Sunmark and Arcon Solar are world-leading technology providers for large-scale solar hot water panels, while consultancies such as Rambøll, Aaen Consulting Engineers or COWI provide expertise concerning planning and implementation. One example is the construction of the world's largest solar thermal energy plant in Chile, which covers 39,300 sq. metres and produces 50,000 MWh/a. The technology has been developed by Sunmark, while the contracting and consultancy has been carried out by Rambøll.

CASE STUDY Arcon Solar

Arcon Solar is a leading manufacturer of solar thermal heating systems and collectors. The company has built 15 out of the 25 largest plants in Europe, among them Europe's largest solar thermal heating plant located in Dronninglund, Denmark. Arcon Solar is owned by SolarCAP – a group of companies which develop, produce, and market solar thermal heating systems and other energy-efficient solutions.

www.arcon.dk

Figure 7 European solar thermal energy capacity
Source: www.solar-district-heating.eu



Geothermal energy

Although Denmark has substantial potential for geothermal energy, there are currently only three geothermal facilities in operation in Denmark providing heat for around 10,000 households. The Geological Survey of Denmark and Greenland, GEUS, estimates that the long-term annual potential for geothermal energy in Denmark is between 25 – 40 PJ, which is the equivalent of 20 – 30 % of current annual district heating consumption. If this is true, less than 2 % of the total market potential for geothermal energy is currently being exploited in Denmark. 12 % of the companies from the survey operate within this area.

SURVEY

27
companies

~ € 631,8m
turnover

~ € 264,4m
average smart energy related turnover

~ 5.400
employees

~2.400
smart energy related employees

The smart energy transmission and distribution sector

The second step of the smart energy value chain after renewable energy production is transmission & distribution. 15 % of companies participating in the survey indicated that they provide some kind of technology or consultancy service relating to smart energy transmission & distribution, the main part of which providing technology or consultancy relating to transmission and distribution of heating and cooling followed by electricity and gas.

Loss of energy through transmission and distribution

If the transmission and distribution of energy is about ensuring the highest level of energy supply security for the consumers while minimizing overall energy loss, then Denmark is a model country. Not only does it rank as number one in the EU when it comes to access and security of delivery in terms of energy supply[1], the overall loss of energy from production to consumption in Denmark is very low.

One of the reasons for this is the highly decentralized energy system in Denmark which helps to keep the overall losses of energy through transmission and distribution at a very low level as it reduces the need to transport electricity over long distances. An issue of concern in many countries is the loss of electricity power through transmission, which in some places amounts to more than 30 %. In Denmark, the total loss associated with electricity transmission is estimated to be around 6 %[2].

District heating and district cooling

For more than four decades, Denmark has been world leader when it comes to district heating technologies. Around 63 % of the Danish population is currently connected to the national district heating grid, which is constantly being upgraded and developed in the areas where district heating is cost effective[3].

The country's many years of focusing on district heating technologies and solutions has had a significant influence on the Danish smart energy sector and - just as it is the case with wind energy – has helped develop a well-consolidated domestic market of technology suppliers and consultancies. Further, Denmark's leading role within district heating has convinced leading global companies, such as ABB, Logstor, Danfoss, and Schneider Electric, to establish their global "centres of excellence" for district heating in Denmark, where they will be at the forefront of new developments.

The central role of district heating competencies in Denmark is also reflected in the survey, where a quarter of the companies stated that they produce technologies or provide consultancy relating to district heating or cooling[4]. The combined exports of these companies exceed €375 M. According to the Danish Board of District Heating (DBDH), more than 7000 people are employed in the Danish district heating sector. Furthermore, Danish district heating companies exported technologies and solutions worth more than €660 M in 2012, which is around 8 % of total Danish exports of energy technologies. This number is expected to more than triple by 2020 with China and Russia as the main markets[5].

1 World Economic Forum 2014, www.reports.weforum.org/global-energy-architecture-performance-index-2014

2 www.indexmundi.com/facts/denmark/electric-power-transmission-and-distribution-losses

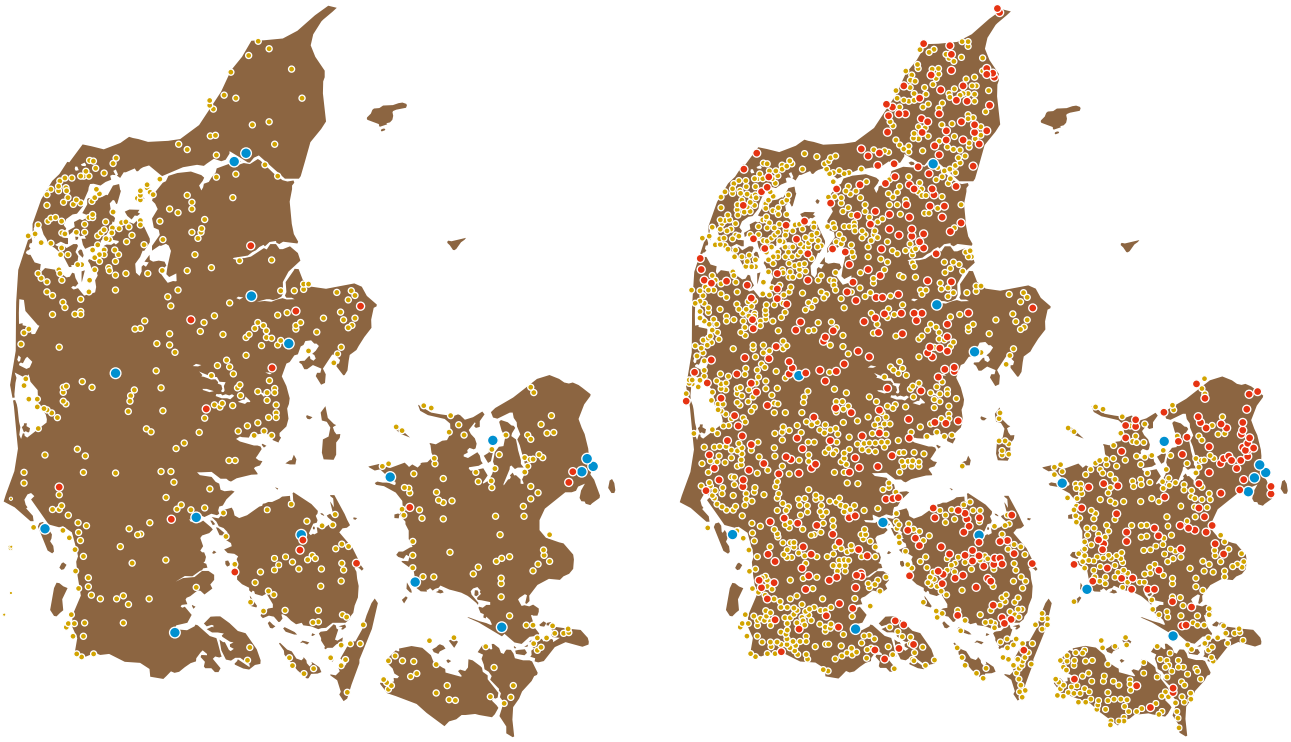
3 DBDH – Danish Board of District Heating, www.dbdh.dk

4 For an in-depth description of the Danish district heating system, please see www.dbdh.dk/characteristics

5 Fjernvarmeindustrien 2012. Rapport om en branche i vækst

Figure 8 Illustration of Denmark's journey from centralised to distributed energy system

Source: Danish Energy Agency, ens.dk. 100% accurate maps available



1985

- Centralised combined heat and power plant
- Decentralised combined heat and power plant
- Wind turbines

2009

- Centralised combined heat and power plant
- Decentralised combined heat and power plant
- Wind turbines

While the future potential for export of district heating technologies is high, the potential for export of district cooling solutions might be even higher. The benefits of district cooling are many. First of all, as opposed to individual cooling solutions, district cooling can benefit from the economy of scale, making it a much more cost-effective solution. Secondly, the district cooling grid can be coupled to large-scale cooling storage systems, which enables more intelligent energy consumption.

"The Danish energy system contains more energy in the form of heat than electricity"

Lars Hummelmose, DBDH

Also, district cooling makes individual rooftop or basement cooling solutions redundant, leaving open spaces which can be used for car parking, rooftop terraces etc. in order to increase liveability in the cities. Lastly, there are major synergies between the district heating and district cooling grids, such as the conversion of surplus district heating to district cooling or the efficient use of heat pumps to create both heating and cooling at the same time.

Although district cooling is not nearly as well-developed in Denmark as district heating, Danish companies are well positioned on the global market for district cooling solutions. One reason for this is the fact that the system and the technologies behind district cooling are very similar to those used for district heating solutions.

A list of Danish companies operating within this area can be found in the matrix on page 57, and a list of the main trade organizations and knowledge institutions can be found on page 83.

Using smart technologies to optimize transmission and distribution

ICTs are being increasingly integrated into the Danish energy system to optimize transmission and distribution processes. One example is the district heating grid, which is equipped with smart meters that allow district heating companies to control and plan the operation of the grid intelligently through remote reading and raise the alarm if any leaks or other problems occur. Besides this, the smart meters enable district heating companies to

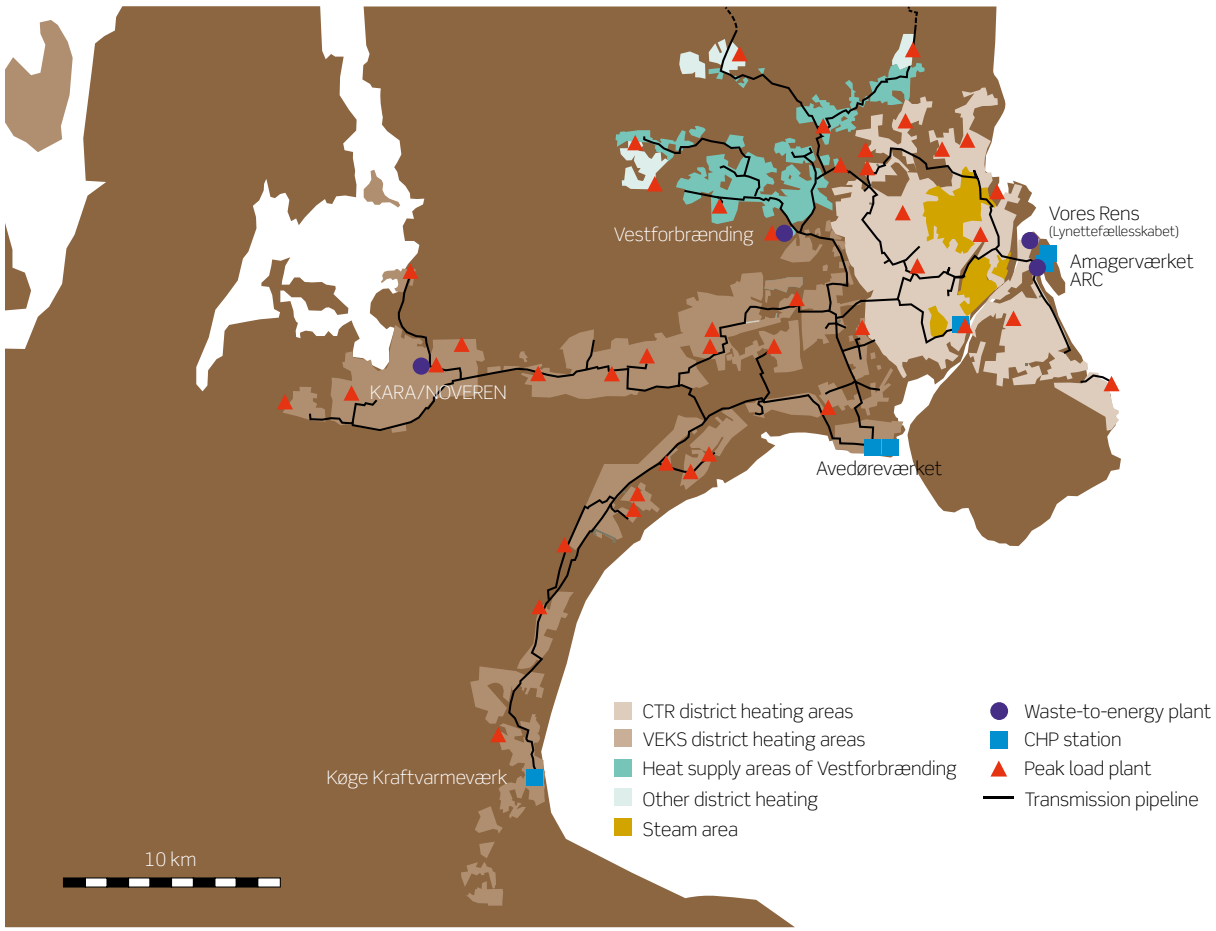
CASE STUDY The district heating network of Greater Copenhagen

The integrated district heating system of the Greater Copenhagen Area supplies more than 1 million people from 22 local municipalities. The total heat production of around 10,000 GWh/a to the integrated district heating system is optimized by the three large district heating companies, CTR, VEKS, and HOFOR, on an hour by hour basis. As a result, the share of combined heat and power (CHP) is 95% and the share of renewable sources is around 50%.
Most of the local authorities in Greater Copenhagen and the region west of Copenhagen have formed three municipal partnership companies, ARC, Vestforbrænding, and KARA/Noveren, which are responsible for waste management and for each operating their own CHP plant fuelled by waste which cannot be recycled. All heat from the plants is utilized in the district heating system.

Besides this, two other CHP plants, owned by the City of Copenhagen and the Dong Energy company, are connected to the integrated district heating system via large thermal storage systems. Moreover, the biomass-fuelled CHP plant in the city of Køge south of Copenhagen, which is owned by the heat transmission company VEKS, is being connected to the heat transmission system. Lastly, there are two local district cooling systems in the City of Copenhagen and several are in the pipeline in the central part of Copenhagen.

Figure 9 Copenhagen District Heating Network

Source: Rambøll



shift to time-tariffs reflecting the marginal costs and tariffs, which give discounts to consumers who can return the circulating water at a lower temperature. This important communication between supplier and consumer helps the consumer to use the heat wisely and invest in cost-effective measures. Lastly, the meters allow consumers to follow their consumption over the internet on an hour by hour basis[1].

In terms of the implementation of ICTs into the electricity power grid, Denmark has been at the forefront of the "smart grid revolution"[2]. The country provides access to unique test and demonstration sites for the integration of ICTs into the energy system, such as the ECO-grid project and PowerLabDK (see p. 43). Furthermore, Denmark is a world-leading research hub for smart grid technologies and solutions, hosting around 30 % of all smart grid related projects within the EU. A complete list of the current projects can be found on page 76.

Connecting with Europe

Connections with neighbouring countries (i.e. Sweden, Norway, and Germany) have long played a central role in the Danish energy system, and the effective exchange of energy contributes positively to balancing out any energy fluctuations in the Danish smart energy system. Due to its geographical location between the hydro-power-producing Nordic countries (i.e. Sweden and Norway) and the abundant wind resources of the North Sea and the northern European continent, Denmark has long served as a regional energy hub.

The Scandinavian power system is a good example of how the interconnection of different regional energy systems can provide mutual

1 Danish Board of District Heating (DBDH)

2 For more on this, see Denmark – a smart grid hub. Copenhagen Cleantech Cluster 2011

CASE STUDY The Danish electricity DataHub

In order to optimize the exchange of data between different stakeholders operating within the Danish electricity market, the Danish Minister for Climate initiated the creation of a DataHub in 2009, which would gather all relevant information about Danish electricity customers on one single platform. Since then, more than 130 electricity companies and traders across Denmark have collaborated to create the DataHub, which was inaugurated in March 2013. The DataHub spurs competition as it makes it easier for Danish electricity customers to switch suppliers and access their own consumption data.

www.energinet.dk/EN/El/Datahub/Sider/DataHub.aspx

benefits. The backbone of the Norwegian power system is hydro power, while Denmark is characterized by wind and thermal power. In dry years, Norway can conserve water by importing excess wind power from Denmark, while Norwegian hydro power can be exported to Denmark when the wind is not blowing. In this way, surrounding regions can serve as buffers for local energy systems.

The interconnections with surrounding energy markets has a positive effect on the price of Danish wind power as it grants producers access to areas with higher electricity prices. Furthermore, it helps to ensure that the excess wind power generated on windy days, which is not absorbed by the district heating grid, can actually be sold for the benefit of neighbouring regions, which get access to cheap, renewable energy.

CASE STUDY SEAS-NVE

In 2005, the two regional companies SEAS and NVE joined to form the largest consumer-owned electricity company in Denmark. Today, the core business is delivery of energy and communication services to its 400.000 customers on Zealand.

The company is known for its dedicated approach to green energy. Customers are offered a range of advisory services on how to reduce consumption and given financial incentives to improve the performance of their homes. Furthermore, the company has launched "GlobalEnergy" - the first electricity product in Denmark where consumers contribute directly to sustainable energy investments through their electricity bill.

Additionally, the company is co-owner of CLEVER - the largest EV-charging provider in Denmark. In 2014 alone, the company plans to install over 50 new turbo charge-points, making electrical cars a viable alternative in Denmark.

www.seas-nve.dk

SURVEY

78
companies

~ € 516,2m
turnover

~ € 232,9m
average smart energy related turnover

~ 8.700
employees

~4.500
smart energy related employees

The energy conversion sector

The third step in the smart energy value chain is energy conversion. The ability to convert one form of energy into another is crucial in smart energy systems as it enables synergies between the different grids. Fluctuating energy sources such as wind, solar, and wave, would be much less valuable if they could not be converted into other forms of energy in periods of peak production. The central position of the energy conversion sector in smart energy systems is reflected in the survey, where 44 % of the companies replied that they provide technology or consultancy relating to some form of energy conversion.

CHP and Waste-to-Energy

One very key form of energy conversion in Denmark is combined heat and power production. All Danish power plants have to be CHP plants by law. Compared to power only plants, combined heat and power plants in combination with heat storages can reduce the fuel consumption for low temperature heat to less than 50 % as long as the plants substitute power produced in condensing mode. As much as 2/3 of total energy production in a conventional power plant is lost already in the production process if the plant is unable to utilize the heat generated[1]. The extensive use of district heating in Denmark makes sure that almost all of this thermal energy does not go to waste.

Denmark has Europe's highest per capita waste incineration capacity, which every year accounts for 4.5 % of the total electricity supply and 20 % of the heating supply in the district heating grid[2]. One of the reasons why Denmark has such a well-developed waste incineration sector is due to the fact that the country was the first in the world to introduce a landfill ban on waste suitable for incineration. After many years of stable development in the waste incineration sector, Denmark is now home to a number of world-leading technology providers and consultancies within waste incineration, such as B&W Vølund, Rambøll, and Burmeister & Wain Energy (BWE)[3].

Heat pumps

By 2020, half of Danish electricity consumption will be covered by wind power. This means that technologies for converting electricity

1 International Energy Agency 2008, CHP: Evaluating the benefits of Greater Global Investments

2 This is equivalent to around 5 % of Denmark's total energy supply

3 In-depth analysis of the waste-to-energy field, Coolsweep project 2014

CASE STUDY B&W Vølund

B&W Vølund is one of the pioneering companies within the waste-to-energy industry. Since the first plant was completed in 1931, the company has grown to become one of the world's leading suppliers of equipment and technologies that turn solid waste and biomass into thermal energy.

State of the art technology and customer support are two defining characteristics of the company. Solutions are tailored to specific needs and requirements of the client, providing an industry-leading product.

This has made B&W Vølund the "go-to" for complex projects. Currently, the company is building one of the largest plants in the world located in Florida, capable of handling 2,700 tonnes of waste per day. The company has also been chosen to build the cutting-edge "Amager Bakke" waste-to-energy facility in Copenhagen.

www.volund.dk

into other forms of energy will be central to future smart energy systems. Heat pumps will play a central role in this development, and Danish investment in heat pumps is set to increase dramatically in the coming years. This development is also reflected in the research sector, where options for the integration of large-scale heat pump and district heating systems constitute one of the biggest research areas relating to smart energy. 48 companies answering the survey provide heat pump technologies or related consultancy.

> "Gas is a flexible energy carrier, which can be converted to electricity, used for heat, and stored in large quantities over time"
>
> Preben Birr-Pedersen, Lean Energy Cluster

Fuel cells and electrolysis

Denmark is a stronghold when it comes to fuel cell and electrolyser technologies with leading companies such as IRD Fuel Cells, Topsoe Fuel Cell, Electrochaea, GreenHydrogen, and Danish Power systems. Fuel cells and electrolysers in general have a wide range of possible applications such as acting as replacements for conventional cycle gas turbines in CHP production, the conversion of electricity into synthetic gas, and in the transport sector, where fuel cell engines are roughly twice as energy efficient as conventional combustion engines.

In particular, the conversion of electricity into synthetic gas that can be stored or upgraded into synthetic fuels has great potential in future energy systems. This is also an area which is receiving increased attention in Denmark, where the need to convert excess wind power into other energy forms is increasing. One example is the new facility at the Avedøre wastewater treatment plant in Copenhagen, which converts excess wind power into NG-quality green gas (see case study).

Because of the fact that fuel cells have several possible applications in future energy systems, it is very important to review their performance in connection with the entire energy system – and not just their individual properties - in order to identify which applications are most feasible and cost efficient.

CASE STUDY **Converting excess wind power into NG-quality green gas**

Wastewater slurry and excess wind power is turned into green gas on a commercial scale at the Avedøre wastewater treatment plant in Copenhagen. The treatment plant generates biogas from the decomposition of wastewater slurry. In addition to methane, biogas also contains CO2, and therefore it cannot be sent to Danish gas customers through the natural gas grid. However, a new biological process, where microorganisms convert hydrogen and CO2 to methane, is upgrading the biogas to natural gas quality.

The necessary hydrogen for this process is created by a newly built 1 MW power-to-gas electrolysis plant, where excess electricity from wind power is converted into hydrogen. The hydrogen is then used for upgrading the biogas created by the wastewater treatment before it is injected into the natural gas grid. The commercial-scale facility will also participate in the Danish ancillary services markets to help stabilize the power grid.

The project is an example of how a link can be established between Denmark's abundance of wind power and the production of eco-friendly gas delivered to the Danish gas grid. This integration is a very necessary piece of the puzzle in Danish efforts to transform the energy system and phase out the consumption of coal, oil, and natural gas.

www.electrochaea.com/technology.html

SURVEY

63
companies

~ € 388,1m
turnover

~ € 176,5m
average smart energy related turnover

~ 7600
employees

~3800
smart energy related employees

The energy storage sector

The fourth step in the smart energy value chain is energy storage, which can be expected to play an increasingly important role in future energy systems based on fluctuating energy sources. The vast majority of energy storage capacity around the world consists of pump storage, which relies on height difference. As there are no mountains in Denmark, Danish companies have had to come up with alternative ways of storing the energy. A total of 35 % of the companies participating in the survey stated that they provide technology and consultancy relating to some form of energy storage (see Fig. 10).

Thermal energy storage

The majority of the companies operating within this field provide thermal energy storage solutions. Thermal energy storage is a very cost-effective way to introduce time flexibility into the overall energy system, both in the form of storage tanks to regulate day-to-day heat consumption and seasonal heat storage, which stores heat generated through the summer period to be used during the winter. The current overall heat storage capacity of the Danish district heating system is estimated to be approximately 50 GWh, corresponding to less than one percent of total annual consumption[1]. However, hot water storage capacity is growing rapidly and the first large chilled water storage systems are under construction.

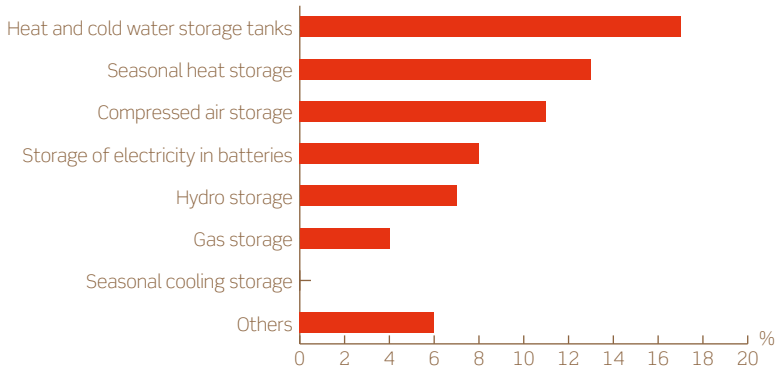
Gas storage

Besides the storage capacity enabled through the district heating grid, Denmark has a substantial capacity for underground gas storage, which is centered around two underground gas storage facilities located in the western (cavern storage) and eastern (aquifer storage) parts of the country. The combined storage capacity of these two facilities is more than 1 billion NM3 or around 30 % of the annual consumption of natural gas in Denmark.
In spite of the extensive energy storage capacity which is currently integrated into

> “Heat storage is often overlooked. However, about 50 % of the energy demand in Denmark is in the form of heat, while only around 18 % is for electricity”
>
> Allan Schrøder Pedersen, DTU

1 Energy Efficiency Improvements. DTU International Energy Report. 2012. P. 99

Figure 10 Energy storage competencies of company respondents (n=63)
Source: CCC survey



the Danish smart energy system, investment in further storage capacity in Denmark is expected to increase significantly in the coming years. In fact, the Danish transmission grid manager Energinet.dk has estimated that there is a need to create an additional 3.5 TWh of storage capacity in order to realize the vision of becoming completely fossil free by 2050.

One possible future solution to the lack of storage capacity could be to use the natural gas grid to store upgraded biogas and syngas generated through electrolysis. This solution becomes increasingly relevant in the long-term as the use of natural gas is gradually phased out.

Storage of electricity in batteries

Although the current storage options based on battery technology have several limitations, such as high price, durability, and power density, batteries might play an important role in the future energy system, for instance in transportation and mobility. 14 of the companies presented in this report provide battery storage technology or consultancy relating to battery storage[1].
Several test and demonstration projects exist focusing on the use of batteries for the storage of renewable energy from solar, wave, and wind. One example is the test facility for grid-scale storage of excess wind power in lithium batteries, which has recently been opened in the western part of Denmark. The project is the result of a partnership between the Danish company Vestas and the US company Altairnano.

1 For more information about energy storage technologies in Denmark, see "Energy storage options for future sustainable energy systems". DTU International Energy report 2013

SURVEY

83
companies

~ € 543,1m
turnover

~ € 243m
average smart energy related turnover

~ 12.400
employees

~6.200
smart energy related employees

The intelligent energy consumption sector

The final step in the smart energy value chain is intelligent consumption. The smart energy system in Denmark is becoming increasingly linked to consumers (i.e. companies, businesses and private consumers) in new and innovative ways.

Green and smart buildings[1]

Just like in the rest of the EU, buildings take up around 40 % of total energy consumption in Denmark. Therefore, a prerequisite for any smart energy system is that it is well-connected to the building stock, providing it with the most cost-effective and sustainable energy supply. The district heating grid in particular plays an important role, as space heating accounts for around 85 % of the energy used in private households in Denmark[2]. However, the distribution of heat through the district heating grid has a natural limit and buildings outside dense urban areas must generate their own energy locally.

Besides this, new buildings must be constructed with energy efficiency in mind, while the existing building stock should be retrofitted to meet modern energy standards. The latter is especially important in Denmark, where 75 % of the existing residential building stock was constructed before 1979 when the first Danish regulation for energy performance in buildings was introduced[3].

1 The Danish sector for green and smart buildings has been mapped by Copenhagen Cleantech Cluster. The report "Green and smart buildings in Denmark" can be downloaded on www.cphcleantech.com

2 DTU Risø Energy Report 10. Energy for smart cities in an urbanized world. P. 23

3 Energy savings in Danish residential building stock. Tommerup & Svendsen. 2006. P. 1

Empowering Danish consumers

It is not enough that the building stock is connected to the energy grids and built or retrofitted with energy efficiency in mind. The building users - be they private homeowners, businesses, public institutions etc. - must also be motivated to save energy. A direct way to enable more intelligent consumption is to make consumers aware of their energy use and base energy bills on hourly or even half-hourly tariffs rather than monthly. This would provide the incentive for the consumers to start using energy in times of peak production when the energy price is lowest.

A precondition for promoting consumer awareness is to make consumption data easily available. In this regard, all Danish electricity customers are required to have remote reading equipment installed by 2020. Danish grid operators have already installed electricity meters for remote reading in more than 1.6 M households, which corresponds to around half of Danish private consumers. Besides this, electricity meters for remote reading have been installed in the 50,000 Danish companies which have an annual consumption of more than 100,000 KWh. All in all, this means that around 75 % of electricity consumption is currently remotely read, which enables flexible pricing based on hourly tariffs[4].

4 Smart Grid-strategi. Fremtidens intelligente energisystem

On top of this, several Danish companies, such as GreenWave Reality, Saseco, and Zensehome, are advancing in the field of home energy management, providing technologies for the remote control of energy consumption in buildings. 28 % of the companies in this report provide intelligent building and control systems which help consumers use less energy. Besides this, a substantial percentage of the companies participating in the survey (18 %) provide smart meter and sensor technology or consultancy.

More and more Danish consumers are investing in their own small-scale electricity production units (e.g. photovoltaics and wind turbines). On days when the sun is shining or the wind is blowing, some of these consumers become prosumers in the sense that they produce more energy than they consume. The smart energy system allows for the excess energy to be sold back into the grid. In order to support this development, the prosumers are relieved from paying tax and Public Service Obligation (PSO) tariffs on their private energy production. This has prompted more than 90,000 private homeowners to invest in solar panels, while the number of private heat pumps has exceeded 45,000. In addition, private wind turbines are becoming increasingly popular along with private solar heat panels[1].

Companies and private businesses can also act as prosumers, for instance by delivering surplus heat from processes including cooling processes to the district heating grid. However, it can be hard for companies to shift to using renewable energy. In order to support this transformation, the Danish government has created a special subsidy for companies that want to establish shared energy facilities or become connected to the district heating grid.

1 www.bolius.dk

CASE STUDY Brunata

The Brunata company has almost 100 years of experience with heating meter systems for housing and buildings. The company produces heating meters, which enable the precise measurement of individual heating consumption. The company actively motivates consumers to save energy by providing them with their energy consumption accounts. In the company's experience, consumers can be motivated to save up to 40 % of their heating and water use when they are made aware of their consumption levels.

www.brunata.dk

Transport

A significant obstacle on the road towards a fossil-free Denmark is the transport sector, which currently constitutes around one-third of total Danish energy demand. The current Danish fleet of electric vehicles (EVs) and hybrids is very small in comparison to that of surrounding countries like Germany and Sweden. There is a total of around 2.2 M passenger cars in Denmark, but less than 1 % of them are EVs[1].

As much as the transport sector presents a challenge to the overall sustainability of the energy system, it also presents unique opportunities. When combined with a smart grid, ELVs can serve as energy buffers to help balance electricity supply and demand. However, a precondition for the electrification of the transport sector is that a wide-ranging charging infrastructure is established. Several Danish companies, such as Lithium Balance, ECOmove, and CLEVER, operate within the field of EV transportation, providing for instance battery and charging technologies.

> "If we are to become fossil free by 2050, we need to focus more on transportation"
>
> Leif Sønderberg Petersen, DTU

Another option is fuel-cell vehicles (FCVs), which run on hydrogen. A number of barriers still need to be removed before widespread use of FCVs might become a reality. The biggest barrier is the necessary development of a hydrogen infrastructure, but also issues concerning the working life of fuel cells and the materials required for fuel cell catalysts are presenting problems[2]. 12 % of the companies participating in the survey provide technology or services relating to electric vehicles or hydrogen vehicles.

Light transport, which can be turned into a surplus for the energy system if approached in the right way, is one thing. Another thing is heavy transport such as planes, shipping, and trucks. As things stand, heavy transport has no low-carbon alternatives to fossil fuels, such as electric power or ethanol, unlike light transport. However, upgraded biogas could be used as fuel for the heavy transport sector. Denmark is currently far behind other European countries such as Sweden or Germany when it comes to establishing a gas charging infrastructure and green-gas-driven heavy road transport. However, the use of upgraded biogas in the transport sector is getting increased attention in Denmark, driven by several municipalities, including Copenhagen, which are currently experimenting with gas-driven public buses.

Lastly, the aviation industry has also started to look at alternative fuel options. Denmark is leading the Nordic Initiative for Sustainable Aviation (NISA), which aims to promote the use of sustainable fuels in the aviation sector[3].

1 Energy research at DTU. 2013. P. 25

2 Energy research at DTU. 2013. P. 25

3 NISA. www.cphcleantech.com

Figure 11 Companies' main collaboration partners: (n=165)
Source: CCC survey

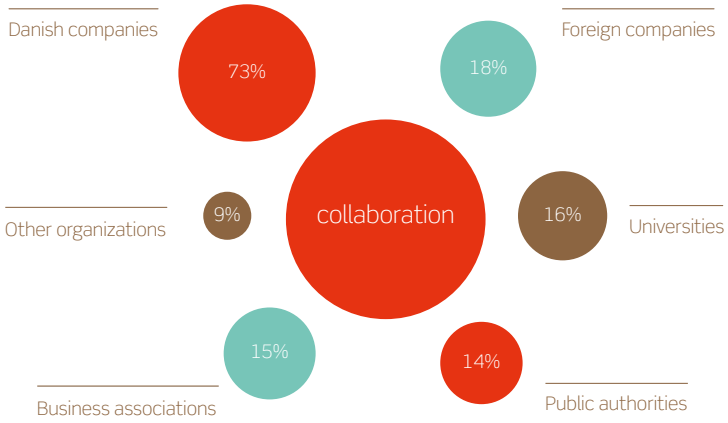
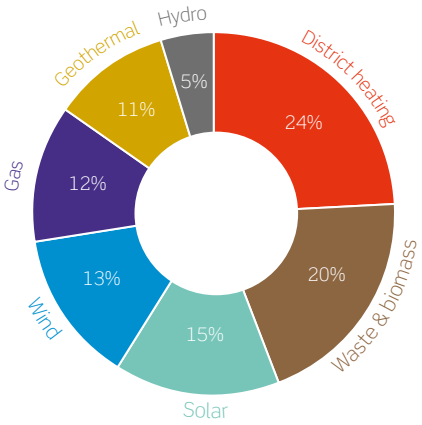


Figure 12 Companies' collaboration with other industry sectors (n=140)
Source: CCC Survey



Collaboration across the smart energy sectors

New innovation, knowledge, and growth within the smart energy sector are very dependent on holistic and system-oriented thinking across various different technology domains. Cooperation and co-creation are key words in a society like the one in Denmark, which is committed to putting its energy production and consumption onto a more sustainable footing. Therefore, the companies participating in the survey were asked to provide information about their collaborative activities.

Figure 11 provides an overview of the main collaboration partners of the companies participating in the survey. As can be seen, business-to-business collaboration is the most common form of collaboration among the companies participating in the survey, followed by collaboration with the university sector and public authorities.

In order to get an insight into the level of cross-sectorial collaboration, the companies were also asked to provide information about their working relationships with stakeholders from other sectors outside of their main area of activity (see fig. 12 on page 37). The answers show that one out of every four of the participating companies collaborates with an actor from within the district heating sector. This testifies to the central role that district heating plays in the Danish smart energy system. The level of collaboration between other sectors and actors working within the sector for waste and biomass CHP is also significant.

In general, 80 % of the companies participat-

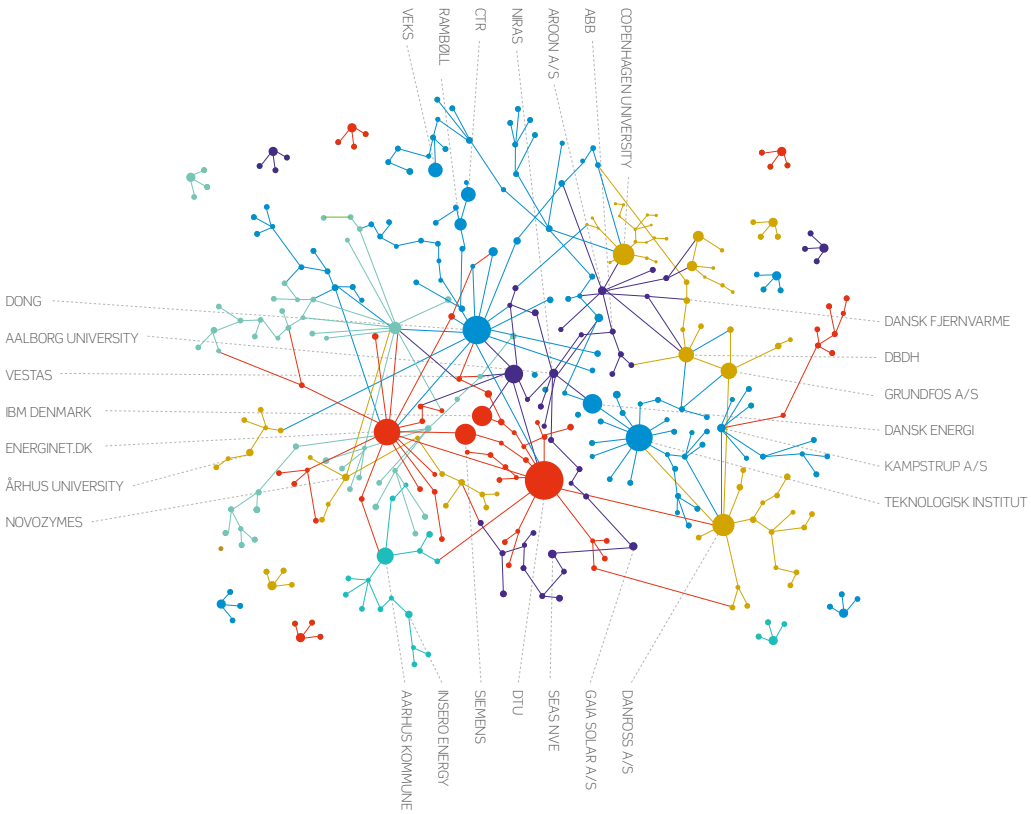
"Innovation is an interactive process, which thrives when individuals and organizations collaborate and learn from each other"

Roman Jurowetzki, Aalborg University

ing in the survey indicated that they collaborate with one or more actors from industry sectors other than their own, indicating a considerable level of cross-sectorial industry collaboration in Denmark. However, there is still room for improvement as further integration between the different energy grids and traditional energy domains seems to be paramount in the future energy system. This calls for holistic and system-oriented solutions, which are created when different stakeholders from across the value chain come together and collaborate.

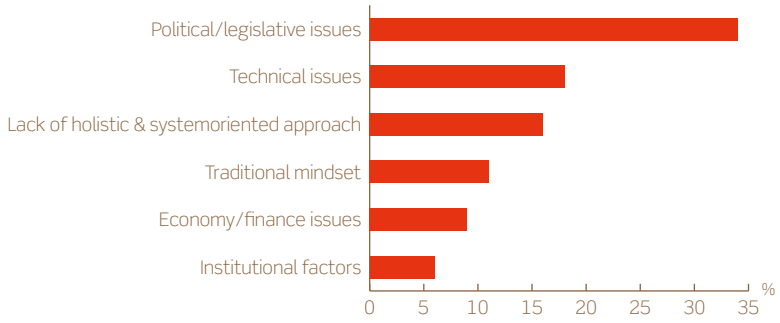
Lastly, the data on collaboration between the companies participating in the survey has been used to create a visualization of the network for Danish stakeholders operating within the smart energy system (see fig. 13). The biggest circles represent the stakeholders, which were mentioned most times in the survey as collaboration partners. As can be seen,

Figure 13 Collaboration network of the Danish smart energy stakeholders participating in the survey
Source: CCC Survey



the universities in general are situated as central collaboration partners, particularly the Technical University of Denmark and Aalborg University, which both have a strong profile when it comes to smart energy. Besides this, some central companies, such as Energinet.dk, DONG Energy, Siemens, Rambøll, Danfoss, Grundfos, and SEAS-NVE stand out as central collaboration partners for a large part of the participating companies in the survey. Also, a number of trade organizations, such as DBDH, the Danish District Heating Association, and the Danish Energy Association are central in the network.

Figure 14 Future obstacles mentioned by the companies: (n=119)
Source: CCC survey



Future challenges

The companies were also asked for their views on future challenges which need to be overcome on the road towards a fossil-free Danish society. The answers have been categorized, with political/legislative issues as the most prevalent type of answer followed by technical issues (see fig. 14). New technologies have to be developed and the political and legislative framework should continue to promote the innovations with the most promising potential. This is how Denmark developed its leading technologies within wind power, district heating, large-scale solar thermal energy, and waste incineration.

Besides this, a large number of companies point to the lack of system-oriented and holistic thinking as a barrier which must be overcome. There is little doubt that future energy will be supplied through a system of integrated energy grids. This increases the need for cross-sectorial collaboration and technology development.

Lastly, it is interesting to note that only a few of the companies mention economic issues as a future barrier. The fact that the companies do not pay much attention to the economic and financial barriers to future developments within smart energy might indicate that investment in green energy solutions and technology development has become good business or even mainstream.

6. Smart Energy research in Denmark

Denmark as a test bed for smart energy solutions

Denmark's ambitious energy policy necessitates large-scale testing and demonstration of new solutions. Over the past decade, Denmark has been pursuing the ambitious target of becoming a European smart energy research and demonstration hub. This goal was once again highlighted in the Government's 2013 Smart Grid Strategy and with the launch of 27 new research projects in 2012 and a further 9 in 2013[1] (see page 78 for a complete list of current Danish smart energy projects).

emphasizes the importance of interaction between companies, public and private organizations, research institutions and customers for the development of successful new technologies. This becomes particularly important when the technologies, business solutions, and regulations to be developed relate to large-scale technical systems as is the case with smart energy.

Denmark has a strong tradition of collaboration between grid companies, research institutes, energy utilities, and the public sector. A widely quoted example is the development of the dominant wind power technologies that evolved out of pioneering interaction between a variety of Danish actors.

Today collaboration, experimentation, and broad scope interaction are core guiding principles of Danish smart energy research, development, and demonstration activities. This set-up allows for leverage of the knowledge and expertise of the different participating actors, while linking technology development with business and user perspectives that are equally important for the diffusion of innovative systems.

> "Danish competencies relating to electrolysis and heat storage are world class"
>
> Allan Schrøder Pedersen, DTU

Innovation system literature that aims to explain technology driven economic growth,

1 Smart Grid-strategi. Fremtidens intelligente energisystem

CASE STUDY **Island of Bornholm as a test bed for smart energy solutions**

Located in the southern Baltic Sea, the island of Bornholm is an ideal place to test smart energy system solutions. With only one submarine power cable from Sweden connecting the island to the rest of the world, it is possible to isolate the grid from outside interferences and track changes precisely.

Additionally, Østkraft (Bornholm's utility company) is continuously building the share of sustainable energy sources in their energy mix. 75% of the electricity produced and 45% of the total energy consumed by the 40.000 residents come from sources like wind, solar and biomass.

Given the favorable environment, Bornholm has been chosen as the site for a number of national and international R&D projects. Examples of these include EV studies, solar cells, energy-efficient construction projects and the development of intelligent electricity systems.

www.brightgreenisland.com

General comparison to the EU – Projects

The 2013 edition of the European Commission's "Smart Grid projects in Europe" report outlines Denmark's strong leading position within smart energy research, development, and demonstration.

- Among all the European countries, Denmark has the highest involvement in R&D projects, as compared to demonstration and deployment, and the highest research investment per capita and consumed KWh.
- A third of all national smart energy projects in Europe are conducted in Denmark[1].
- Furthermore, Denmark is participating in 30 percent of all multinational smart grid projects in Europe.
- Together with Germany, Denmark is the leading country for projects focusing on consumer engagement.

"A third of all national smart energy projects in Europe are conducted in Denmark"

The Danish Research Environment

Successful research and development of new technologies is impossible without sound financing schemes. Danish smart energy research benefits from 6 active programmes that together cover all stages within the R&D process - from basic R&D to commercialization.

The first publically supported research in the broader smart energy field started back in 1996. However, not until 2005 was there any significant growth in the number of new smart energy research projects in Denmark. Today, the programmes' joint online catalogue, energiforskning.dk, lists 103 projects within the area of smart grid and systems. A recent study carried out at Aalborg University on the composition of the project participants found that incumbent companies from the energy sector are displaying a growing interest in smart energy research. The dynamic network analysis suggested that over time these companies have become more engaged and more dominant as leaders of smart energy projects[2].

For this report, we have used structured data on the projects' budgets, participants and the time of implementation, together with brief project descriptions of the 103 projects in the database, to map out key technology trajectories within Danish smart energy research. Rather than sorting the projects into predefined technical classifications, we have used a natural language processing approach that relies on word co-occurrence patterns in project descriptions to identify similarities between the projects, which allows us to recognize technology clusters. Fig. 16 on page 43 is a network visualization of this exercise. The nodes of the network represent single projects, while the connecting edges describe the context similarity between them. The size of the nodes is determined by the total budget of the project.

1 Calculation made by Aalborg University (Roman Jurowetzki) based on the project overview provided by JRC

2 Incremental by Design? On the Role of Incumbents in Technology Niches: An Evolutionary Network Analysis. Hain, Daniel S.; Jurowetzki, Roman. 2014

The overall picture shows a mix of many small and a few large projects. This is the result of a 'step by step' approach, which has created a research landscape dominated by cost-effective small-scale projects in many different areas, providing a high level of technological variety.

Most of the current demonstration projects with large budgets were initiated around 2012 and build on existing R&D experience in a particular field. These projects are often led by large established companies that have the resources and capabilities to bridge knowledge from the R&D into the demonstration and commercialization stages. Their size enables them to combine various technologies in a systemic setup and explore the innovation's potential by looking at the whole value chain.

We identify 19 coherent clusters, 10 of which make up approximately 75 percent of all the projects in the database and build large enough groups to be considered as parts of a technological trajectory within the emerging Smart Energy area. Already this decomposition demonstrates the technical diversity present within the Danish smart energy sector. The listed research projects range from flexible electricity consumption, data security and communication to heating and transportation.

The systemic nature of the involved technologies makes a clearer clustering into more distinct project groups very hard. Therefore the clustering provides only guidance for the presentation of the Danish research landscape and shouldn't be seen as a definitive technical classification.

Research area one: Heat-pumps and District heating

The largest identified project-cluster relates to the development of heat-pump technologies. It contains projects that involve exploring options for the integration of large-scale

Figure 15 Initiated projects per year by programme
Source: Energiforskning.dk

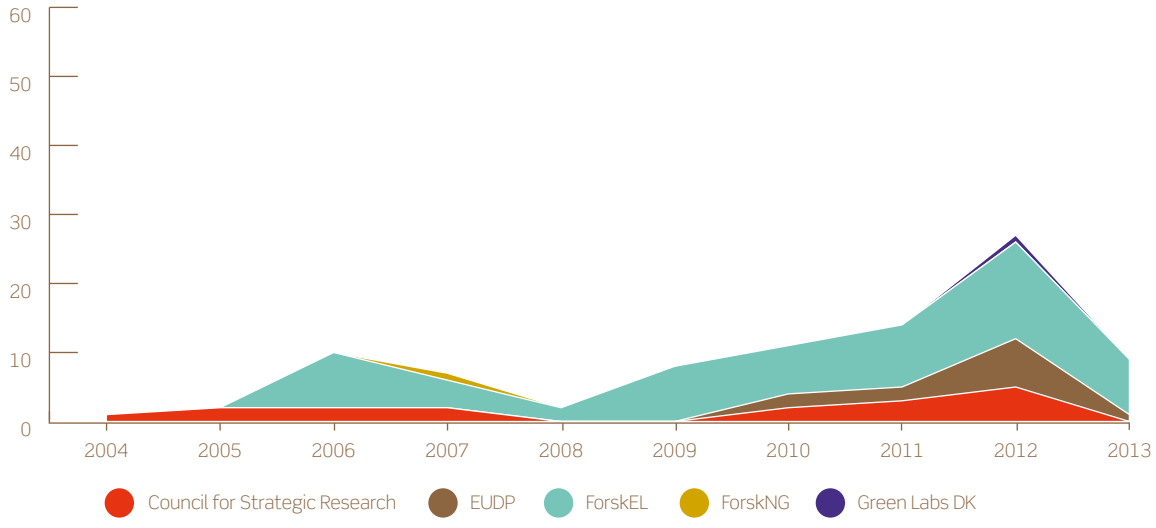
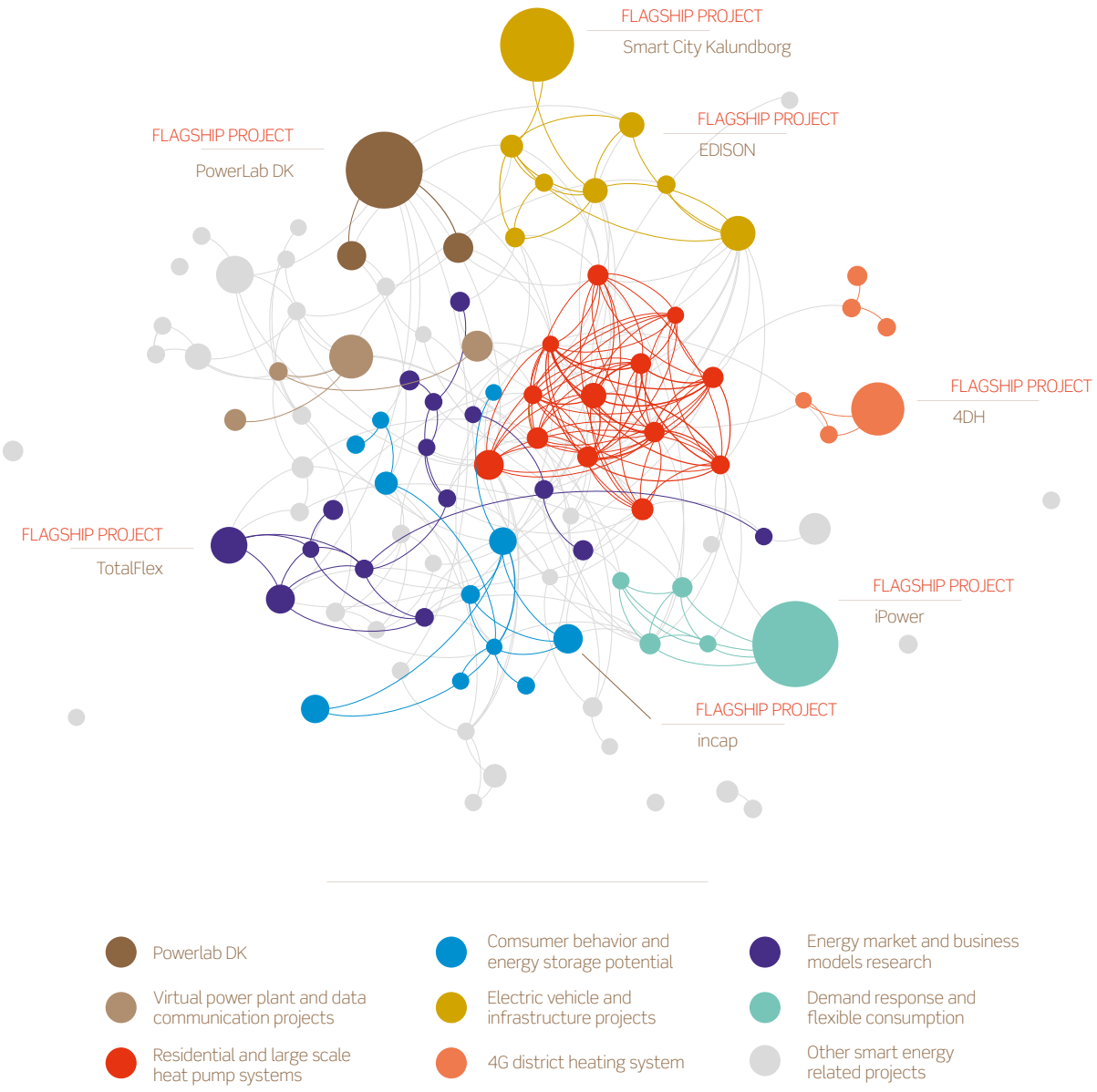


Figure 16 Semantic mapping of all Danish "Smart Grid and Systems" projects
Source: Aalborg University, made with data from Energiforskning.dk



heat pump and district heating systems by connecting CHP plants with large heat pumps, and also solar systems in some cases. Such combined systems could become a more centralized way of allowing for more intermittent wind power in the overall energy system, while combining the efficiency and storage options of heat pumps with the existing CHP infrastructure.

A significant number of projects are focusing on residential small-scale applications. These activities are aimed at developing and testing standards for smart-grid-ready 'plug-and-play solutions', the remote controlling of pumps, test protocols, and other technology standards. One example is the groundbreaking work being carried out by the Technological University of Denmark concerning so-called ORC[1] power plants, which are able to function at individual household level in connection with, for instance, a solar heat collector. The solar collector generates waste heat, which can be used to warm up and vaporize certain liquids that evaporate at a lower temperature than water. The steam is then transferred through a turbine to generate electricity before condensing back into liquid form[2].

The heat pump project cluster is connected to a smaller cluster of projects concerning research into district heating systems. The projects are focused on the development of the 4th generation of district heating systems that can be integrated into renewable flexible energy production and new residential housing concepts, and can implement the concept of a cost-efficient, low-temperature heating infrastructure.

Overall, the strong standing of heat-pump and district-heating-related research demonstrates the importance of space heating within smart energy and the ongoing fusion of the electricity and heating sectors.

1 Organic Rankine Cycles (ORC)

2 Energy research at DTU. 2013. P. 16

Research area two: Demand response and consumer engagement

The energy market system of the future will contribute to balancing the energy distribution grid in order to prevent bottlenecks and overload situations. Six of the identified projects are targeting the market challenges that will emerge as a result of the flexibilization of the energy system. These projects are developing, testing, and evaluating systems and models that allow for interaction between energy generation units and intelligent energy consumption devices, which respond to dynamic electricity prices.

Are energy users ready to embrace remote control solutions of their household appliances in order to contribute to grid stabilization? Are industrial users and organizations capable of modifying production and organization processes to help in balancing the energy system? One of the central competence areas in Danish smart energy research is built around a number of studies about consumer response to the emerging flexibilization of energy usage. The central project in this area is iPower, which started in 2011 and will continue until 2016. Drawing on the experience of many smaller past projects, the goal is to develop, demonstrate, and evaluate solutions that can address all the critical stages in a system with flexible energy consumption.

Research area three: Virtual Power Plants and Data Communication

The increasing number of distributed and often intermittent energy generation units challenges the energy system's stability and creates the need for flexible consumption. However, the diversity of energy sources and their dispersion in conjunction with smart energy storage units can be deployed in order to balance the system in the generation and transmission stages. A number of Virtual Power Plant projects are studying the potential of using this concept in the design of emerging

CASE STUDY iPower

iPower is the largest and most comprehensive Danish smart energy project running from 2011 until 2016. Its focus is on the systemic interplay between energy producers, utility companies, and consumer appliances, building on results from previous research into the individual smart energy technologies that now have to be linked together. With a budget of more than €16 M and 32 Danish and foreign project partners from industry and research, it has generated a platform for the development of systemic standards that are a necessary basis for the production of market and export-ready solutions within home and industry automation.

Apart from technical development, the project is evaluating the broader socio-economic potential and impact of energy flexibility. This includes cost estimations for distribution and transmission system operators and industrial, commercial, and residential consumers. Companies which are interested in developing new, intelligent products which can interact with the energy system are welcome to use the results of the project.

www.ipower-net.dk

intelligent energy systems.
The automatized coordination of a large variety and number of components requires intelligent control systems, but also innovative and secure data communication and management systems linked to the energy grids. Danish research projects on communication in the energy grid have been focused on developing standards for remote control and communication for CHPs. The most recent project, CHPCOM, is building on insights from previous projects in Denmark and international research collaborations. The project is bringing together CHP operators, equipment producers, transmission system operators, and market players to demonstrate and further develop existing, mature international communication standards.

The smaller projects are supported by investments in the research infrastructure such as the PowerLabDK, which provides a world-class testing platform. The testing facility is open to Danish and international researchers and companies and can be used to conduct experiments on laboratory, utility, and real-world scale.

CASE STUDY PowerLabDK

PowerLabDK is the name of an interconnected network of laboratories and test facilities owned by the Technological University of Denmark and the private company Østkraft, which forms a unique platform for experiments within integrated energy infrastructures, smart grid technologies, distributed energy sources, and component testing in SYSLAB at DTU Risø campus. The facilities can be used for a variety of test and demonstration purposes, ranging from fundamental research to large-scale testing. A unique feature of PowerLabDK is the 1:1 replica of Østkraft's SCADA system covering the electricity needs of more than 43.000 citizens. The PowerLabDK platform can be used to perform tests of new technologies and solutions in a virtual environment based on real-time and real-life data, which is constantly updated from the Bornholm energy system.

www.powerlab.dk

Research area four: Electric Mobility and Urban Infrastructure

Electric mobility is a central component area of the future energy system. Already today electric-powered vehicles are available on the mainstream market. However, any broad diffusion has yet to happen. Electric vehicles (EVs) have the potential to address several issues at the same time: while reducing the negative climate impact of transportation, they can potentially provide grid stabilization services. When connected to the grid, remote charging control systems can use the battery capacities of the vehicles as flexible energy storage units. Charging will be shifted to time periods when renewable energy is abundant in the system, while stored energy can be retrieved from the batteries in peak-load situations.

> "Denmark is a frontrunner when it comes to smart energy test and demonstration"
>
> Leif Sønderberg Petersen, DTU

These applications require an intelligent charging infrastructure and need to be accepted and embraced by the consumers. The integration of EVs into the Danish energy system was explored in the EDISON project between 2009-2011 and continues to be one of the focal points within Danish intelligent energy system research. Among the more technical projects that are targeting the development of advanced battery technologies and charging solutions, such as the recently started NICOLA smart charging project, there is a significant amount of consumer-related research being carried out that is investigating driving patterns and more broadly the disposition of drivers to accept these technologies and to adjust their behaviour.

The integration of these technologies into the complexity of an urban infrastructure is currently being explored in the large-scale demonstration project, Smart City Kalundborg. The project is bringing together smart energy technologies relating to electricity, water, heating, various forms of transportation, and energy efficiency in buildings. The combination of most of the relevant technologies allows an analysis of the entire value chain and the energy usage behaviour of individuals and companies, and is targeted at helping to develop sustainable business and service models for the energy system of the future.

CASE STUDY Smart City Kalundborg

With a total project budget of 100m. DKK (13,4m EUR), Smart City Kalundborg is the most ambitious smart-grid project in Danish history. The aim is to build a next-generation energy system that combine information from electricity, heating, water provision along with transportation and building data. The broad scope of the project is clear when looking at the 12 project partners. EV's, solar, utilities, smart grid management systems, sensor technology companies and more are all involved the process.

A central part of the project is the "Energy Hub" – an open platform that offers citizens and companies user-friendly services that increase flexibility within the grid. Using the hub, 3rd party developers will be able to build apps that inform end-users about production, grid capacity, consumption patterns, real-time price fluctuations and more.
As a dedicated green industrial municipality, Kalundborg has substantial experience with complex challenges. As an example, the city is home to the first Symbiosis network in the world where resources from industrial complexes are shared within a common network.

www.smartcitykalundborg.dk

7. Conclusion

Supported by ambitious and long-term political goals, the Danish energy system is undergoing a transformation away from fossil fuels towards green and renewable energy sources. Replacing conventional fossil fuels with fluctuating renewables such as wind power, large-scale and small-scale solar power, and wave power is no small challenge.

The different energy grids must be integrated into one single coherent and cost-effective energy system, which can be managed intelligently and enables two-way communication between supply and demand. Furthermore, consumers must be empowered and motivated to invest in: cost-effective energy-saving measures.

This report illustrates some of the many synergistic effects which can be promoted between the energy grids for electricity, gas, district heating, and district cooling. The Danish smart energy system of the future will be based on the integration of these grids. Besides this, the report draws a picture of a Danish sector for smart energy, which is highly interconnected and innovative, and which possesses world-leading competencies within several technology domains relating to smart energy, such as large-scale solar heat, district heating, wind power, combined heat and power, waste incineration, fuel cell technology, and heat storage.

Lastly, the report outlines the central position that Denmark occupies when it comes to smart energy research and development, hosting 30 % of all research projects within the EU. The country is home to several unique test facilities, such as the PowerLabDK, Smart City Kalundborg, and the National Test Center for Large Wind Turbines, which provide Danish as well as foreign companies with the opportunity to test the solutions of tomorrow.

Denmark is one of the leading countries in the world when it comes to creating smart and distributed energy systems based on fluctuating renewables, and Danish companies are in a strong position to dominate part of the growing market for smart energy solutions.

DENMARK RANKS AS NUMBER ONE IN THE EU WHEN IT COMES TO ACCESS AND SECURITY OF DELIVERY IN TERMS OF ENERGY SUPPLY

World Economic Forum

8. Company matrices

The matrixes list the companies according to the technologies or consultancy services they provide within the smart energy value chain. There are a total of five matrixes corresponding to the number of steps in the value chain (i.e. production, distribution & transmission, conversion, storage, and intelligent consumption).

The company matrixes are limited to technology companies or consultancies operating within the Danish smart energy market. The information presented in the matrixes has been provided by the companies through the survey. The symbols in the matrix are as follows:

Type of product:
● = Technology or consultancy provider

Number of employees:
● 1-10
●● 11-25
●●● 26-50
●●●● 51-100
●●●●● 101-500
●●●●●● >500

● = employees carrying out smart-energy-related tasks

○ = employees not carrying out smart-energy-related tasks

Companies which are not included in the list but wish to be so, can write to jom@cphcleantech.com to be included in the online pdf.

9. Matrix: Energy production

Company name	Contribution	Wind Energy	Hydro Energy (incl. tidal and wave)	Photovoltaics/solar cells	Solar hot water panels	Biogas	Syngas	Geothermal energy	Biomass	Other
ABB A/S ●●○○○○	Systems to integrate and optimize the production and distribution of energy, including complete automation and control with incorporated demand-response technologies.	●	●	●		●			●	
Accenture ●○○○○○	Accenture Smart Grid Services focuses on delivering innovative business solutions supporting the modernization of electric, gas and water network infrastructures to improve capital efficiency and effectiveness, increase crew safety and productivity, optimize the operations of the grid and achieve the full value from advanced metering infrastructure (AMI) data and capabilities.	●							●	
Aguasol ●	Aguasol Unibody is "Best in Class" solar water heater. It is top-performing in climates with winter. And it does not get too hot (boiling) in hot climates.				●					
ALECTIA ●○○○○○				●	●			●		
alfred priess ●○○○	Lighting column with integrated solar panels for stand alone operation.			●						●
Alstom Grid ○○	Manufacturer and Service provider for HV Grid	●	●						●	
Averhoff Energi Anlæg A/S ●○	Customized Energy Solutions Energy production and optimization.				●	●			●	●
Babcock & Wilcox Vølund ●●●●○	Our expertise is in technology and customer support. We have designed and built more than 500 waste-to-energy and biomass production lines.						●		●	●
Balslev ●●●○	Our expertise comprises innovative, sustainable and profitable solutions within Intelligent Building Automation, energy supply, security and transportation, corrosion protection, hospital planning and energy optimization.	●		●	●	●	●	●	●	
Barker Jørgensen ●○	Barker Jørgensen A/S design and construct various types of fans and blowers for worldwide projects within the Power Generation Industry.					●			●	
Bigadan A/S ●○	International provider of contracting services for large-scale co-digestion biogas plants. Operation and ownership of similar biogas plants.					●			●	
Bioenergi Vest ●	Implementation of decentral biogas production, biogas grid transmission and integration of energy systems					●			●	
BioGasclean A/S ●	Biological desulfurization of biogas and landfill gas.					●				
BKF Klima /AS ○	Dealer of Daikin (Daikin Altherma) and Rotex heating products for Danish market				●			●		●
Brix & Kamp Energi A/S ●○○						●		●	●	
Capgemini Sogeti ●○○○○	We provide smart energy services to over 75 global utility clients representing 113 million metered customers actively engaged in smart energy programs.	●	●			●	●	●	●	

Company name	Contribution	Wind Energy	Hydro Energy (incl. tidal and wave)	Photovoltaics/solar cells	Solar hot water panels	Biogas	Syngas	Geothermal energy	Biomass	Other
CGI ●○○○○○	Implementation and operation of Dataclearance centers (datahubs), Smart Meter & Headend systems, Meter Data Management systems, Customer Service and Billing platforms and Asset Management and mobile workforce management systems.	●	●	●	●	●	●	●	●	
CO Rør Blik & VVS ○○					●					
COWI ●○○○○○	360 degree consultancy approach including all aspects of planning, development, implementation and evaluation activities within energy, enginering, enviromental and financial issues	●	●	●	●	●	●	●	●	●
CTR ●○	DH transmission company responsible for - purchase of DH, - load dispatch of CHP production, - production of reserve and peak heat only boiler - operation of transmission network							●		
Danish Geothermal District Heating ●	Our consultancy services are centered around project development and implementation, operations support and R&D.							●		
Danish Technological Institute ●○○○○○	Research, Development and demonstration of Smart Energy solutions. Test and certification of Smart Energy products. Consulting jobs within Smart Energy and user behavior.			●	●	●			●	
Dansk Energi Service ●●	Boilers for steam & thermal oil. Burners for gas & oil All kind of installation works				●			●	●	
Dansk Solar Energi ApS ○	Danish Solar Energy delivers solar energy systems of high quality at competitive prices.			●	●					
DanSolar ApS ●	DanSolar offers the complete package of configuring, calculating, installation and monitoring. This gives us the possibility to compete for projects within the regular and large-scale projects.			●	●					
DI Energy ●	Public affairs and business development									●
Dialight BTI ●●	Aviation Obstruction Lights (top of nacelle) - Marine Aids to Navigation (offshore wind turbines)	●								
DrivhusEffekten aps ●●	Deliveries of solarplants - turn key solutions incl. internet based informationssystems			●						
Dronninglund Fjernvarme ●	District heating				●					●
Ea Energy Analyses ●○	Ea Energy Analyses is a Danish consulting company providing consulting services and performing research in the field of energy and climate change.	●		●		●	●		●	●
EasyBIPV Aps ●	Production of high efficient PV which in ONE product can be used for: on roof - BIPV and as PVT = one PV product for all PV/PVT demands			●						
EC Power A/S ●○○	As base we offer the most efficient conversion of natural gas into heat and power. We also offer such distributed systems to be operated as an virtual power plant.									●

Company name	Contribution	Wind Energy	Hydro Energy (incl. tidal and wave)	Photovoltaics/solar cells	Solar hot water panels	Biogas	Syngas	Geothermal energy	Biomass	Other
Ekolab	Consultancy on low energy houses and renewable energy			●	●				●	
EMD	Software for design of sustainable energy systems	●		●	●	●		●	●	
Enopsol ApS	Aquifer Thermal Energy Storage (ATES) for district heating and cooling, building heating and cooling and industrial heating and cooling.							●		
Euro Therm A/S	Euro Therm A/S is a world class company within design, development and production of biomass combustion plants								●	
EWS GmbH & Co. KG	We represent market-leading products and offer services of equally high standards. Our focus is on renewable energies, centered around pellet heating, solar thermal heating, photovoltaics and heating pumps.			●						
Focus BioEnergy	Engineering, procurement and contract management of small biomass CHP plants, primarily used within industries with high energy consumption. (1-15 MW thermal outlet from boiler).								●	
FORCE Technology	We provide consultancy services related to smart technology for enhancing energy efficiencym, reducing enviromental impact and production costs.								●	●
Frichs A/S	Conversion of bio mass and waste into gas. Utilising the produced gas into a CHP or CCHP. Conversion of waste into liquid fuel. Utilising the produced liquid fuel into a heavey duty special diesel generator.	●				●	●		●	●
FRIGORTEK Cooling Systems	Industrial Heat pump systems for Agri business, Aqua Culture & public buildings		●					●		●
Gaia Solar A/S	Total supplier of PV solutions: Gaia Solar supplies high quality PV systems for residential buildings, businesses, government and municipalities.			●						
GEO	Complete subsurface engineering and design of shallow geothermal energy systems for heating and cooling. Turn-key solutions for individual buildings and district heating systems. Offshore geotechnical investigations engineering services related to wind farms.	●						●		
Grundfos A/S	Grundfos produce and sell high quality pumps and controls for all parts of the district energy system.		●		●	●		●	●	
HedeDanmark a/a	Producing and delivering biomass from danish forestry to the power and heating plants in Denmark.								●	
HMN Gassalg A/S	Gas to glad consumers					●	●			
HOFOR	Supply of electricity, district heating, district cooling,and city gas	●		●		●		●	●	●
HS Tarm	Biomass boilers Development, production and sales								●	
Høje Taastrup Fjernvarme a.m.b.a.	district heating system with 6000 customers, 230 km pipelines, 9 centrales				●		●			
IBUS Innovation A/S	IPR within the field of Integrated Biomass Utilisation Systems					●			●	

Company name	Contribution	Wind Energy	Hydro Energy (incl. tidal and wave)	Photovoltaics/solar cells	Solar hot water panels	Biogas	Syngas	Geothermal energy	Biomass	Other
IC Electric A/S	Ventilation, lightning, sun wells			●	●			●		
IEN Consultants	Sustainability consultancy mostly within the building sector	●		●	●					
Infuser	Infuser has a license for the University of Copenhagen technology for removing smells from air with a very low specific energy input, and without degrading methane present in the fuel.					●	●		●	
Innogie ApS	Innogie ApS is a technology driven company specializing in solar energy and how to integrate this technology into modern homes.				●			●		
inpower	Power grid balancing system, by use of large scale high voltage Electric boiler in district heating systems.	●								●
IRD Fuel Cells A/S	Components for fuel cells for OEM's. Systems are produced in the form of hydrogen producing electrolyzers and micro heat & power units for residential heating and power production based on hydrogen.									●
KIRT THOMSEN	As a visual R&D consultancy firm, Kirt-Thomsen combine technical knowledge and insights from various green technology markets to offer their clients improved visualization and communication in R&D.	●	●	●				●		
KP Komponenter A/S	Subsupplier of components to Europes leading manufacturer of windturbines.	●								
Lauridsen Industri	Lauridsen Industri is manufactor of valves and heting valves					●	●		●	●
Lean Energy Cluster	The cluster services concern knowledge sharing, project development and system export within the field of energy efficiency and smart energy.			●	●	●	●	●	●	
LEANCON Wave Energy	Development of a wave energy converter and the belonging manufacturing technology.		●							
LH Energy A/S	Energy efficient system and equipment					●			●	●
Logics	Building model based decision basis for energy system owners and operators, e.g. modelling new technology platforms or new technologies in existing platforms.									●
Markedskraft Danmark	Consultancy and Energy trading. Advising clients in getting the most value of the market possiblities	●	●			●			●	
Naturgas Fyn						●			●	
Nyrup plast A/S	Development, sales and consulting in: rainwater harvesting, cleaning of wastewater, use of ground tempeture for ventilation, sun energy.			●	●					●
OE3i	Our key product Mentor Planner is a decision support and optimizing system for CHP's and disstrict heating Companies. Our system helps the customer to optimize the production and distribution.				●			●	●	●

Company name	Contribution	Wind Energy	Hydro Energy (incl. tidal and wave)	Photovoltaics/solar cells	Solar hot water panels	Biogas	Syngas	Geothermal energy	Biomass	Other
OK ●○○○○	Selling all kinds of Energy solutions for households (heatpumps, gasboilers, PV systems) We are selling above mentioned products for Commercial market as well.			●						●
P&I Engineering ApS ●	Development of industrial process for drying, evaporation, waste to energy and biogas, including digestate handling					●			●	●
Pettinaroli A/S ○○	Heat pumps, photovoltaic and heatdistribution			●	●			●		
PlanAction ●	Consultancy in planning, implementation of biogas systems including technical and logistic set up,smart operation of biogas in relation to biomass input and utilization of digestate, optimizing of production and use of biogas as well as financial and environmental impact analysis.					●				
PlanEnergi ●○	District heating systems with 100% RES and integrated in electricity and gas grids	●		●	●	●			●	●
PowerLabDK, DTU Elektro ●●●	PowerLabDK is a unique experimental platform for technology development, testing, training and demonstration within electric power and energy.	●		●						
ProEnergi ●	ProEnergi advises companies, housing associations, institutions and private homeowners on how to optimize energy consumption.			●	●				●	
PureteQ A/S ●○	PureteQ Modular Turbo Scrubbers for heat exchanging of sour flue gasses with or without heat pumps. PureteQ Energy system converts low caloric value industrial by-products and liquid hazerdous waste into clean energy					●			●	●
Q2 A/S ●	Biogas Projects and Landfill gas Projects. Upgrading of biogas removing CO2					●				
Q-PRO ApS ●	SUN-PRO.dk Solvarme Scotte Pillefyr and PH Stokers				●				●	
Ramboll ●○○○○○	We offer independent and multidisciplinary consultancy services within all energy forms and including all relevant sectors. We help our clients to plan, develop, design, procure and operate energy and environmental friendly solutions, which are the most cost effective for the society, for the local community and for our client.	●	●	●	●	●	●	●	●	●
Ross Engineering ○○	Ross Engineering provides well management services for operators of geothermal licenses and other license holders of onshore drilling projects.							●		
SCANPOCON ○	Import of inverters, charger and batteries for wind and solar powered off-grid systems	●		●						
SEAS-NVE ●○○○○○	End user comfort through responsible smart energy products supporting the renewable energy transition.	●								
Simatek A/S ●○○	- Bag House Filters - Hot air and Hot gas filtration (removal of particles and acid components)					●	●		●	●

Company name	Contribution	Wind Energy	Hydro Energy (incl. tidal and wave)	Photovoltaics/solar cells	Solar hot water panels	Biogas	Syngas	Geothermal energy	Biomass	Other
Solar ●○○○○○	Join different supplier's technologies to a complete solution to the customer. Make awareness and educate of solutions/technologies			●	●	●		●	●	
Solarpark DK A/S ●	Tailoring pv solutions to customer needs			●						
SolCell aps - Dansk Solenergi Int ●○	Solcell Ltd. - Danish Solar Energy Int. produces a broad range of high quality (subsidiaries HEM Photovoltaic Ltd.) modules, related electronic components and solar energy solutions, an competitive clean alternative to fuel-burning engines. The company offers complete photovoltaic turnkey solutions.			●						
Solia International ○	In Solia we work for life, by spreading the use of solar energy. The sun gives energy to the planet every day, let us use it for a better climate.			●						
Vaillant A/S ●○	Heat pumps, solar energi, fuel cells, micro CHP, zeolite appliances				●			●		
VE Energy.dk ●	Distribution of heatpumps, biomass (Wood pellets, Wood-boilers, Wood-chips) storage water systems. Furthermore, we develop big field power solarcell plants.			●	●			●	●	
Vestforsyning ●○○○	Multi supply company within: Heat and electricity production and supply, Water supply, Waste water handling, street light, Biogas produktion and supply, biorefenery	●	●			●			●	●
Vindstød A/S ○	We have produced the most advanced system to handle all aspects of running an energy utility.	●								
Wave Dragon ●	We develop the multi MW floating wave energy converter Wave Dragon		●							
Waveenergyfyn ○	Waveenergyfyn is developing Cresting wave energy converter. Cresting is thoroughly tested, very efficient and economical. The converter is roomy and with lots of dry space for production and storage of electricity.		●							
Weptos A/S ●	Weptos has developed a new technology to explore wave energy. Through extensive testing the results show evidence that Weptos technology is efficient enough to compete against existing energy sources.		●							
Østkraft ●●○○		●		●		●			●	
AAEN Consulting Engineers A/S ●○	AAEN A/S works with the Planning, Development and Establishment of Green Energy Production (e.g. Biomass, Solar Thermal), Energy Efficient distribution and utilization of Energy (e.g. low t emp. DH, Energy Savings) and Energy System Integration (e.g. green power in DH, Solar thermal in Biogas).				●		●	●	●	
Aalborg CSP ●○	Aalborg CSP designs, delivers and commissions CSP technology for power plants, and CSP solar boilers for process and district heating industries.									●
Aalborg Engineering ●●○	We supply customised Heat Recovery Systems after gas turbine and industrial process									●

NONE OF THE RENEWABLE ENERGY TECHNOLOGIES WILL SOLVE THE CHALLENGE ON THEIR OWN. WE NEED TO COMBINE THE TECHNOLOGIES IN ORDER TO OBTAIN THE OPTIMUM SOLUTION

Future challenge described by participating company

10. Matrix: Energy transmission & distribution

Company name	Contribution	Transm. & distrib. of electricity	Transm. & distrib. of gas	Transm. & distrib. of heating	Transm. & distrib. of cooling	Control and monitoring systems	Advanced metering infrastructure	Grid integration	Trade of energy	Other
ABB A/S ●●○○○○	Systems to integrate and optimize the production and distribution of energy, including complete automation and control with incorporated demand-response technologies.	●	●	●	●	●	●	●		●
Accenture ●○○○○○	Accenture Smart Grid Services focuses on delivering innovative business solutions supporting the modernization of electric, gas and water network infrastructures to improve capital efficiency and effectiveness, increase crew safety and productivity, optimize the operations of the grid and achieve the full value from advanced metering infrastructure (AMI) data and capabilities.	●	●			●	●	●	●	
Acti-Chem A/S ●○	Acti-Chem provide water treatment for district heating and cooling, to protect the transmittion pipes and storage tanks from corrosion, bacteria and deposits risks.			●	●					●
ALECTIA ●○○○○○				●	●	●				
Alexandra Instituttet A/S ●○○	We offer consultancy, innovation and research services for SME, large companies, utilities and municipalities in Denmark and abroad. Specifically we offer ethnographic services, business development and software development including applications and services.						●			●
Alstom Grid ○○	Manufacturer and Service provider for HV Grid	●	●			●	●	●	●	
Amplex ●	Amplex delivers turn-key solutions for streetlight management, energy management, smart metering, distribution automation and demand management. The solutions is a combination of software and hardware for retrofitting existing installations.					●	●	●		●
Averhoff Energi Anlæg A/S ●●	Customized Energy Solutions Energy production and optimization.	●		●		●				
Balslev ●●●○	Our expertise comprises innovative, sustainable and profitable solutions within Intelligent Building Automation, energy supply, security and transportation, corrosion protection, hospital planning and energy optimization.	●	●	●	●	●		●		
Bioenergi Vest ●	Implementation of decentral biogasproduction, biogas grid transmission and integration of energy systems		●			●	●	●	●	
BN Teknik ApS ○				●	●					
Brix & Kamp Energi A/S ●○○				●	●	●				
Capgemini Sogeti ●○○○○	We provide smart energy services to over 75 global utility clients representing 113 million metered customers actively engaged in smart energy programs.	●	●	●	●	●	●	●	●	

Company name	Contribution	Transm. & distrib. of electricity	Transm. & distrib. of gas	Transm. & distrib. of heating	Transm. & distrib. of cooling	Control and monitoring systems	Advanced metering infrastructure	Grid integration	Trade of energy	Other
CGI ●○○○○○	Implementation and operation of Dataclearance centers (datahubs), Smart Meter & Headend systems, Meter Data Management systems, Customer Service and Billing platforms and Asset Management and mobile workforce management systems.	●	●	●		●	●	●	●	
CO Rør Blik & VVS ○○					●					
COWI ●○○○○○	360 degree consultancy approach including all aspects of planning, development, implementation and evaluation activities within energy, enginering, enviromental and financial issues	●	●	●	●	●	●	●		
CTR ●○	DH transmission company responsible for - purchase of DH, - load dispatch of CHP production, - production of reserve and peak heat only boiler - operation of transmission network	●		●					●	
Danfoss District Energy ●●●○○○	District heating substations, and control equipment for district heating installations.			●		●				
Danish Technological Institute ●○○○○○	Research, Development and demonstration of Smart Energy solutions. Test and certification of Smart Energy products. Consulting jobs within Smart Energy and user behavior.			●	●	●	●	●		
Dansk Energi Service ●●	Boilers for steam & thermal oil. Burners for gas & oil All kind of installation works			●	●	●				
DESMI Danmark A/S ●○○○	High Effeciency Pumps			●	●					
Develco Products A/S ●●	Develco Products provides wireless communication modules and products. Products includes gateways enabling remote monitoring and control of devices in house holds, Wireless Relays/sensors as well as communication modules for meters and other 3rd part devices.	●	●	●		●				
Devoteam ●●○○	We connect business and technology bringing 30 years of Telecoms and IT knowhow into future energy systems. We help you with strategy, businesscases and technology implementation.	●				●	●	●		
DGC ○○	DGC offers consulting services, research and development, laboratory testing, measurement, demonstration projects, and training.		●							
DI Energy ●	Public affairs and business development									●
Dronninglund Fjernvarme ●	District heating			●		●				
ea energy ●	Transport of hot and cold fluids in pipelines			●						
Ea Energy Analyses ●○	Ea Energy Analyses is a Danish consulting company providing consulting services and performing research in the field of energy and climate change.	●		●			●	●	●	

Company name	Contribution	Transm. & distrib. of electricity	Transm. & distrib. of gas	Transm. & distrib. of heating	Transm. & distrib. of cooling	Control and monitoring systems	Advanced metering infrastructure	Grid integration	Trade of energy	Other
Energinet.dk ●●●●●○	Energinet.dk is the Danish TSO for electricity and gas. We plan, build, operate and manage the two energy infrastructures.	●	●					●	●	●
Enopsol ApS ●	Aquifer Thermal Energy Storage (ATES) for district heating and cooling, building heating and cooling and industrial heating and cooling.			●	●	●				
FRIGORTEK Cooling Systems ●	Industrial Heat pump systems for Agri business, Aqua Culture & public buildings			●	●					
GridManager A/S ●●	We offer intelligent software that combines analysis, finance and energy management, with relevant subcontractors.					●	●	●		
Grundfos A/S ●○○○○○	Grundfos produce and sell high quality pumps and controls for all parts of the district energy system.			●	●					
HedeDanmark A/S ●○○○○○	Producing and delivering biomass from danish forestry to the power and heating plants in Denmark.								●	
hmn gassalg ●○○○○	Gas to glad consumers		●					●	●	
HOFOR ●●●●●○	Supply of electricity, district heating, district cooling,and city gas		●	●	●	●	●		●	
Høje Taastrup Fjernvarme a.m.b.a. ●○	district heating system with 6000 customers, 230 km pipelines, 9 centrales									●
IBM ●○○○○○	IBM is helping utilities add a layer of digital intelligence to their grids. These smart grids use sensors, meters, digital controls and analytic tools to automate, monitor and control the two-way flow of energy across operations — from power plant to plug.					●	●	●		
inpower ●●	Power grid balancing system, by use of large scale high voltage Electric boiler in district heating systems.	●		●				●		
Insero Software A/S ●○	Insero Software specialises in handling of demand side flexibility, optimization of energy consumption, delivery of ancillary services, and control of energy storage systems. The solutions are mainly deployed in buildings ranging from single family houses to large facilities.					●				
Kamstrup ●●●●●○	We supply the innovative metering solutions for energy and water consumption						●			
KH vent a/s ○	Ventilation system			●	●					
KIRT THOMSEN ●	As a visual R&D consultancy firm, Kirt-Thomsen combine technical knowledge and insights from various green technology markets to offer their clients improved visualization and communication in R&D.	●				●		●		
Lauridsen Industri ○	Lauridsen Industri is manufactor of valves and heting valves		●	●						

Company name	Contribution	Transm. & distrib. of electricity	Transm. & distrib. of gas	Transm. & distrib. of heating	Transm. & distrib. of cooling	Control and monitoring systems	Advanced metering infrastructure	Grid integration	Trade of energy	Other
Lean Energy Cluster	The cluster services concern knowledge sharing, project development and system export within the field of energy efficiency and smart energy.	●	●	●	●	●	●	●	●	
LOGSTOR	Pre-insulated pipe systems for transmission and distribution of district heating and district cooling. We offer technical support for optimization of installation and operation to ensure lowest possible service life cost of the network.			●	●					
Naturgas Fyn			●					●	●	
NettoPower						●		●	●	
Nyrup plast A/S	Development, sales and consulting in: rainwater harvesting, cleaning of wastewater, use of ground tempeture for ventilation, sun energy.									●
OE3i	Our key product Mentor Planner is a decision support and optimizing system for CHP's and disstrict heating Companies. Our system helps the customer to optimize the production and distribution.			●	●	●			●	
P&I Engineering ApS	Development of industrial process for drying, evaporation, waste to energy, and biogas, including digestate handling.		●	●				●		●
Pettinaroli A/S	Heat pumps, photovoltaic and heatdistribution									●
PlanAction	Consultancy in planning, implementation of biogas systems including technical and logistic set up,smart operation of biogas in relation to biomass input and utilization of digestate, optimizing of production and use of biogas as well as financial and environmental impact analysis.		●	●					●	
PlanEnergi	District heating systems with 100% RES and integrated in electricity and gas grids			●		●		●		
PowerLabDK, DTU Elektro	PowerLabDK is a unique experimental platform for technology development, testing, training and demonstration within electric power and energy.	●				●	●	●	●	
PowerSense	PowerSense provides distribution automation and distribution supervision via their DISCOS platform. The technology consist of sensors, management modules and communication modules. The key in the technology is that it can be retrofitted onto any existing assets.	●				●				
ProEnergi	ProEnergi advises companies, housing associations, institutions and private homeowners on how to optimize energy consumption.	●		●		●				
Ramboll	We offer independent and multidisciplinary consultancy services within all energy forms and including all relevant sectors. We help our clients to plan, develop, design, procure and operate energy and environmental friendly solutions, which are the most cost effective for the society, for the local community and for our client.	●	●	●	●	●	●	●		

Company name	Contribution	Transm. & distrib. of electric-	Transm. & distrib. of gas	Transm. & distrib. of heating	Transm. & distrib. of cooling	Control and monitoring systems	Advanced metering infra-structure	Grid integration	Trade of energy	Other
Saseco ApS	Our main product, eButler, is an online software-as-a-service application for visualisation of energy consumption and controlling wireless home automation devices like switches, dimmers, smoke/movement sensors, thermostats etc.					●				
SEAS-NVE	End user comfort through responsible smart energy products supporting the renewable energy transition.	●				●	●	●		
Spirae.dk	Spirae's BlueFin platform is based on a distributed architecture that enables distinct application areas including: - Renewable and Distributed Energy Integration - Electric Vehicle and storage Integration - Intelligent Demand Response Management - Dynamic Network Topology Management - Power Flow Management - Microgrid Controls	●				●		●		
Thermaflex Nordic Aps	Flexible system solutions to districh heating and cooling			●	●					
TVIS	Transportation of surplus heat from refinery, power plant and waste incineration plant to district heating networks. Heat producer installations, transportation network and district heating Networks are divided from each other by plate heat exchanger units.			●						
Vestforsyning	Multi supply company within: Heat and electricity production and supply, Water supply, Waste water handling, street light, Biogas produktion and supply, biorefenery.	●	●	●	●					
Viborg Fjernvarme	District Heating Company - Distribution and administration			●						
Vindstød A/S	We have produced the most advanced system to handle all aspects of running an energy utility.	●					●		●	●
ZZzero ApS	ZZzero produces ultra-efficient power supplies and energy-saving electronics. ZZzero products eliminates stand by consumption.	●				●	●	●		
Østkraft		●				●	●	●	●	
AAEN Consulting Engineers A/S	AAEN A/S works with the Planning, Development and Establishment of Green Energy Production (e.g. Biomass, Solar Thermal), Energy Efficient distribution and utilization of Energy (e.g. low temp. DH, Energy Savings) and Energy System Integration (e.g. green power in DH, Solar thermal in Biogas).			●	●			●	●	

ENERGY STORAGE CAPACITY IS CRUCIAL FOR THE FLEXIBILITY OF THE FUTURE SMART ENERGY SYSTEM

Sune Thorvildsen, DI Energy

11. Matrix: Energy conversion

Company name	Contribution	Waste-to-Energy, biomass and/or gas CHP	Compressor heat pumps	Electric boilers	Absorption heat pumps	Syngas	Other
ABB A/S ●●○○○○	Systems to integrate and optimize the production and distribution of energy, including complete automation and control with incorporated demand-response technologies.	●	●	●			
Accenture ●○○○○○	Accenture Smart Grid Services focuses on delivering innovative business solutions supporting the modernization of electric, gas and water network infrastructures to improve capital efficiency and effectiveness, increase crew safety and productivity, optimize the operations of the grid and achieve the full value from advanced metering infrastructure (AMI) data and capabilities.	●					
Alpcon A/S ○	Alpcon has developed products for early market applications: Energy harvesting (waste water, district heating, industry systems), Self-powered heating (Multi-fuel cabin and space air/water heaters), Residential Combined Heat & Power (Self powered multifuel Co-gen)	●					
ASAP energy ○	Optimizing energy consumption in heating and cooling of large buildings using heat-pumps and passive cooling. Optimizing existing burner systems on distributed heating plants by reusing exhaust energy.		●				
Averhoff Energi Anlæg A/S ●○	Customized Energy Solutions Energy production and optimization.	●	●	●	●		
B&V KØLETEKNIK ○			●				
Babcock & Wilcox Vølund ●●●●○	Our expertise is in technology and customer support. We have designed and built more than 500 waste-to-energy and biomass production lines, the vast majority of which are still functioning smoothly and efficiently and providing heat and electricity to their communities.	●	●		●		
Balslev ●●●○	Our expertise comprises innovative, sustainable and profitable solutions within Intelligent Building Automation, energy supply, security and transportation, corrosion protection, hospital planning and energy optimization.	●	●	●	●	●	
Banke Accessory Drives ●	The Banke E-PTO (Electrical Power Take-off) is a lithium-ion battery powered unit which makes it possible to handle work functions e.g on refuse trucks like lifting and compacting of garbage electrically instead of using the truck's engine.						●
BKF Klima A/Sv ○	Dealer of Daikin (Daikin Altherma) and Rotex heating products for Danish market				●		
Bigadan A/S ●○	International provider of contracting services for large-scale co-digestion biogas plants. Operation and ownership of similar biogas plants.	●					
Bioenergi Vest ●	Implementation of decentral biogasproduction, biogas grid transmission and integration of energy systems.						●
Brix & Kamp Energi A/S ●○○		●	●	●	●		
BWE A/S ●●○○	Steam-generating biomass boilers for a wide range of biomasses, based on high steam parameters. The technology can be either pulverised fuel combustion (e.g. conversion of utility boilers) or units based on water-cooled vibration grates.	●					
Capgemini Sogeti ●○○○○	We provide smart energy services to over 75 global utility clients representing 113 million metered customers actively engaged in smart energy programs.	●	●	●	●	●	

Company name	Contribution	Waste-to-Energy, biomass and/or gas CHP	Compressor heat pumps	Electric boilers	Absorption heat pumps	Syngas	Other
CO Rør Blik & VVS			●				
COWI	360 degree consultancy approach including all aspects of planning, development, implementation and evaluation activities within energy, enginering, enviromental and financial issues.	●	●	●	●	●	
Dall Energy	Multifuel, Low emission Furnace.	●					●
Danish Geothermal District Heating	Our consultancy services are centered around project development and implementation, operations support and R&D.		●		●		
Danish Power Systems	we produce fuel cells for various energy related products.	●					●
Danish Technological Institute	Research, Development and demonstration of Smart Energy solutions. Test and certification of Smart Energy products. Consulting jobs within Smart Energy and user behavior.	●	●	●	●		
Dansk Energi Service	Boilers for steam & thermal oil. Burners for gas & oil All kind of installation works	●		●			
DGC	DGC offers consulting services, research and development, laboratory testing, measurement, demonstration projects, and training.	●				●	
DI Energy	Public affairs and business development.						●
Dronninglund Fjernvarme	District heating.				●		
ea energy	transport of hot and cold fluids in pipelines.	●					
Ea Energy Analyses	Ea Energy Analyses is a Danish consulting company providing consulting services and performing research in the field of energy and climate change.	●	●	●	●	●	●
Ekolab	Consultancy on low energy houses and renewable energy.		●				
Electrochaea.dk ApS	Electrochaea's power-to-gas technology is an efficient and robust solution for the conversion of low-cost renewable electricity to pipeline-grade methane. Key applications of the technologies are energy storage and biogas upgrading.						●
EMD	Software for design of sustainable energy systems.	●	●	●	●		
Enopsol ApS	Aquifer Thermal Energy Storage (ATES) for district heating and cooling, building heating and cooling and industrial heating and cooling.	●	●				●
EWS GmbH & Co. KG	We represent market-leading products and offer services of equally high standards. Our focus is on renewable energies, centered around pellet heating, solar thermal heating, photovoltaics and heating pumps.	●			●		●

Company name	Contribution	Waste-to-Energy, biomass and/or gas CHP	Compressor heat pumps	Electric boilers	Absorption heat pumps	Syngas	Other
Focus BioEnergy	Engineering, procurement and contract management of small biomass CHP plants, primarily used within industries with high energy consumption. (1-15 MW thermal outlet from boiler).	●					
FORCE Technology	We provide consultancy services related to smart technology for enhancing energy efficiencym, reducing enviromental impact and production costs.	●					
Frichs A/S	Conversion of bio mass and waste into gas. Utilising the produced gas into a CHP or CCHP. Conversion of waste into liquid fuel. Utilising the produced liquid fuel into a heavey duty special diesel generator.	●			●	●	●
FRIGORTEK Cooling Systems	Industrial Heat pump systems for Agri business, Aqua Culture & public buildings.		●				
Gastech-Energi A/S	Efficient heating systems with minimum emission.		●	●	●	●	
GEO	Complete subsurface engineering and design of shallow geothermal energy systems for heating and cooling. Turn-key solutions for individual buildings and district heating systems. Offshore geotechnical investigations engineering services related to wind farms.		●				
GreenHydrogen.dk	Prodduction and development of electrolyser systems.						●
Grundfos A/S	Grundfos produce and sell high quality pumps and controls for all parts of the district energy system.	●					
hmn gassalg	Gas to glad consumers.				●	●	
HOFOR	Supply of electricity, district heating, district cooling,and city gas.	●	●	●	●		
IBUS Innovation A/S	IPR within the field of Integrated Biomass Utilisation Systems.						●
IC Electric A/S	Ventilation, lightning, sun wells.		●	●			
IC Miljøteknik	Flue gas cleaning systems on boiler plants.	●					
IEN Consultants	Sustainability consultancy mostly within the building sector.	●	●	●	●		
Incoteco (Denmark) ApS	Energy project developments with selected OEMs.						●
Innogie	Innogie ApS is a technology driven company specializing in solar energy and how to integrate this technology into modern homes.	●					
INNOTERM A/S	Engineering, supply, installation and servicing of industrial heat pump systems. Our services extend to absorption heat pump systems, compression heat pump system and high temperature hybrid heat pumps (up to 110 degC).		●		●		
Intelligent BygningsAutomatik		●	●	●	●	●	

Company name	Contribution	Waste-to-Energy, biomass and/or gas CHP	Compressor heat pumps	Electric boilers	Absorption heat pumps	Syngas	Other
IN-Therm AS ○	Brazed, gasketed and welded heat exchangers.	●	●				
IRD Fuel Cells A/S ●●	Components for fuel cells for OEM's. Systems are produced in the form of hydrogen producing electrolyzers and micro heat & power units for residential heating and power production based on hydrogen.	●					●
Klimadan ●○	HP installation solutions in the agriculture segment (bio or slurry)as well business segment, and within classical HP installations for the domestic segment	●	●		●		
Lean Energy Cluster ●○	The cluster services concern knowledge sharing, project development and system export within the field of energy efficiency and smart energy.	●	●	●	●	●	
LH Energy A/S ●○	Energy efficient system and equipment	●	●				
Lodam electronic A/S ●●○	Controller for Air-To-Water and Water-to-Water domistic heat pumps. Both fixed speed and inverter driven compressors		●				●
Markedskraft Danmark ○○	Consultancy and Energy trading. Advising clients in getting the most value of the market possiblities			●			
Naturgas Fyn ●○○		●					
Neas Energy ●○○○	Neas Energy is a Balance Responsible Party and an electricity trader. Today Neas Energy is active in more than 20 European countries and employs approx. 190 employees.	●	●	●		●	
NNE Pharmaplan ●○○○○○	NNE Pharmaplan is a leading engineering and consulting company within the life science industry.		●	●	●		
OE3i ●	Our key product Mentor Planner is a decision support and optimizing system for CHP's and disstrict heating Companies. Our system helps the customer to optimize the production and distribution.	●	●	●	●		
OK ●○○○○	Selling all kinds of Energy solutions for households (heatpumps, gasboilers, PV systems) We are selling above mentioned products for Commercial market as well.	●	●		●		
P&I Engineering ApS ●	Development of industrial process for drying, evaporation, waste to energy, and biogas, including digestate handling.	●	●		●		●
PlanAction ●	Consultancy in planning, implementation of biogas systems including technical and logistic set up,smart operation of biogas in relation to biomass input and utilization of digestate, optimizing of production and use of biogas as well as financial and environmental impact analysis.	●					
PlanEnergi ●○	District heating systems with 100% RES and integrated in electricity and gas grids	●	●		●		
PowerLabDK, DTU Elektro ●●●	PowerLabDK is a unique experimental platform for technology development, testing, training and demonstration within electric power and energy.	●	●	●	●		
ProEnergi ●	ProEnergi advises companies, housing associations, institutions and private homeowners on how to optimize energy consumption.	●	●				
PureteQ A/S ●○	PureteQ Modular Turbo Scrubbers for heat exchanging of sour flue gasses with or without heat pumps. PureteQ Energy system converts low caloric value industrial by-products and liquid hazerdous waste into clean energy	●					●

Company name	Contribution	Waste-to-Energy, biomass and/or gas CHP	Compressor heat pumps	Electric boilers	Absorption heat pumps	Syngas	Other
Q2 A/S ●	Biogas Projects and Landfill gas Projects. Upgrading of biogas removing CO2	●					
RadiJet ●	Power on demand. Light-weight, minimum size, multi-fuel, low emission power and heat generator.	●				●	●
Ramboll ●○○○○○	We offer independent and multidisciplinary consultancy services within all energy forms and including all relevant sectors. We help our clients to plan, develop, design, procure and operate energy and environmental friendly solutions, which are the most cost effective for the society, for the local community and for our client.	●	●	●	●		
Robert Bosch A/S ●○○○○	Innovative green solutions for different kinds of industries: Heating, hot water, soft ware solutions, batteries for electrical cars, battety storage facilities, inverter for PV's and storage, Charging technology	●	●		●		●
SEG A/S ●○○	Selling, installing and servicing absorption heat pumps and chillers.				●		
Simatek A/S ●	- Bag House Filters - Hot air and Hot gas filtration (removal of particles and acid components)	●					
Svedan Industri Køleanlæg A/S ○○	Ammonia Heat Pumps with possibility to retrieve heat from heat sources of lower temperatures and producing the heat for higher temperature levels compatible with district heating systems, ie up to 90 degC.		●				
Trioterm Aalborg Aps ○			●				
Vestforsyning ●○○○	Multi supply company within: Heat and electricity production and supply, Water supply, Waste water handling, street light, Biogas produktion and supply, biorefenery.	●					●
Vesttherm A/S ●●	Production of domestic hot Water heatpumps for the European markets.		●				
Østkraft ●●○○		●					
AAEN Consulting Engineers A/S ●○	AAEN A/S works with the Planning, Development and Establishment of Green Energy Production (e.g. Biomass, Solar Thermal), Energy Efficient distribution and utilization of Energy (e.g. low temp. DH, Energy Savings) and Energy System Integration (e.g. green power in DH, Solar thermal in Biogas).	●	●		●	●	

THE COMPLEX FUTURE ENERGY MARKET REQUIRES NEW BUSINESS MODELS, WHICH ARE LESS FOCUSED ON COMPONENT SALES AND MORE ON SYSTEM SOLUTIONS AND SERVICE RENTALS

Preben Birr-Pedersen
Lean Energy Cluster

12. Matrix: Energy storage

Company name	Contribution	Hydro storage	Gas storage	Heat and cold water storage tanks	Seasonal heat storage	Seasonal cooling storage	Storage of electricity in batteries	Compressed air storage	Other
ABB A/S ●●○○○○	Systems to integrate and optimize the production and distribution of energy, including complete automation and control with incorporated demand-response technologies.	●		●			●	●	
Acti-Chem A/S ●○	Acti-Chem provide water treatment for district heating and cooling, to protect the transmittion pipes and storage tanks from corrosion, bacteria and deposits risks.			●	●		●		
Aguasol ●	Aguasol Unibody is "Best in Class" solar water heater. It is top-performing in climates with winter. And it does not get too hot (boiling) in hot climates.			●					
Alstom Grid ○○	Manufacturer and Service provider for HV Grid	●						●	
ASAP energy ○	Optimizing energy consumption in heating and cooling of large buildings using heat-pumps and passive cooling. Optimizing existing burner systems on distributed heating plants by reusing exhaust energy.			●	●		●		
Averhoff Energi Anlæg A/S ●●	Customized Energy Solutions Energy production and optimization.			●	●				
Balslev ●●●○	Our expertise comprises innovative, sustainable and profitable solutions within Intelligent Building Automation, energy supply, security and transportation, corrosion protection, hospital planning and energy optimization.		●	●	●		●	●	●
Banke Accessory Drives ●	The Banke E-PTO (Electrical Power Take-off) is a lithium-ion battery powered unit which makes it possible to handle work functions e.g on refuse trucks like lifting and compacting of garbage electrically instead of using the truck's engine.							●	
BKF Klima A/S ○	Dealer of Daikin (Daikin Altherma) and Rotex heating products for Danish market	●		●					
BN Teknik ApS ○					●		●		
Brix & Kamp Energi A/S ●○○				●					
CLEVER A/S ●●	Charging, and management of charging for Electric Vehicles							●	
COWI ●○○○○○	360 degree consultancy approach including all aspects of planning, development, implementation and evaluation activities within energy, enginering, enviromental and financial issues			●	●		●	●	
CTR ●○	DH transmission company responsible for - purchase of DH, - load dispatch of CHP production, - production of reserve and peak heat only boiler - operation of transmission network			●					
Danfoss District Energy ●●●○○○○	District heating substations, and control equipment for district heating installations.			●					

Company name	Contribution	Hydro storage	Gas storage	Heat and cold water storage tanks	Seasonal heat storage	Seasonal cooling storage	Storage of electricity in batteries	Compressed air storage	Other
Danish Geothermal District Heating ●	Our consultancy services are centered around project development and implementation, operations support and R&D.				●				
Danish Technological Institute ●○○○○○	Research, Development and demonstration of Smart Energy solutions. Test and certification of Smart Energy products. Consulting jobs within Smart Energy and user behavior.			●				●	●
Dansk Energi Service ●●	Boilers for steam & thermal oil. Burners for gas & oil All kind of installation works			●					
DGC ○○	DGC offers consulting services, research and development, laboratory testing, measurement, demonstration projects, and training.		●						
DI Energy ●	Public affairs and business development								
Dronninglund Fjernvarme ●	District heating				●				
Ea Energy Analyses ●○	Ea Energy Analyses is a Danish consulting company providing consulting services and performing research in the field of energy and climate change.	●	●	●	●	●	●	●	●
Ekolab ●	Consultancy on low energy houses and renewable energy			●					
EMD ●●	Software for design of sustainable energy systems	●		●	●		●		
Energinet.dk ●●●●●○	Energinet.dk is the Danish TSO for electricity and gas. We plan, build, operate and manage the two energy infrastructures.		●						
Enopsol ApS ●	Aquifer Thermal Energy Storage (ATES) for district heating and cooling, building heating and cooling and industrial heating and cooling.				●		●		
EWS GmbH & Co. KG ○	We represent market-leading products and offer services of equally high standards. Our focus is on renewable energies, centered around pellet heating, solar thermal heating, photovoltaics and heating pumps.				●		●	●	
Gaia Solar A/S ○○	Total supplier of PV solutions: Gaia Solar supplies high quality PV systems for residential buildings, businesses, government and municipalities.							●	
Gastech-Energi A/S ●●○○	Efficient heating systems with minimum emission			●	●				
GEO ●○○○	Complete subsurface engineering and design of shallow geothermal energy systems for heating and cooling. Turn-key solutions for individual buildings and district heating systems. Offshore geotechnical investigations engineering services related to wind farms.				●		●		
Geologisk Rådgivning ●	Thermal energy storage in sediments				●		●		
GODevelopment ApS ●	Energy Membrane Underground Pumped Hydroelectric Storage - EM-UPHS	●							

Company name	Contribution	Hydro storage	Gas storage	Heat and cold water storage tanks	Seasonal heat storage	Seasonal cooling storage	Storage of electricity in batteries	Compressed air storage	Other
Grundfos A/S ●○○○○○	Grundfos produce and sell high quality pumps and controls for all parts of the district energy system.	●		●	●				
hmn gassalg ●○○○○	Gas to glad consumers								
HOFOR ●●●●●○	Supply of electricity, district heating, district cooling,and city gas			●					
HS Tarm ●○	Biomass boilers Development, production and sales	●							
IC Electric A/S ○○	Ventilation, lightning, sun wells.				●				
IEN Consultants ●	Sustainability consultancy mostly within the building sector			●				●	
Incoteco (Denmark) ApS ●	Energy project developments with selected OEMs							●	●
inpower ●●	Power grid balancing system, by use of large scale high voltage Electric boiler in district heating systems.			●					
IRD Fuel Cells A/S ●●	Components for fuel cells for OEM's. Systems are produced in the form of hydrogen producing electrolyzers and micro heat & power units for residential heating and power production based on hydrogen.		●		●				
Lean Energy Cluster ●○	The cluster services concern knowledge sharing, project development and system export within the field of energy efficiency and smart energy.	●	●	●	●		●	●	●
LeanEco ○	LeanEco has a Unique solution for uninterruptible power supply systems for IT, hospitals, enterprises etc. offering a living infrastructure, performance improvements on all key parameters and prepared for various interactive functions between grid management and power consumption.								
Lithium Balance A/S ●●	Lithium Balance's core competence is the development and production of battery management systems (BMS) for Lithium Ion batteries as well as design and production of complete battery packs.							●	
Nyrup plast A/S ○○	Development, sales and consulting in: rainwater harvesting, cleaning of wastewater, use of ground tempeture for ventilation, sun energy.			●					
OE3i ●	Our key product Mentor Planner is a decision support and optimizing system for CHP's and disstrict heating Companies. Our system helps the customer to optimize the production and distribution.			●	●				
P&I Engineering ApS ●	Development of industrial process for drying, evaporation, waste to energy, and biogas, including digestate handling.			●	●		●		
PlanAction ●	Consultancy in planning, implementation of biogas systems including technical and logistic set up,smart operation of biogas in relation to biomass input and utilization of digestate, optimizing of production and use of biogas as well as financial and environmental impact analysis.		●						
PlanEnergi ●●●●○○○○○	District heating systems with 100% RES and integrated in electricity and gas grids	●	●	●	●				

Company name	Contribution	Hydro storage	Gas storage	Heat and cold water storage tanks	Seasonal heat storage	Seasonal cooling storage	Storage of electricity in batteries	Compressed air storage	Other
PowerLabDK, DTU Elektro ●●●	PowerLabDK is a unique experimental platform for technology development, testing, training and demonstration within electric power and energy.	●							
ProEnergi ●	ProEnergi advises companies, housing associations, institutions and private homeowners on how to optimize energy consumption.							●	
Ramboll ●○○○○○	We offer independent and multidisciplinary consultancy services within all energy forms and including all relevant sectors. We help our clients to plan, develop, design, procure and operate energy and environmental friendly solutions, which are the most cost effective for the society, for the local community and for our client.	●	●	●	●				
Robert Bosch A/S ●○○○○	Innovative green solutions for different kinds of industries: Heating, hot water, soft ware solutions, batteries for electrical cars, battety storage facilities, inverter for PV's and storage, Charging technology			●				●	
SCANPOCON ○	Import of inverters, charger and batteries for wind and solar powered off-grid systems							●	
Seahorn Energy ●	The Green Power Plant concept is an offshore energy storage facility with integration of wind power and optional integration of wave and solar power. The concept is based on mature technologies and the prefabrication of elements results in reduced cost and a short construction period.	●							
Solar ●○○○○○	Join different supplier's technologies to a complete solution to the customer. Make awareness and educate of solutions/technologies			●	●			●	
Solarpark DK A/S ●	Tailoring pv solutions to customer needs							●	
Solia International ○	In Solia we work for life, by spreading the use of solar energy. The sun gives energy to the planet every day, let us use it for a better climate.							●	
Waveenergyfyn ○	Waveenergyfyn is developing Cresting wave energy converter. Cresting is thoroughly tested, very efficient and economical. The converter is roomy and with lots of dry space for production and storage of electricity.	●						●	
Østkraft ●●○○				●					
AAEN Consulting Engineers A/S ●○	AAEN A/S works with the Planning, Development and Establishment of Green Energy Production (e.g. Biomass, Solar Thermal), Energy Efficient distribution and utilization of Energy (e.g. low temp. DH, Energy Savings) and Energy System Integration (e.g. green power in DH, Solar thermal in Biogas).			●	●				

13. Matrix: Energy consumption

Company name	Contribution	HVAC installations in buildings	Home and building automation systems	Smart phone app for intelligent energy consumption	Smart energy sensors and meters	Electric vehicles (incl. charging infrastructure)	Hydrogen vehicles (incl. charging infrastructure)	Other
ABB A/S ●●○○○○	Systems to integrate and optimize the production and distribution of energy, including complete automation and control with incorporated demand-response technologies.	●	●		●	●		
Accenture ●○○○○○	Accenture Smart Grid Services focuses on delivering innovative business solutions supporting the modernization of electric, gas and water network infrastructures to improve capital efficiency and effectiveness, increase crew safety and productivity, optimize the operations of the grid and achieve the full value from advanced metering infrastructure (AMI) data and capabilities.		●	●				
ALECTIA ●○○○○○		●						
Alexandra Instituttet A/S ●○○	We offer consultancy, innovation and research services for SME, large companies, utilities and municipalities in Denmark and abroad. Specifically we offer ethnographic services, business development and software development including applications and services.		●	●	●			
Amplex ●	Amplex delivers turn-key solutions for streetlight management, energy management, smart metering, distribution automation and demand management. The solutions is a combination of software and hardware for retrofitting existing installations.		●	●	●			●
ASAP energy ○	Optimizing energy consumption in heating and cooling of large buildings using heat-pumps and passive cooling. Optimizing existing burner systems on distributed heating plants by reusing exhaust energy.	●	●					
Balslev ●●●○	Our expertise comprises innovative, sustainable and profitable solutions within Intelligent Building Automation, energy supply, security and transportation, corrosion protection, hospital planning and energy optimization.	●	●		●	●		
BKF Klima A/S ○	Dealer of Daikin (Daikin Altherma) and Rotex heating products for Danish market	●	●	●				
BN Teknik ApS ○	Climate walls	●	●					
Brix & Kamp Energi A/S ●○○			●					
Brunata A/S ●●○○○	Individual metering and collection on all energy types. Surveillance of humidity and other indoor climate factors. Active behaviour change system.			●	●			
Capgemini Sogeti ●○○○○	We provide smart energy services to over 75 global utility clients representing 113 million metered customers actively engaged in smart energy programs.		●	●	●	●		
CLEVER A/S ●●	Charging, and management of charging for Electric Vehicles			●		●		
COWI ●○○○○○	360 degree consultancy approach including all aspects of planning, development, implementation and evaluation activities within energy, enginering, enviromental and financial issues	●	●		●	●		●

Company name	Contribution	HVAC installations in buildings	Home and building automation systems	Smart phone app for intelligent energy consumption	Smart energy sensors and meters	Electric vehicles (incl. charging infrastructure)	Hydrogen vehicles (incl. charging infrastructure)	Other
Danfoss District Energy ●●●○○○	District heating substations, and control equipment for district heating installations.	●	●	●	●			
Danish Power Systems ●	we produce fuel cells for various energy related products						●	●
Danish Technological Institute ●○○○○○	Research, Development and demonstration of Smart Energy solutions. Test and certification of Smart Energy products. Consulting jobs within Smart Energy and user behavior.	●	●		●	●		
DEIF ●○○○○	Energy meters, instruments and components for switchboard installation. To be used for Energy metering and power quality analysis, log energy consumption locally, display energy consumption, remote monitoring and storage.	●	●		●			
Develco Products A/S ●●	Develco Products provides wireless communication modules and products. Products includes gateways enabling remote monitoring and control of devices in house holds, Wireless Relays/sensors as well as communication modules for meters and other 3rd part devices.	●	●		●			
Devoteam ●●○○	We connect business and technology bringing 30 years of Telecoms and IT knowhow into future energy systems. We helpyou with strategy, business-cases and technology implementation.			●				●
DFF-EDB A.m.b.a. ○○	Administrative og tekniske systemer samt services til forsyningsvirksomhed primært fjernvarmeforsyning							●
DGC ○○	DGC offers consulting services, research and development, laboratory testing, measurement, demonstration projects, and training.						●	
DI Energy ●	Public affairs and business development							●
ea energy ●	transport of hot and cold fluids in pipelines	●	●					
Ea Energy Analyses ●○	Ea Energy Analyses is a Danish consulting company providing consulting services and performing research in the field of energy and climate change.	●	●	●	●	●	●	●
EKJ rådgivende ingeniører A/S ●○○○	Planning- and Design-engineers on Sustainable Buildings. Especially Buildings for daycare, education, Universities, Laboratories, Hospitals a.o.	●	●					
Ekolab ●	Consultancy on low energy houses and renewable energy	●						
Elma Instruments A/S ●●	Test and measurement equipment. To measure and controls energy		●		●			
EnergiData ●●	Energy Management Systems		●		●			
EnergyAware ●	Energy savings - system for documentation and management of energy savings from business, private consumers, and projects.			●				

Company name	Contribution	HVAC installations in buildings	Home and building automation systems	Smart phone app for intelligent energy consumption	Smart energy sensors and meters	Electric vehicles (incl. charging infrastructure)	Hydrogen vehicles (incl. charging infrastructure)	Other
Enopsol ApS	Aquifer Thermal Energy Storage (ATES) for district heating and cooling, building heating and cooling and industrial heating and cooling.	●						
EXHAUSTO A/S	Air Handling Units which are making a good indoor inviroment using as little energy as possible. In the air hansling units we allways have heat recovery with high temperature efficiency and using tailer made fans and EC-motor to lower the energy consumption for air transport.	●						
Frese	Energy saving dynamic valves	●						
FRIGORTEK Cooling Systems	Industrial Heat pump systems for Agri business, Aqua Culture & public buildings	●						●
Gastech-Energi A/S	Efficient heating systems with minimum emission	●	●	●				
GreenWave Reality ApS	GreenWave Reality empowers consumers to achieve the smart connected lifestyle by delivering personalized information and entertainment, enhanced comfort and savings.		●	●	●			●
GridManager A/S	We offer intelligent software that combines analysis, finance and energy management, with relevant subcontractors.	●	●	●	●	●		●
HOFOR	Supply of electricity, district heating, district cooling,and city gas				●			
IBM	IBM is helping utilities add a layer of digital intelligence to their grids. These smart grids use sensors, meters, digital controls and analytic tools to automate, monitor and control the two-way flow of energy across operations — from power plant to plug.		●	●	●			
IC Electric A/S	Ventilation, lightning, sun wells.	●	●		●			
IEN Consultants	Sustainability consultancy mostly within the building sector	●		●	●	●		
Insero Software A/S	Insero Software specialises in handling of demand side flexibility, optimization of energy consumption, delivery of ancillary services, and control of energy storage systems. The solutions are mainly deployed in buildings ranging from single family houses to large facilities.		●					
Intelligent BygningsAutomatik		●	●	●	●			
IRD Fuel Cells A/S	Components for fuel cells for OEM's. Systems are produced in the form of hydrogen producing electrolyzers and micro heat & power units for residential heating and power production based on hydrogen.	●	●				●	
KIRT THOMSEN	As a visual R&D consultancy firm, Kirt-Thomsen combine technical knowledge and insights from various green technology markets to offer their clients improved visualization and communication in R&D.		●	●		●		

Company name	Contribution	HVAC installations in buildings	Home and building automation systems	Smart phone app for intelligent energy consumption	Smart energy sensors and meters	Electrical vehicles (incl. charging infrastructure)	Hydrogen vehicles (incl. charging infrastructure)	Other
Kvm-Conheat ●○	District Heating units and Substation	●						
Lean Energy Cluster ●○	The cluster services concern knowledge sharing, project development and system export within the field of energy efficiency and smart energy.	●	●	●	●	●	●	
LeanEco ○	LeanEco has a Unique solution for uninterruptible power supply systems for IT, hospitals, enterprises etc. offering a living infrastructure, performance improvements on all key parameters and prepared for various interactive functions between grid management and power consumption.							●
Lodam electronic A/S ●●○	Controller for Air-To-Water and Water-to-Water domistic heat pumps. Both fixed speed and inverter driven compressors	●	●					●
Logics ●	Building model based decision basis for energy system owners and operators, e.g. modelling new technology platforms or new technologies in existing platforms.							●
Markedskraft Danmark ●○	Consultancy and Energy trading. Advising clients in getting the most value of the market possiblities							●
Naturgas Fyn ●○○		●	●					
Neas Energy ●○○○	Neas Energy is a Balance Responsible Party and an electricity trader. Today Neas Energy is active in more than 20 European countries and employs approx. 190 employees.							●
Neogrid Technologies ●	Neogrid Technologies develops a software application/tool enabling aggregators to control individual or a large pool of heat pumps towards energy markets.		●	●				●
NettoPower ○			●	●				
NNE Pharmaplan ●○○○○○	NNE Pharmaplan is a leading engineering and consulting company within the life science industry.	●						
NorthQ ●	We supply retrofit meter reding solutions for gas, electricity, water and heating meters. Additionally, we have a complete end-2-end meter collection and home automation platform.	●	●	●	●			
P&I Engineering ApS ●	Development of industrial process for drying, evaporation, waste to energy, and biogas, including digestate handling.	●	●		●			●
PlanEnergi ●○	District heating systems with 100% RES and integrated in electricity and gas grids							●
PowerLabDK, DTU Elektro ●●●	PowerLabDK is a unique experimental platform for technology development, testing, training and demonstration within electric power and energy.		●		●	●		
PowerSense ●●	PowerSense provides distribution automation and distribution supervision via their DISCOS platform. The technology consist of sensors, management modules and communication modules. The key in the technology is that it can be retrofitted onto any existing assets.				●			

Company name	Contribution	HVAC installations in buildings	Home and building automation systems	Smart phone app for intelligent energy consumption	Smart energy sensors and meters	Electrical vehicles (incl. charging infrastructure)	Hydrogen vehicles (incl. charging infrastructure)	Other
PureteQ A/S ●○	PureteQ Modular Turbo Scrubbers for heat exchanging of sour flue gasses with or without heat pumps. PureteQ Energy system converts low caloric value industrial by-products and liquid hazerdous waste into clean energy	●						
RadiJet ●	Power on demand. Light-weight, minimum size, multi-fuel, low emission power and heat generator.					●		●
Ramboll ●○○○○○	We offer independent and multidisciplinary consultancy services within all energy forms and including all relevant sectors. We help our clients to plan, develop, design, procure and operate energy and environmental friendly solutions, which are the most cost effective for the society, for the local community and for our client.	●	●		●			
Robert Bosch A/S ●○○○○	Innovative green solutions for different kinds of industries: Heating, hot water, soft ware solutions, batteries for electrical cars, battety storage facilities, inverter for PV's and storage, Charging technology	●	●	●	●	●		
Saseco ApS ●	Our main product, eButler, is an online software-as-a-service application for visualisation of energy consumption and controlling wireless home automation devices like switches, dimmers, smoke/movement sensors, thermostats etc.		●	●	●			●
SEAS-NVE ●○○○○○	End user comfort through responsible smart energy products supporting the renewable energy transition.		●	●	●	●		
Senmatic A/S ●○○	Controller which is designed to control temperature, CO2 and Relative Humidity at housings, offices, warehouses, schools, hospitals or other buildings and public areas.	●						
Skafte A/S ○	Heat and Coolingsystems, Biogas, LNG. flexibil Pipesystems	●						●
Solar ●○○○○○	Join different supplier's technologies to a complete solution to the customer. Make awareness and educate of solutions/technologies	●	●	●	●			
Spirae.dk ●	Spirae's BlueFin platform is based on a distributed architecture that enables distinct application areas including: - Renewable and Distributed Energy Integration - Electric Vehicle and storage Integration - Intelligent Demand Response Management - Dynamic Network Topology Management - Power Flow Management - Microgrid Controls							●
Trioterm Aalborg Aps ○		●						
Vestforsyning ●○○○	Multi supply company within: Heat and electricity production and supply, Water supply, Waste water handling, street light, Biogas produktion and supply, biorefenery.						●	●
Zensehome ●	Intelligent Home Automation		●					
ZZzero ApS ○	ZZzero produces ultra-efficient power supplies and energy-saving electronics. ZZzero products eliminates standby consumption.	●	●		●			
Østkraft			●	●	●	●		
AAEN Consulting Engineers A/S	AAEN A/S works with the Planning, Development and Establishment of Green Energy Production (e.g. Biomass, Solar Thermal), Energy Efficient distribution and utilization of Energy (e.g. low temp. DH, Energy Savings) and Energy System Integration (e.g. green power in DH, Solar thermal in Biogas).							

14. Appendices

List of smart energy projects

Title	description	Period	Managing organisation
Application of smart grid in photovoltaic power systems	The target of the proposed project is to study how to integrate large amount of Renewable Energy Sources (RES) into the network, without having to reinforce the network. This is done by examining different types of grid voltage control, applying Smart Grid functionalities and introducing other ancillary services integrated into the RES.	2011-2015	DANFOSS A/S
Information and education of the future power consumer	The project will result in a concept for the information needed, when power consumers are to participate more actively in the power market by making their consumption flexible in time and dependent on price. The developed concept will be validated on 2000 power consumers on Bornholm, who will participate in the smart grid project EcoGridEU	2011-2015	Østkraft A/S
Smart Grid Ready Energy Efficient Lighting System for Green House Horticulture	The project aims to develop an energy-cost-effective artificial light management system, which optimizes plant growth in relation to energy costs and also integrates greenhouse horticulture with the grid through DONG Energy's Power Hub concept, which enables the growers to deliver GRID-system performance by dynamically regulate their consumption.This is part of a joint proposal for GUDP and EUDP.	2012-2015	Syddansk Universitet
Manual power reserves from telesites	The focus of the project is to investigate if there are potential flexible energy reserves in serverrooms and telesites that can be implemented and exploites as manual energy reserves in the electricity system. Lately developed extreme energysaving cooling systems could be the gateway to this new application.	2013-2014	Energy Cool ApS
SmartGrid Ready Battery Storage System	The purpose of the project is to generate hands-on experience of developing and operating a battery energy storage system in the renewable energy based power system of the future. During the project an efficient project team will develop and test a 600 kW/1,2 MWh energy storage, which will provide high value grid services	2012-2014	Teknologisk Institut
ChoosCOM - Large-scale demonstration of charging of electric vehicles	Developing of ChoosCOM for intelligent charging and communication with electric cars and is test it by 2400 families in 300 EVs. Main investigation is whether it is possible to move the charge of EVs to a more production and environmental friendly time – and is the EV owner interested in it.	2011-2015	ChoosEV A/S
CHPCOM Combined Heat and Power Communication	CHPCOM (Combined Heat and Power Communication) is a project that through practical experience will analyse, develop and demonstrate the use of international Smart Grid related data communication standards, specifically IEC 61850 and IEC 62351 for IT security. CHPCOM focuses on distributed generation, specifically CHPs and their business partners.	2013-2015	Dansk Energi
INCAP - Inducing consumer adoption of automated reaction technology for dynamic power pricing tariffs	Can consumers be induced to adopt varying tariffs and automatic response technology for common household appliances at costs that make this socially attractive? The project implements a large scale field experiment using an automatic response application for a common appliance (e.g. refrigerators).	2012-2016	Københavns Universitet

Title	description	Period	Managing organisation
iPOWER - strategic platform for innovation and research in intellligent power	Wind power and other variable production constitute a significant share of a future renewable energy system. This requires flexible and intelligent solutions. IPOWER focuses on flexible electricity consumption, where intelligent appliances can regulate own consumption to fit with the wind power production and user needs.	2011-2016	Danmarks Tekniske Universitet
ENSYMORA - Energy systems modelling, research and analysis	A future energy system based on sustainable energy requires flexible production, consumption and transmission of electricity. We are to make large investments in the infrastructure. ENSYMORA will advance statistical and economic models for designing energy systems, so taht we can adapt them to challenges of tomorrow.	2011-2014	Danmarks Tekniske Universitet
Efficiency optimisation of biomass CHP gas engines	The goal of the project is to increase the efficiency and reduce emissions for engines operating on biogas and biomass producer gas. Engine operation will be characterised experimentally and theoretically at lab scale and bench scale with the aim of identifying the optimal operation mode for gas engines operating on biomass derived gas.	2011-2014	Danmarks Tekniske Universitet
Smart City Kalundborg	To develop and test a market based smart city energy management platform using Kalundborg as fullscale demo. Grid-responsive energy services are aligned with intelligent grid operations and dynamic enduser actions to optimize use of renewable and distributed energy, energy management choices, utilization of existing energy infrastructure and be a template that can be replicated in other cities	2012-2015	SEAS-NVE STRØMMEN A/S
Smart Grid School Renovation in Copenhagen	The project will create an “added value” from “intelligent low cost BIPV solutions” linked to integrated systems for “Performance Documentation” and a ”Smart Grid operation. Results can directly be used in planned 50 school renovation projects in Copenhagen.	2013-2015	CENERGIA PROJEKT ApS
Strategic research alliance for Energy Innovation Systems and their dynamics - Denmark in global competition (EIS)	These years, Denmark is banking on green growth and innovation. However, our understanding of energy innovation systems is limited. EIS explores and analyses the dynamics of knowledge-sharing within energy research with a view, among others, to make closer connections between Danish and foreign research environments.	2011-2016	Danmarks Tekniske Universitet
SOSPO - Secure Operation of Sustainable Power Systems	Focus is on how control of the power system, at transmission level, needs to be changed to meet the needs of stable and uninterrupted power, despite the fluctuating energy sources in the grid of the future. The project will address the future power system at the transmission level and develop methods for real-time assessment when unsafe operation is approaching and it will make control countermeasures as needed.	2012-2015	Danmarks Tekniske Universitet
System services from small-scale distributed energy resources	The overall objective is to enable the integration of larger amounts of distributed renewable energy sources (especially wind power) in the energy systems. The specific goal is to develop an assessment concept for the ability of Distributed Energy Resources to deliver system services	2011-2014	Danmarks Tekniske Universitet

Title	description	Period	Managing organisation
ReLiable - Reversible Lithium-Air Batteries	Switching to energy from fluctuating energy sources such as sun and wind requires invention of new energy carriers for the transport sector. The project will develop reversible lithium-air batteries that utilise oxygen in the production of electricity. They are up to ten times as efficient as existing batteries and therefore a realistic alternative to petrol and diesel for transportation.	2012-2015	Danmarks Tekniske Universitet
PROAIN - PROActive INtegration of sustainable energy resources enabling active distribution networks	The transition to RE demands for new energy management systems (EMS). It is investigated how modularity-based control can be used in EMS to meet the fluctuating production of renewables using flexible demand and what it demands from ICT. The project’s solutions will be tested in Beijing.	2014-2017	Danmarks Tekniske Universitet
PowerLabDK	"PowerLabDK is an experimental platform for electric power and energy The facilities constitutes an unique experimental platform, ranging from flexible fundamental research and test laboratories to large-scale experimental facilities and a complete full-scale power distribution system, which will be a data source and platform for full-scale and real-life experiments. The PowerLabDK facilities are open for all. The facilities support technology development, test, training and demonstration."	2012-2015	Danmarks Tekniske Universitet
IEA-DHC Annex X: 4th generation district heating	The high level objective of this project is to analyze and extend the scope of lessons arising from early exemplar low-temperature district heating (supply temperature 50-55°C) schemes, in order to improve the cost effectiveness and environmental benefits, effectively formulating a blueprint for a new generation of district heating systems.	2012-2014	Danmarks Tekniske Universitet
BPES - Balancing power energy system	Objectives: a) to address the problems related to balancing power in a system with a substantial part of fluctuating renewable power sources and b) to develop planning methods and operational strategies for the future European energy system incorporating the needs of balancing power using modeling concepts like Power Node combined with MPC.	2012-2015	Danmarks Tekniske Universitet
Consumer acceptance of intelligent charging	Batteries of electric vehicles are a potential storage for excess power supply. The project investigates the users of EVs' willingness to participate in intelligent charging and the consequences of actual driving patterns for the recharging infrastructure.	2012-2015	Danmarks Tekniske Universitet
CITIES - Centre for IT-Intelligent Energy Systems in Cities	CITIES aims at developing methodologies and ICT solutions for the analysis, operation, planning and development of fully integrated urban energy systems. A holistic research approach will be developed, to provide solutions at all levels between the appliance and the overall system, and at all-time scales between operations and planning. The necessity of novel, data driven and IT intelligent solutions is stressed. A focus is placed on energy system planning in systems with high penetrations of renewable energy, or those entirely independent of fossil fuels.	2014-2019	Danmarks Tekniske Universitet

Title	description	Period	Managing organisation
Nikola - Intelligent Electric Vehicle Integration	Smart charging services for electric vehicles can help reduce the cost for both owner and power system. They are, however, unlikely to be adopted by OEMs and market players if left unresolved. While the rollout of EVs and charging infrastructure is still in its infancy, a window of opportunity is open to influence how great an asset EVs will become	2013-2016	Danmarks Tekniske Universitet
Smart Grid Open	The "Smart Grid Open" project will secure the realization of guidelines, methods and testing protocols enabling conformance testing of communication interfaces for Smart Grid Ready products. Reference testing systems will be designed and implemented. Stakeholders will be involved in investigations and subsequent dissemination activities.	2013-2015	Teknologisk Institut
SDVP2 Styrdinvarmepumpe version 2	The project's primary focus is to develop and maintain a system that controls the heat production and electricity consumption of heat pumps, in order to improve local energy efficiency and to optimize production and distribution costs in the overall power grid. The project elaborates on Energinet.dk's former project 'From wind power to heat pumps"	2013-2015	Insero Energy A/S
ESWA - Energy Smart Water Utilities	The purpose of the project is to map and assess the potential for a water utility to adapt current operating practices to respond to the needs of a the electricity system through a flexible demand driven by a market signal for electricity; and by extrapolation to estimate the potential for the entire Danish water utility sector.	2012-2014	Århus Vand og Spildevand
Efficient incorporation of wind power in district heating systems	Electrical heat pumps have great potential to obtain the announced energy and climate goals. A heat pump of around 1 MW (heating) will be installed in Ans. The project aims at a quick installation allowing for comprenhensive documentaiton of performance and running costs during 1-2 years of operation.	2012-2014	ANS FJERNVARMEVÆRK A M B A
Costmodells of Energystorage in the EU project stoRE	EU has granted 1.2 mio. € to the EU-project stoRE. EMD International is one out of 9 European participants that in stoRE will promote the establishment of Pumped Hydro Storage (PHS) and Compressed Air Energy Storage (CAES). In this PSO-project the energy system analysis tool energyPRO will be extended with PHS and CAES optimized in more el. marke	2012-2015	EMD INTERNATIONAL A/S
TotalFlex	TotalFlex is a demonstration project that intelligently manages flexible consumption and production. This is done by flex-offers from a technical and commercial VPP, which are traded on a marketplace. Thereby the full flexibility is utilized in an optimum way, while power-balance-liability and network capacity is taken into account.	2012-2015	Neogrid Technologies
Micro-grid Technology, Research and Demonstration	The proposed solution of the project will facilitate planning and operational analyses. Robust stability and power quality by the proper control of the power electronics interfaces and the integration of advanced metering infrastructure (AMI) and smart-grid ready communication technologies will be considered as well. The project will serve and support innovation processes in companies and research programs within the identified technology areas and clusters based on two levels: 1. System level and 2. Component level.	2014-2017	Aalborg university, Department of Energy Technology

Title	description	Period	Managing organisation
Enabling and governing transitions to a low carbon society	Through a combination of historical analysis, case studies and action research, the research alliance will analyse the roles of socio-technical experiments, creation and utilisation of ''windows of opportunity'' and stabilisation of changes in societal niches into regime transformation in transitions to a low carbon society. (Energy 10)	2010-2014	Aalborg Universitet
EDGE - Efficient Distribution of Green Energy	The mission of the project is to radically improve integration of wind energy in the power grid through effective coordination of both electricity generation and consumption. Specifically, the project aims at developing rigorous methods for managing the flow of energy among actors - consumers and producers - connected to the power grid.	2012-2016	Aalborg Universitet
Development of a secure, economic and environmentally-friendly modern power system	The project develops a number of new concepts and intelligent approaches for a modern power system which includes renewable energy, storage units, distributed generation, plug-in hybrid electric vehicles, etc. The considerations include grid security, electricity market, stability, protection, optimum control and cost-effective utilisation of generation units. (Energy 10)	2010-2014	Aalborg Universitet
4DH - Strategic Research Centre for 4th Generation District Heating Technologies and Systems	Improved district heating technology is important for utilisation of power planted heat, geothermal energy, waste, biomass, sun and wind and contributes to making Denmark independent of fossil fuel before 2050. The centre researches in e.g. low temperature district heat systems, heating of low energy houses and planning tools and has participation of operators from the district heating sector.	2012-2017	Aalborg Universitet
Control, Protection and Flexible consumption in the Low Voltage Grid	The aim of the project is to develop and validate control and protection system architectures to coordinate the elements of smart grids taking capacity limits of the network grid into account. The development is based on model simulations using test cases, and the controls are tested on prototypes in laboratories and in a demonstration network.	2012-2015	Aalborg Universitet
Integrating Households in the Smart Grid (IHSMAG)	IHSMAG studies the integration of households in the smart grid and develops design recommendations. The Danish part focuses on how electric vehicles are integrated into the everyday life of households and affect the residential load profile. The study is based on in-depth interviews, log data and hour-based electricity consumption data.	2012-2015	Aalborg Universitet
PRO-NET	The project aims to develop the communication technology based intelligent protection and post fault control methods for distribution systems. The developed protection and control methods would minimise the possibility of losing power supply in an abnormal situation and restore normal operation as quickly as possible.	2012-2014	Aalborg Universitet
READY - Smart Grid ready VPP controller til varmepumper	The aim is analyzing, developing and demonstrating a smart grid ready Virtual Power Plant controller that includes the complex challenges of large scale demonstration with demand flexibility, balancing possibilities, grid constraints, optimizing across a pool of heat pumps, house models, user comfort, acceptability and business models.	2012-2014	NEAS ENERGY A/S

List of organisations and knowledge institutions

Trade Organisations

Name	Short description (3-4 sentences)	Website
AKB Autoriserede Kølefirmaers Brancheforening	The aim of AKB is to gather the licensed cooling companies in Denmark and represent their interests towards governments and support them in technical, economical, legal matters.	www.koeleteknik.dk
Association for Danish Biogas Plants	An interest organisation for owners of biogas plants in Denmark promoting knowledge sharing between the different operators and plant owners.	www.biogasdk.dk
DAKOFA	A member based organisation for waste management companies operating in Denmark.	www.dakofa.dk
Danish District Heating Association	The association was founded in 1957 and is financed by its members who are suppliers of district heating. The tasks of the association is to influence the rules and conditions in Denmark and gather and disseminate knowledge between members.	www.danskfjernvarme.dk
Danish Energi Association	The Danish Energy Association is a commercial and professional organisation for Danish energy companies. The association functions as a platform for interaction between netcompanies, traders, production companies, and other stakeholders.	www.danskenergi.dk/
Danish Environmental Technologies	The trade organization for Danish environmental technology suppliers has the aim to support innovation and technology development as well as promoting Danish solutions to complex environmental problems.	www.danskmiljøteknologi.dk
Danish Intelligent Energy Alliance	The DIEA was founded in 2012 by the Danish Energy Association and energy companies in Denmark. The aim of the new alliance is to support the conversion of the power system to smart grid in Denmark.	www.ienergi.dk/English.aspx
Danish Partnership for Hydrogen and Fuel Cells	The Danish Partnership for Hydrogen and Fuel Cells is a member organisation promoting hydrogen and fuel cells so that they can compete as an energy technology on the market for alternative energy.	www.hydrogennet.dk/
Danish Solar Cell Association	The Danish solar panel association is a member organisation for b2b businesses (consultants, engeneers, architects, designers etc) and is working on enhancing the framework conditions and the political focus on the industry.	www.solcelleforening.dk/
Danish Solar Thermal Energy Association	DSF is focused on improving the framework conditions and the familiarity of solar heating in Denmark. Thereby DSF seeks to expand the usage of solar heating.	www.dansksolvarmeforening.dk
Danish Wind Industry Association (DWIA)	The Danish Wind Industry Association (DWIA) is an interest and industry association with more than 240 members across Denmark. Focus areas of DWIA is to ensure that Danish companies are competitive and at the forefront of the international development and, that Danish test and demonstration facilities are world leading.	www.windpower.org/en/about_us/focus_areas.html
Dansk Fjernvarmes geotermiselskab (DFG)	DFG was established in 2011 by the Danish District Heating Association and its members due to the fact that geothermic plants are associated with great investments and differ from previous experiences and competences. The aim of the association is to build a platform of knowledge, tools etc. that local district heating companies can utilise from.	www.geotermi.dk/

Navn	Short description (3-4 sentences)	Website
DBDH	DBDH represents leading actors within the district energy sector and provide and international platform to strengthen export of Danish technology and knowledge.	www.dbdh.dk
DI Energy	Members of DI Energy is a diverse portfolio of stakeholders interested in the energy sector. DI offers different platforms, networks etc. specialised within different fields. Furthermore, a main objective is to ensure political focus and framework conditions in Denmark.	www.energi.di.dk/english
IDA	Interest organisation for Danish engineers providing networking opportunities and arranging different events.	www.ida.dk
Tekniq	Tekniq represents 2.800 a broad portfolio of technical installation companies of any size and was established in 2002. Tekniq negotiates collective agreements and safeguard the members' rights politically and offers different kind of guidance.	www.tekniq.dk
The Trade Association for Biogas	The association for biogas represents all players with interests for biogas and is focused on enhancing the development and implementation of biogas facilities in Denmark and abroad.	www.biogasbranchen.dk
varmepumpefabrikantforeningen	The aim of the heat pump union is to secure that the developed heat pumps corresponds to the quality requirements. The union is likewise engaged in R&D activities in collaboration with other stakeholders related to the heat pump industry.	www.varmepumpefabrikanterne.dk/

Other Organisations

Name	Short description (3-4 sentences)	Website
Biorefining Alliance	The alliance aims to promote Denmark's position in the whole value chain from sustainable use of biomass to bio-based products.	www.biorefiningalliance.com
Danish District Energy Development Center	The Development Center is a national cluster. the Developmentcenter was created by a group of District Energy Power plants, Colleges and supplyers for the industri in order to facilitate innovation in the Danish District Energy Sector.	www.fvu-center.dk/om
DANVA	DANVA is an interest organisation for every professional working with water and waste water. DANVA is a non-profit organisation financed by its members whom interests it represents. The aim is to foster a ethical and sustainable development.	www.danva.dk
Ren1ergi	"Ren1ergi consists of installation companies with expertise within renewable energy technologies: Bio-heat, solar heat, heat pumps, wind mills, and solar electricity.Ren1ergi is a section under Teqnik."	www.ren1ergi.dk
Solar City Copenhagen	Solar City Copenhagen is an independent association with the aim of turning Copenhagen and the rest of Denmark into a research and demonstration hub for solar energy and energy efficient buildings.	www.solarcitycopenhagen.dk
Green Tech Center	A newly constructed center of excellence within smart energy systems, where research, sparring, testing, and commercialization are gathered under the same roof.	www.greentechcenter.dk

Innovation networks

Name	Short description (3-4 sentences)	Website
Danish Marine and Offshore Group	The association was founded in 2001 by Danish producers and service companies. The aim of the association is to support business and market development within the offshore industry by establishing a platform for development of joint system solutions which is wanted by the market today globally.	www.offshore-denmark.dk
INBIOM	"The idea of the INBIOM network is to create projects between private companies and knowledge institutions where commercial technologies and processes related to biomass can be developed.	www.inbiom.dk
InfinIT	InfinIT is a Danish network for innovative utilization of IT with the goal to convert the infinite possibilities that technology offers into concrete collaborations between research and industry.	www.infinit.dk
INLEC	Lean Energy is a national cluster organisation with more than 240 members. The aim of the cluster is to promote energy efficiency based on sustainability throughout the value chain of the entire energy system.	www.leanenergy.dk/english
Inno-MT	The Innovation Network for Environmental Technologies (Inno-MT) is working to promote innovation in the Danish environmental technology sector with special focus on SMEs.	www.inno-mt.dk
Offshore energy	Offshoreenergy.dk is a member-based non-profit organisation. The purpose of the organisation is to unify the offshore sectors players through development projects and networking.	www.offshoreenergy.dk

Knowledge Institutions

Name	Short description (3-4 sentences)	Website
AMU-Vest	The AMU-center is an adult - and continuing education school who offer courses and certificates needed to maneouvre on for instance offshore and windmill facilities.	www.amu-vest.dk
AU: Department of Engineering	Department of Engineering conducts research within four classic engineering fields and use technical science to create solutions that benefit society	www.eng.au.dk/en
AU: Department of Environmental Science	The Department deal with some of the major challenges facing society, such as pollution and pollution control mechanisms, management of soil, water, air and biodiversity, protection of ecosystem services, climate change, and energy systems.	www.envs.au.dk/en
Danish Building Research Institute (SBi)	SBi, the Danish Building Research Institute is an institute at Aalborg University. Situated in Copenhagen the institute deals with all subjects within constructions and buildings and develops research-based knowledge to improve buildings and the built environment.	www.sbi.dk/en
DTU Chemical Engineering	DTU Chemical Engineering's main activities lie within the areas of product design, process design and production in the chemical, biotechnological, pharmaceutical, food technological and energy technological industries.	www.kt.dtu.dk/english
DTU Chemistry	DTU Chemistry does research within physical chemistry, organic chemistry, and inorganic chemistry. The department is collaborating closely with the industry.	www.kemi.dtu.dk/english

Navn	Short description (3-4 sentences)	Website
DTU Civil Engineering	Besides the education and research activities the civil engineering department is focused on the major challenges currently faced by society with sustainable development as the overall theme	www.byg.dtu.dk/english/
DTU Compute	DTU Compute is Denmark´s largest environment for mathematics and computer science	www.compute.dtu.dk/english
DTU Electrical Engineering	The Department of Electrical Engineering is the central DTU department within electrical and biomedical engineering and are highly active within the field of electric energy systems and the like. R&D is done in collaboration with industrial partners.	www.elektro.dtu.dk/english
DTU Energy Conversion	At DTU Energy Conversion focus is on R&D within functional materials and their application in sustainable energy technologies. Emphasis is on fuel cells, electrolysis, solar cells, batteries, magnetic refrigeration and other sustainable energy technologies.	www.ecs.dtu.dk/english
DTU Management Engineering	The department aims to develop and utilise new knowledge about Systems Analysis, Production and Service Management, Management Science, and Technology and Innovation Management to benefit society.	www.man.dtu.dk/english
DTU Mechanical Engineering	The Department covers the fundamental engineering disciplines within the field of mechanics, including mechanical properties of materials, strength and vibration analyses, thermodynamics, fluid mechanics, safety theory and control engineering.	www.mek.dtu.dk/english
DTU National Laboratory for Sustainable Energy	DTU National Laboratory for Sustainable Energy is working to foster interdepartmental cooperation and synergies. The laboratory also aims to strengthen DTU's participation in international alliances and forums.	www.natlab.dtu.dk/english
DTU Nutech	The Danish national competence center for nuclear technologies. The aim of the center is to develop and utilize knowledge concerning radioactivity and ionizing radiation for the benefit of society.	www.nutech.dtu.dk/english
DTU Photonics Engineering	DTU Fotonik's main areas of research (clusters) are Nanophotonics, Light sources and Industrial Sensors, Dynamic photonics, and Communication technology.	www.fotonik.dtu.dk/english
DTU Transport	The purpose of the department is to strengthen transport research with special focus on such fields as transport safety and risk as well as transport economics and transport modelling.	www.transport.dtu.dk/english
DTU Wind Energy	The overall objectives of the department are to maintain and further develop Denmark as a leading knowledge and development centre for wind energy and to support and develop the wind energy sector though research, innovation, education and research-based consultancy.	www.vindenergi.dtu.dk/english
IT-universitetet - Energy Futures	The activities of ITU is concentrated on the digital society's role in the energy system. Key questions that are dealt with is how communities, individuals, and professionals adapt to the development of the energy system.	www.energyfutures.itu.dk/
KU: Centre for Exploitation of Solar Energy	CESE was established at Department of Chemistry and aims at developing new solutions to the exploitation of solar energy.	www.ki.ku.dk/Forskning/cese
KU: Bio4Bio	The Bio4Bio center combines some of the strongest danish expertise from academia and industry, with the ambitious goal of working along the whole chain from plant genes and cell wall molecules to fields and biorefineries.	www.bio4bio.ku.dk/

Navn	Short description (3-4 sentences)	Website
RUC: Department of Environmental, Social, and Spatial Change	The Department is engaged in interdisciplinary work in working life and health promotion, mobility and urban studies, climate change mitigation and adaptation, biological production, environmental risk and designing human technologies.	www.ruc.dk/en/departments/department-of-environmental-social-and-spatial-change
SDU: Centre for Smart Energy Solutions	An interdisciplinary research and innovation centre located at the Faculty of Engineering. The Centre brings together energy experts, software engineers, computer scientists, applied physicists, and social and managerial studies experts in the analysis, design, and implementation of smart solutions to increase the efficiency of energy demand and supply systems.	www.sdu.dk/en/om_sdu/institutter_centre/centre+for+smart+energy+solutions
SDU: Department of Chemical Engineering, Biotechnology and Environmental Technology	Research areas include: Chemical process engineering, Functional materials and fuel cells, Biomass technology, Processing of vegetable raw materials for food, feed and natural medicine, System analysis and environmentally efficient technology, and Biosystems technology.	www.sdu.dk/en/Om_SDU/Institutter_centre/Ikbm_kemi_bio-_og_mijoeteknologi
SDU: Department of Environmental and Business Economics	The Department focuses on a number of issues relating to resources and environment including management, markets, consumer behavior and more.	
SDU: Department of Technology and Innovation	The Department contributes with innovative knowledge within a wide spectrum of research areas such as Nano Technology, Sensors, Energy Technology, Production, Innovation and Design, Robot Technology etc.	www.sdu.dk/en/Om_SDU/Institutter_centre/ITI
UNEP Risø Centre	The activities of the centre is organised under the following thematical programmes: Cleaner energy development, low carbon development, climate resilient development, and Sustainable Energy for All Hub.	www.uneprisoe.org
AAU: Department of Energy Technology	The Department of Energy Technology carries out research and education within a broad field of Energy Technology, covering both Electrical, Thermal and Mechanical Energy.	www.et.aau.dk
AAU: Department of Mechanical and Manufacturing Engineering	The research and teaching of the department is oriented towards production conditions in the private and public sector and contain elements such as production, materials science, logistics, IT, organisation, product development, automation, mechanics and management.	www.en.m-tech.aau.dk
AAU: Department of Electronic Systems	The Department of Electronic Systems is one of the largest departments at Aalborg University with a total of more than 300 employees. The department is internationally recognized in particular for its contributions within Information and Communication Technology (ICT).	www.es.aau.dk

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