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DENMARK: A EUROPEAN SMART GRID HUB

Asset mapping of smart grid competencies in Denmark

Table of content

Foreword

This report is an extensive mapping of the Danish smart grid sector. The purpose of the report is to:

1. Provide an overview and general outline of the competencies in the Danish smart grid industry
2. Display Danish competencies within smart grid research, development, test and demonstration
3. Describe the possible future developments within the smart grid industry in Denmark

Through this study, Copenhagen Cleantech Cluster and Copenhagen Capacity aim to strengthen Danish smart grid stakeholders and Copenhagen Cleantech Cluster by providing a unique overview of over 60 smart grid companies. The report also seeks to visualize the array of smart grid business opportunities in Denmark, and will serve as a tool for international stakeholders (e.g. companies, public authorities or research units) that wish to approach the Danish smart grid sector as, for example, possible partners, customers or suppliers.

The report has been prepared by Copenhagen Capacity with extensive assistance from Mikael Togeby, partner at Ea Energy Analyses.

Acknowledgements

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Copenhagen Capacity would also like to thank all the companies that are listed in the company matrix for their participation.

Editor:
Cecilie Hestbæk

Contact:
Copenhagen Capacity,
tel: +45 33 22 02 22
www.copcap.com

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Introduction

Denmark has developed unique experience over several decades with the integration of renewables into the power supply, and has a very flexible electricity market as a result. Thus, the country has already got a head start in the development of a new intelligent power grid that is planned to allow the integration of 100% renewable energy.

As Denmark already manages the integration of more wind power into the grid than any other country in the world and has a wide array of smart grid assets within test and demonstration and over 60 smart grid firms, it has the potential to be a world leader in the smart grid industry in the coming years.

Smart grid is a necessary and cost-effective solution

A smart grid is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users. Smart grids co-ordinate the needs and capabilities of generation assets, grid operators, end users and electricity market stakeholders to operate all parts of the system as efficiently as possible, thereby minimizing costs and environmental impact while maximizing system reliability, resilience and stability.[1]

Globally, there is a pressing need to accelerate the development of carbon free energy technologies in order to address the global challenges of energy security, climate change and economic growth. To enable this technological development and implementation, smart grids are essential. Moreover, they will turn out to be a more cost-effective solution in most cases than merely expanding capacity in the existing grid.

Our findings

The present study has been conducted to provide an overview of the smart grid sector in Denmark from a business perspective. The aim of the report was to identify and showcase the strengths of the Danish smart grid sector as well as to highlight opportunities for international smart grid actors. The results give a clear picture of a Danish smart grid sector with strong assets, continuous innovation and increasing growth: over 60 companies work in the smart grid industry and together they cover all of the eight smart grid technology categories defined by the IEA. Moreover, Denmark is recognized as a unique location for test and demonstration, as is reflected in the large number of R&D and demonstration projects: 22% of all projects concerning intelligent power grids in the EU take place in Denmark. [2]

In addition to the overview of Denmark's strengths within the smart grid industry, the report has identified some possible future trends within the smart grid market. Due to a number of factors, experts suggest that Denmark will experience rising demand within certain smart grid business areas, including electrical vehicles and charging infrastructure; metering infrastructure; transmission enhancement; and integrated, flexible demand response solutions.

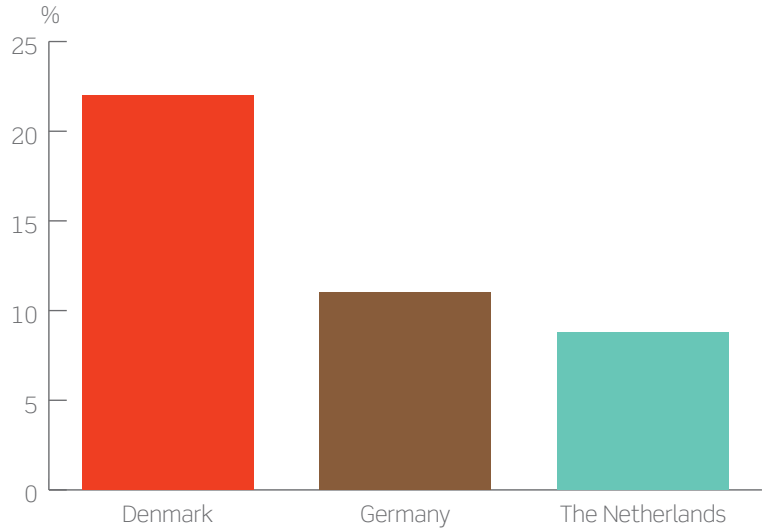
1 OECD/IEA: Technology Roadmap – smart grids, 2011
2 EU JRC report, 2011

Smart Grid in Denmark

The power supply sector will have to undergo significant infrastructural changes in the coming decades. An increasing part of electricity production will come from renewable energy, especially wind.

By 2020, renewable energy will amount to 30% of total energy consumption in Denmark and wind power is expected to supply 50% of Danish electricity consumption. Furthermore, a significant change in consumption patterns will occur due to the wider use of Electrical Vehicles (EVs) and heat pumps, for example. These challenges will require not only extensive changes in the energy system structure, but also the development of intelligence within the system. [1] These fundamental changes in the sector are going to result in a situation where the production as well as the consumption of electricity will fluctuate to a greater degree in the future.

Figure 1. Smart grid projects in EU
Source: EU JRC report, 2011



A smarter way to enhance the grid

The changes in the nature of power supply and demand will necessitate investment in the enhancement of the power grid, but the costs will vary significantly depending on whether the existing, traditional grid is expanded or if a smart grid solution is implemented.

Smart grid refers to the transformation of the electric power system into an 'energy internet', allowing utilities and customers to share information in real time, often automatically, so that both sides can manage electricity use more effectively.[2]

New power system, new technologies

Future energy systems will be radically different from what we know today. Danish energy production in the system will continue to be divided into power and heating, but to achieve a system which is as flexible as possible, it will be essential that these two sectors are not mutually dependent on each other. The key factor in the energy system will be that it consists of decentralized and distributed production based on a broad array of technologies that are integrated on a power grid and a number of heating grids. With a large number of plants on the grid, it is essential that these are monitored and constantly regulated, and that a power and heating storage capacity for use in times of surplus production is established. The systems created must be as intelligent as possible and made flexible and robust enough to cope with fluctuations in consumption as well as production over hours, days and weeks.[3]

Estimated investment needs

The specific investment needs with regard to smart grid expansion are: system software for controlling the grid; monitoring of the distribution grid; intelligent systems for the end user and the upgrading of metering infrastructure.

During the period up to 2025, investments totaling at least Euro 1,32 billion will be necessary in Denmark alone if the grid is to be expanded 'intelligently'.

1 Confederation of Danish Industry, 2010.

2 CGGC, Duke University, 2011

3 Fonnesbech et al, 2009

The smart grid will give rise to a number of socioeconomic benefits, such as lower electricity costs as the flexibility of electric vehicles and heating pumps allows part of electricity consumption to be moved to time slots where the electricity is cheaper, and a decrease in the cost of power generation regulation. The value of these benefits is estimated to be about Euro 1,1 billion. Traditional expansion of the grid would require investments of Euro 1,03 billion but would not result in similar socioeconomic gains.[1] Furthermore, the expansion of the Danish smart grid is roughly estimated by 2025 to have led to the creation of 10,000 new jobs.[2]

In the EU, the estimated investement needs are Euro 500 billion by 2030 if transmission and distribution investments are included.[3]

Ambitious political aims

The long-term vision for the Danish energy system is independence from fossil fuels, and there is the political ambition to achieve that goal no later than 2050. A long-term Danish energy system based on indigenous energy resources can be obtained most cost-effectively via a combination of initiatives leading up to 2050: the massive development of wind power; substitution of fossil fuels with biomass, biogas and waste; implementing the smart grid; energy exchange with neighboring countries; and a considerable level of energy saving and improvements in overall energy efficiency.[4]

Long experience with wind energy

Denmark has four decades of experience in the implementation of wind energy, and has therefore been the first country to meet and address the challenges posed by the integration of a large degree of wind energy in the power system. Today, Denmark produces more than 33% of its electricity from renewable energy sources – wind, biomass, solar and geothermal. Wind alone accounts for 20,7%.[5] This is a notably high proportion – in fact Denmark has the largest proportion of such electricity production in Europe.[6] Figure 2 illustrates Denmarks transition from central to decentral energy system.

However, the potential is much greater: Mikael Togeby, Partner in Ea Energy Analyses estimates that in the longer term, with an intelligent power grid, up to 75% of energy supplied by wind is realistic.

Flexible and coordinated power market

The circumstances outlined above have caused Denmark to be involved in the development of one of the world's most flexible electricity markets, and thus the country is already one step ahead when it comes to a flexible demand response power system. Brian Vad Mathiesen, who is Associate Professor at Aalborg University as well as the main author of and scientist behind the renewable energy system in IDAs[7] Climate Plan 2050, explains that "Denmark has the world's most well developed market for handling wind and the resulting fluctuations in its production. Large and small electricity producers already regulate their production, e.g. using thermal storage. In fact, this means that there is already a close interaction between consumption and production in Denmark."

Nord Pool Spot

This market interaction is possible due to Nord Pool Spot. In 1991, Norway was one of the first countries in the world to deregulate its power market, and was shortly followed by the other Nordic countries, who combined their individual markets into a common Nordic market. This was done in order to optimize social welfare and increase the security of supply. Available power capacity can be used more efficiently over a large region compared to a small one, and integrated markets enhance productivity and improve efficiency.

1 Energinet.dk, 2011
2 Deloitte, 2011 (own translation and currency exchange)
3 EU JRC report, 2011
4 Confederation of Danish Industry et al, 2010
5 Danish Energy Agency, 2010
6 Confederation of Danish Industry, 2010
7 IDA is the Danish Association of Engineers

Figure 2. Illustration of Denmark's journey from centralised to distributed energy system
Source: Danish Energy Agency, ens.dk, 100% accurate maps available

The power price is determined by the balance between supply and demand, taking into account transmission capacity. Today, there is general consent among politicians and other stakeholders in the Danish market that this model serves society well.

Nord Pool Spot was established as a company in 2002 as the world's first market for trading power. Today, it is also the world's largest market of its kind, and constitutes the leading marketplace for buying and selling power in the Nordic region, as well as Estonia, Germany and Great Britain. Nord Pool Spot runs the leading power market in Europe and offers both day-ahead and intraday markets to its customers. 350 companies from 18 countries trade on the market. [1]

The world's most developed district heating system

The Danish energy system is one of the world's most energy efficient systems. This is to a high degree to an extensive expansion of district heating that utilizes renewable energy and heat from combined heat and power (CHP) units. District heating today comprises about 60% of the heating market, and over 95% of the heating is produced with renewable energy or CHP.[2] In an energy system using 100% renewable energy, an intelligent power grid with flexible consumption should be combined with an expansion of district heating, as existing district heating systems in large cities can be converted cost-effectively from coal to biomass and new plants can be designed for using biomass, e.g. straw or wood pellets.

From a smart grid perspective, this extensive system can be used to store heat from electricity production by installing heating elements (e.g. electric kettles). Due to the district heating system, the heating boilers can be placed in a large number of places in the system. As there is already a regulating market in which the price of electricity determines whether these units use electricity or gas for heating, the district heating system is one of the elements that will contribute to stabilizing the power grid when production and consumption experience greater fluctuations.

Heat pumps

The extension of heat pumps into areas where district heating is not available is rapidly increasing in Denmark: Energinet.dk estimates that around 500,000 Danish homes will have heat pumps by 2030. This is an essential component for the implementation of the smart grid, as the intelligent remote control of electricity-driven heat pumps can pave the way for more wind power in the energy system by helping to create balance in an energy system based on fluctuating energy production from renewable sources. The remote control of heat pumps allows the coordination of electricity price, weather forecast and knowledge of the specific houses that need to be heated, which will then make it primarily possible to have the pumps running when power production is high and the price of electricity low.

Electric vehicles

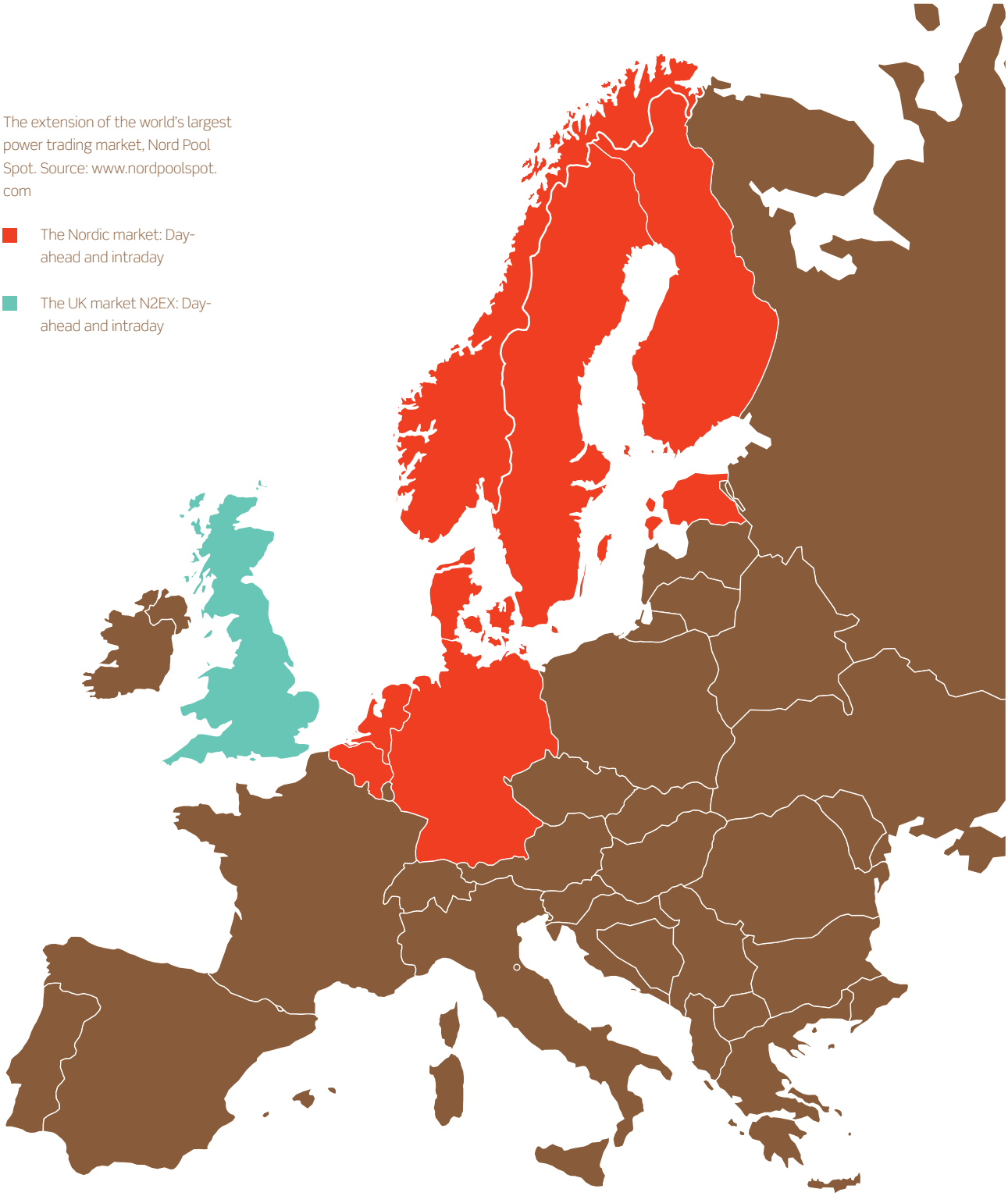
EVs are another technology that will contribute significantly to stabilizing a future smart grid with power from 100% renewable sources. With flexible control systems, cars can charge when electricity production is high, and thus serve as storage capacity. Hence, although EVs can end up being a heavy drain on the grid at times, they are, with the right intelligent solutions, also a part of the smart infrastructure that will keep the grid stabilized.

1 www.nordpoolspot.com
2 Fonnesbech et al, 2009

The extension of the world's largest power trading market, Nord Pool Spot. Source: www.nordpoolspot.com

The Nordic market: Day-ahead and intraday

The UK market N2EX: Day-ahead and intraday



Denmark has a unique concentration of smart grid assets

"Denmark is a world-leader in the smart grid industry." This is the conclusion of several experts working in the field. A variety of factors contribute to Denmark being seen as an international hot spot for smart grid technology.

Leading test and demonstration facilities

Denmark has a vision of becoming the world's green test lab and is already well on the way to achieving this due to framework conditions and business-oriented research.

Denmark is European leader in the development of smart grids as 22% of all demonstration and development projects relating to intelligent power grids in the EU take place in Denmark, with Germany in second place with 11% of the projects.[1]

Examples of exceptional projects

One of Europe's most ambitious smart grid projects is currently taking place on the island of Bornholm in Denmark. The full-scale EcoGrid project (see page 40) is aiming to lead the way in establishing the energy system of the future. Over the next few years, the largest intelligent power supply system in the world will be set up on Bornholm, and the project will test and demonstrate how a region can become fully self-sufficient with renewable energy.[2]

Also taking place on Bornholm, the EDISON project (see page 41) is utilizing Danish and international competencies to develop optimal system solutions for EV system integration, while the DTU Centre for Electric Technology and Ea Energy Analyses are testing electricity as a frequency controlled reserve (see page 42).

Yet another example is the world's largest test project on the intelligent remote control of heat pumps, which is taking place in Denmark over the next few years, and has over 300 families participating. Furthermore, several research platforms offer facilities for these activities, one of them being Powerlab (see page 43).

EU spearhead in R&D and T&D

Over the last few years, public funding for research in Denmark has increased, and in 2011, approx. 135 million EUR was allocated for research. In addition to this, European funding from Frame Program 7 is contributing further to the development of smart grid technology in Denmark. Jacob Østergaard, Professor and Head of the Centre for Electric Technology at the DTU Department of Electrical Engineering, confirms the image of Denmark as a green test hub: "The EU considers Denmark to be a lighthouse; a spearhead in research, test, development and demonstration, and these are also the areas we need to keep prioritizing and strengthening if we want to maintain our position as leading in the world in smart grid technology. I believe it is absolutely achievable for us to become the European centre for smart grid technology if we keep focusing on and prioritizing our efforts in the area."

Mikael Togeby, a partner at Ea Energy Analyses, agrees that the test and development projects are fundamental for Denmark's strong position within the smart grid industry: "The potential of smart grid is way larger than we can imagine. For example, a technology such as energy storage in water tanks has enormous potential. If you are open to new ideas, there are plenty of examples of what can be achieved.

1 EU JRC report, 2011
2 Energinet.dk, 2011

Universities, specialized R&D centres and a highly skilled work force

Denmark has a number of world class universities and a highly educated work force. In Denmark, the production of scientific articles on climate technology per million inhabitants is 70. This is four times as many as in the US and EU, where the production of scientific articles per million inhabitants is 16 and 17 respectively.[1]

Business oriented research

The research being conducted into smart grid technology in Denmark is closely linked to industry and public needs. Academics working in the energy sciences have traditionally been in dialogue with industry and the authorities, and this long experience of interdisciplinary collaboration and projects is now part of what makes Denmark a leader in the smart grid sector. A few outstanding research institutions in Denmark are:

1. **DTU:** Technical University of Denmark (DTU) is the country's largest technical university. It offers highly specialized research within several core smart grid areas. One of the research centres is the Centre for Electric Technology, which is undertaking essential research into electric energy systems and electric components. Another is the Risø DTU National Laboratory for Sustainable Energy, which is one of Europe's leading research laboratories for sustainable energy. Risø DTU achieves pioneering research results and contributes actively to their implementation in close dialogue with the wider society. Risø's research is the basis of customer-driven activities including advising the business community, institutions and authorities. Risø DTU takes initiatives and sets targets for research through continuous dialogue with the business sector, the authorities and the research community, and the laboratory's research is part of national and international networks. Risø DTU's research could have a particular impact on energy supply and consumption. The research laboratory has large test facilities and interdisciplinary research environments that enable problem solving across traditional professional boundaries and competences, and training and education as well as innovative activities are naturally integrated into Risø DTU's research activities.[2]

2. **Aalborg University:** Aalborg University conducts research into smart grid technology in a number of ways, one of these being through the university's Sustainable Energy Planning Group, which works with an interdisciplinary approach on sustainable energy planning and management. The research group is assessing energy planning in general, with a focus on technical aspects such as energy system analysis and GIS[3], as well as economic and institutional aspects such as feasibility studies and public regulation seen in the light of technological change. Since the early 1970s, the group has taken a strong interest in the Danish energy planning process. At the national level, strategies for the development of energy conservation, renewable energy sources and CHP have been put forward from the very start. The researchers have regularly been involved in the design of Danish energy policy and its implementation at both local and national levels.[4]

1 Confederation of Danish Industry, 2010

2 www.risoe.dtu.dk/en/

3 A Geographic Information System is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographically referenced data

4 www.en.aau.dk/

Smart grid commercial landscape of Denmark

In this study, Copenhagen Capacity has sought to list all the companies in Denmark that deliver the types of products or services which have been defined as smart grid and categorized in eight technology areas by the International Energy Agency (IEA).

The mapping (see "Technology company matrix" on page 24) shows that Denmark has over 60 smart grid companies. Smart grid technology brings together a wide range of players such as technology providers, power providers, investors, regulators, government agencies, research institutions and standard-setting organizations. In this study, we have focused on technology and consultancy companies, and narrowed it down to those who offer products that correspond to the IEA smart grid technology areas. We have not included companies that produce renewable energy devices, such as solar cells and micro wind turbines. Furthermore, we have excluded from the study storage technologies like, for example, fuel cells and stationary batteries, despite knowing that these products might well be part of the solution in the intelligent power grid. In the matrix, however, there are a few examples of companies that produce electrical devices which intelligently interact with the power grid, e.g. EVs and pumps – and we are well aware that the list is not exhaustive within this business area.

IEA's eight technology categories

To identify the capabilities of Danish smart grid companies, we did a firm-by-firm inventory (see "Technology company matrix" on page 24) across the spectrum of IEA's technology categories (see page 21), which was then confirmed by the companies listed.[1]

In the study, the value chain of smart grid technology has been simplified to a representation as seen in "Figure 3. Smart Grid Technology areas" on page 13 The left-to-right structure begins with power generation, moves through transmission and distribution, and ends with consumption. This roughly parallels the process in which electric power is delivered to the customer: first, electricity is generated, then it is stepped up by transformers to a high voltage so it can be transmitted over long distances, then it arrives at a substation where it is stepped back down to a lower voltage safer for local distribution.[2]

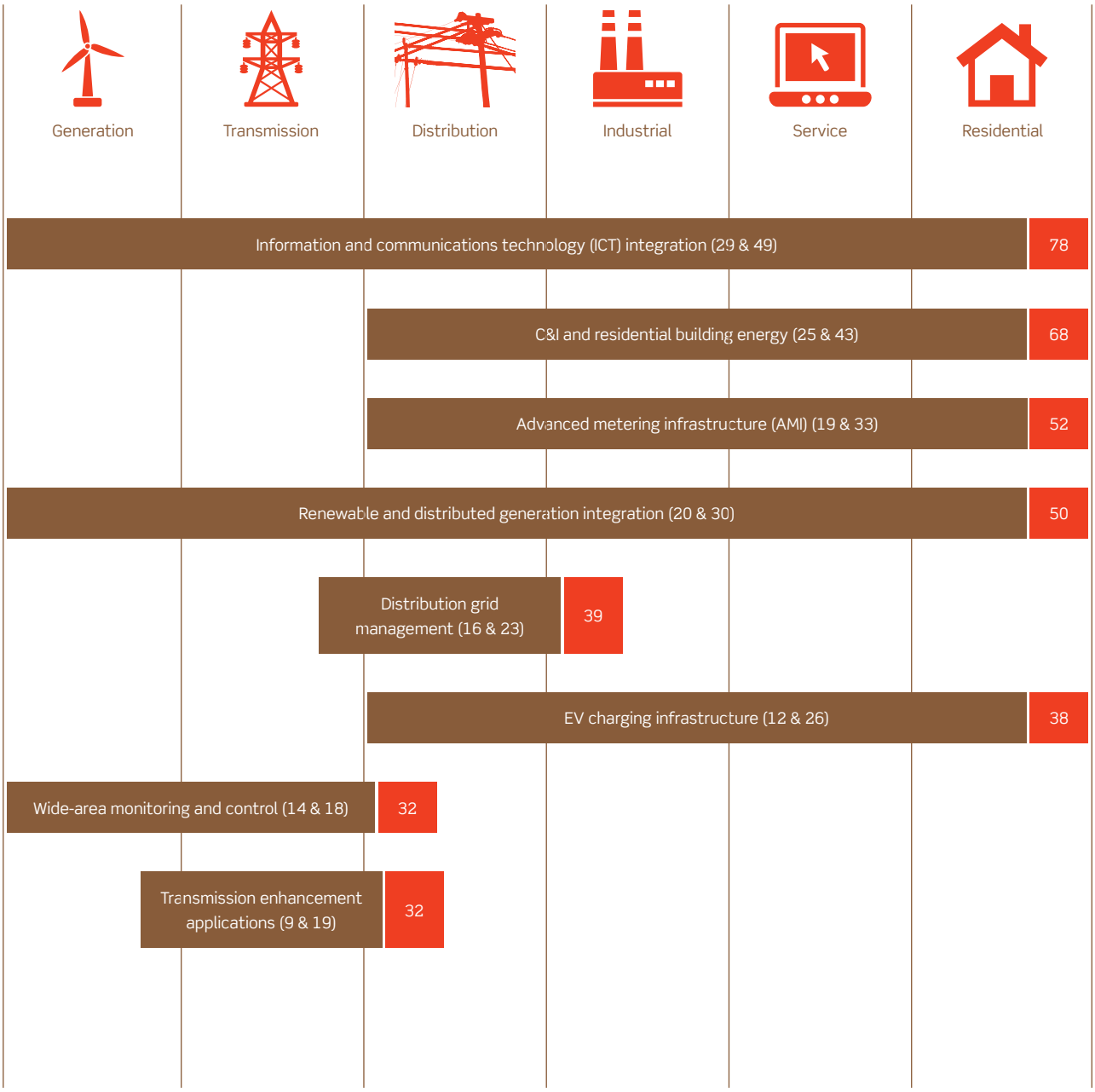
As can be seen in figure 3 and the technology company matrix on page 25, the data from our study reveal the following:

- Denmark's over 60 smart grid companies span the entire value chain as defined by the IEA.
- They are roughly estimated to have at least 15,500 employees.
- Denmark has firms involved in all of the eight IEA technology categories. The highest number of firms appears in information and communications technology integration
- The large multinational firms such as ABB, Siemens, Schneider Electric, Eltel Networks etc. stretch across most categories.
- A large number of smaller and medium sized companies are present in the Danish smart grid commercial landscape. Most of these specialize within particular smart grid technology areas.
- Danish companies are more involved in smart grid software and services than in hardware, with 61 in software and services and 40 in hardware.

1 No independent verification of the information reported by the companies has been performed.

2 CGGC, Duke University, 2011

Figure 3. Smart Grid Technology areas
Source: Technology categories and descriptions are adapted from IEA
Note: Numbers in brackets relates to the number of companies working within (hardware & software). The number in the red box is the total. Each companywork in several technology areas, thus the high number in total.



Future smart grid challenges in Denmark

As was concluded from the matrix, smart grid firms in Denmark cover all eight of the IEA technology areas. There are, however, strong clues as to where demand for solutions will increase and thus where new actors would be able to enter the market and contribute with valuable competencies at premium demand.

According to Jacob Østergaard, professor and head of center DTU, Denmark will not be able to "deliver all the building blocks necessary" for smart grid merely from domestic production. Denmark is thus dependent on attracting industry players of all sizes. As an example, he mentions system solutions for the smart control room of the future grid as just one concrete business area in which Denmark is currently short of industrial products. Through extensive interviews with experts a number of other possible future market opportunities are estimated to be as follows:

Integrated flexible solutions

As Denmark is already now becoming one of the first countries to implement smart grid solutions, the demand for intelligent, integrated and flexible solutions for controlling energy consumption will arise. The solutions will need to provide better service and lower prices for the consumers. Mikael Togeby from Ea Energy Analyses explains that "the current design of the electricity market suits the needs of the utilities very well, but it needs to be adjusted to the new system with a large number of electricity producers." He adds that the politicians will have to remove the barriers to flexible demand and response suitable for the market if they are to achieve their own climate goals. To Mikael Togeby, the Danish objective of being fossil free by 2050 is "a challenge, but definitely a strength, too, as it necessitates better regulation which will spur the faster development of smart grid technology and help keep Denmark in its current leading position with regards to smart grid."

Transmission enhancement

The conversion of the existing grid to smart grid will take some innovation with regard to the distribution grid, as it will be necessary to secure an effective extension of the transmission capacity in the distribution grid. The introduction of electric and plug-in hybrid cars and extention of heat pumps will mean that the power grid will have to transmit more electricity than it is currently designed for. Maintaining a constant voltage in spite of fluctuating energy production from renewable sources and a new consumption pattern is of crucial importance, and currently the development of the smart grid is being held back by the lack of common standards. However, when these standards have been decided and implemented, the demand for transmission enhancement solutions is expected to increase.

Metering infrastructure

In the IDA Climate Plan 2050, it is made clear that a flexible market supporting the development and expansion of the energy supply with renewable energy will demand old metering infrastructure to be replaced by new ones that will enable realtime monitoring and remote reading.

Brian Vad Mathiesen from Aalborg University explains that new meters are essential if local consumers are to be activated. "Of course being able to move demand will have some positive effect on the system, but a more important effect is energy conservation. One way of reducing consumption is metering. It is simply common sense to enable people to see the price of what they are buying, and it will reduce people's energy use." In Denmark, a number of industry players are already working on metering infrastructure, but as smart grid solutions win ground in both industry and private homes, and transmission infrastructure is improved and expanded, metering solutions will be in high demand. For new firms on the Danish market that can offer experience and strong competencies in metering solutions, opportunities may arise.

Electric vehicles and charging

The commitment to supporting EVs in Denmark is not entirely about green transportation. They are also seen as a storage option for all the wind energy produced. Therefore, the smart grid aspects of the EV infrastructure are imperative for EVs to become a success in a Danish context.

Recently, a consortium of partners including DONG Energy, Østkraft, IBM, Siemens, the Danish Energy Authority and Eurisco has been working on developing a smart electrical power infrastructure for charging EVs in the EDISON project (electric vehicles in a distributed and integrated market using sustainable energy and open networks, see "EDISON: Utilizing Danish Expertise to Create Sustainable Solutions" on page 41). This infrastructure must enable electric vehicles to communicate intelligently with the grid so that charging and dis-charging happens in an intelligent way in order to reap the benefits of EVs without putting a strain on the electrical grid or upsetting EV owners. To spur the development of the EV market, the Danish Government has implemented a registration tax exemption on EVs until 2015 as part of a comprehensive plan to promote green growth in the Danish economy. In contrast, the typical car registration tax in Denmark is 180% of the dutiable price.

A perfect place for EV testing

Brian Vad Mathiesen from Aalborg University expects flexible solutions for charging will be available on a larger scale in 2-3 years, and that now it is all about getting the new cars out there on the roads for everyone to see and try out. He believes that Denmark is the perfect place for developing, testing and demonstrating electric vehicle solutions as these depend on a more intelligent energy system.

The solutions required are sometimes referred to as a "smart grid", however he emphasizes that it is also about organizing the markets and the behaviour of consumer groups: "Denmark is definitely the one country which is furthest advanced with regard to a smart grid. The main reason is that we already know how to handle the integration of a large amount of wind energy – which no one else does," says Brian Vad Mathiesen and continues: "Technically, it is possible to integrate a lot more wind energy into the system, and as we, because of our ambitious political goals, will meet these challenges first, will have to develop the solutions before anyone else. We already have parts of the solution: a flexible market, a district heating system, massive amounts of research into electric vehicles and heat pumps, and a lot of activity within the smart grid sector. When we start integrating even more wind power and developing a system for controlling flexible electric vehicle charging and energy consumption, the whole world will be watching to learn how we are managing and organizing it."

Intelligent buildings

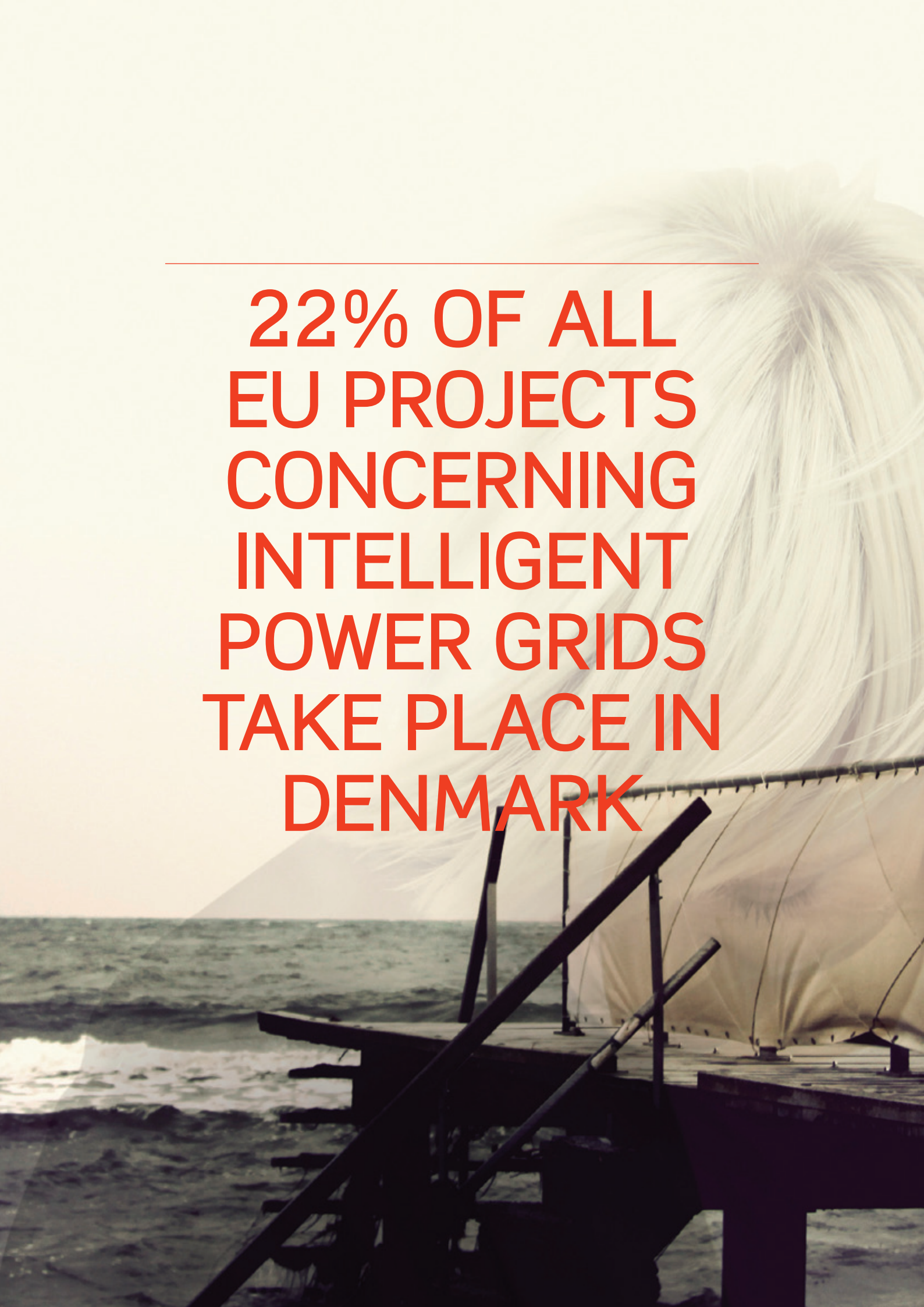
Although Denmark has a large number of companies working on smart grid software, according to Göran Wilke, consultant at Exergi and former director of the Danish Electricity Saving Trust, even more compentecies are needed to develop the intelligent buildings of the future that will play an active role in the smart grid. "We lack medium-sized players that have a focus on consumer issues. The consumer does not feel that he has a problem right now, so the smart solution has to appeal to the consumer first and foremost. So we are looking for companies with vision and muscle that can combine energy, green IT and consumer issues. Denmark would be the starter market, where companies from different countries can test and show their products destined for a much larger market," Göran Wilke says.

Denmark is a good test market

Göran Wilke agrees that our challenges will make us first movers, but also calls for improved competencies within integrated solutions: "We need to be better at building flexible solutions into heat pumps, electric vehicles etc., so that power supply and heat pumps, for example, come in one 'package'," he says. Göran Wilke also believes that Denmark is a "fantastic test country" for new smart grid technology, as the Danes are curious, want smart solutions and are open to new technology – the products, however, still need to be great and viable in market conditions. "This means," he says, "that Denmark is a 'natural environment' for new products, and good solutions will therefore be quickly taken up on the Danish market."

Benefits of being in the world's leading green lab

When considering whether to enter the Danish market to contribute specific smart grid capabilities, companies should also take into account the conditions into which they are locating their activities: Denmark's status as the 'green demonstratorium of the world' makes it a location which is both easy and beneficial to enter for business purposes. "One of the challenges in the grid today is that the companies that deliver products and services for utilities are often large international companies. These players have a natural platform from which to expand their portfolio to include smart grid products, but they do not always have the full picture of the necessary solutions in an electric power system with a very high proportion of renewable energy – and this understanding is important for being able to develop good future products and solutions. For that, research, development and testing are essential components," Jacob Østergaard from DTU explains.This is a key aspect in the Danish smart grid sector today and will be in the future.



22% OF ALL EU PROJECTS CONCERNING INTELLIGENT POWER GRIDS TAKE PLACE IN DENMARK

Conclusion

Denmark has over 60 smart grid companies which span the entire value chain. Furthermore, the country has decades of experience with the integration of renewables and thus has a unique combination of smart grid assets including leading test and demonstration facilities. However, Denmark will not be able to deliver all the building blocks for the future smart grid 2.0 merely from domestic competencies.

A number of clues indicate where the demand for intelligent solutions will increase and thus where new actors would be able to enter the market and contribute valuable competencies at premium demand, i.e. solutions that will later on be in high demand in other countries where large-scale integration of renewables and smart grid development will be a future focus for investment.

Opportunities for both large and small companies

For large multinationals, therefore, testing, developing and launching new products in Denmark can give a unique insight into current and future demand for smart grids and the possibilities for full-scale implementation, while for smaller companies the environment in which they will be acting has a number of potential benefits. The Danish market is easy to enter, and as a variety of large players are also present, partnerships or supplier-customer relations throughout the value chain are more easily achievable than in locations with only smaller players. Moreover, all types of industrial players in the smart grid sector in Denmark can take advantage of the close connections to the local surrounding markets through e.g. Nord Pool Spot. Entering the Danish market thus gives a head start into operating in future energy markets and provides a unique hub for Scandinavia and Northern Europe.

”We strongly believe that being part of developing solutions in the Danish smart grid sector will provide future access to a potential smart grid market in Europe estimated to be worth Euro 500 billion until 2030”, says Jakob Elmer, Business Development Manager at Copenhagen Capacity.

ENTERING THE DANISH MARKET GIVES A HEAD START INTO OPERATING IN FUTURE ENERGY MARKETS

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Source	Publication/article
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Nord Pool Spot	www.nordpoolspot.com/
Energinet	www.energinet.dk
The Danish Society of Engineers, IDA	www.ida.dk

Introduction to company matrix

To provide an overview of the players in the smart grid sector, we have listed them in a matrix containing information on their size (number of employees) and their area of business (technology areas). The listings only apply to the parts of each company that are based in Denmark (e.g. multinationals are only listed under the products and services their Danish branches offer.) The symbols in the matrix are as follows:

Type of product:

- Hardware
- Software and other services

Number of employees:

- 1-10
- 11-25
- 26-50
- 51-100
- 101-500
- > 500

IEA technology areas

In the matrix, we have chosen to use the same eight main smart grid technology areas as defined by the International Energy Agency [1]

Each of the eight categories described in this section comprises a number of smart grid technologies involving various configurations of hardware, software, communications and services. The categories extend across one or more stages of electric power delivery, from generation through transmission and distribution, to consumption.

The many smart grid technology areas – each consisting of sets of individual technologies – span the entire grid, from generation through transmission and distribution to various types of electricity consumers. Some of the technologies are actively being deployed and are considered mature in both their development and application, while others require further development and demonstration.

A fully optimized electricity system will deploy all the technology areas in “Figure 3. Smart Grid Technology areas” on page 13. However, not all technology areas need to be installed to increase the ‘smartness’ of the grid. The technology areas are defined as follows:

Information and communications technology integration
Make it possible to integrate intelligence throughout the entire power system, and to achieve real-time, two-way communication in order to manage energy more effectively.

Commercial, Industrial or Residential Building Energy Management.
Building automation systems with more integrated customer-side systems, using networked sensors and monitors and incorporating data from individual systems such as lighting and heating, ventilation and air conditioning (HVAC). New technologies include energy readers, smart appliances, and local energy storage. An important smart grid application is “Demand Response”, which involves cutting demand through voluntary agreements with power customers. To create a large pool of capacity to reduce peak power loads through demand response, utilities are turning to curtailment service providers.

Advanced Metering Infrastructure (AMI)
The foundation of the smart grid’s two-way flow of data, and the key to most smart grid initiatives to date, is the underlying infrastructure that combines smart meters, communications and data management. AMI involves a number of functions, including:

- smart meters, the network infrastructure to transmit data from smart meters to the utility, and
- software to compile and manage the massive quantities of data produced.

Electric vehicle charging infrastructure.
Electric vehicles rely on energy storage in the form of advanced vehicle batteries. Connecting electric vehicles to the grid for battery recharging requires infrastructure to handle billing, scheduling and other intelligent functions. If charging stations allow power to flow both ways, electric vehicles can serve as a

1 OECD/IEA, 2011

source of distributed energy storage—discharging electricity back to the grid during hours when the vehicle is parked and peak power is needed.

Transmission enhancement
Enhancement applications involve a number of technologies that can make transmission networks easier to control, maximize the transfer of power, reduce transmission losses, and decrease the risk of overloads. Transformers are devices that reduce the voltage of electricity so it can be safely distributed to consumers. Advanced transformers reduce electricity losses compared to conventional ones. New transformer designs greatly reduce the waste of electricity during distribution.

Distribution grid management
Combines sensor technologies and automation to continuously:
- maintain voltage levels
- locate faults
- reconfigure feeders
- control distributed generation so that equipment performs optimally and outages are minimized.

Renewable and distributed generation integration require
- Connecting solar arrays, wind farms and other sources to power grids. This involves new products in addition to standard technologies used to connect traditional sources such as coal and nuclear. Because solar panels produce direct current (DC), they require inverters to convert DC to alternating current (AC). Accommodating small-scale, distributed power sources such as rooftop solar requires different capabilities from grid-scale renewable sources such as a concentrating solar array. Energy storage can play a key role in neutralizing the variable nature of renewables by supplying energy at times when there is no sun or wind.
- The storage device itself is required, along with converters (rectifier inverters), and traditional field equipment associated with conventional power.

Wide area monitoring and control
Helps system operators monitor, control and optimize the power system over large geographic areas, avoiding blackouts and facilitating the use of renewables. Advanced system analytics generate data used to inform decisions and make systems more reliable.

Source: OECD/IEA, 2011 and CGGC, Duke University, 2011

Examples of products

Technology category	Examples of hardware	Examples of software or systems
IT & communications technology integration	Communication equipment (Power line carrier, WIMAX, RF mesh network, cellular), routers, relays, switches, gateway, computers (servers)	Enterprise resource planning software (ERP), Customer information systems (CIS)
C/I building or home energy management	Building automation systems, smart appliances, routers, in-home displays, demand-response enabling devices	Energy readers, energy management systems, energy applications for smartphones and tablets, demand-response curtailment services
Advanced metering infrastructure	Smart meters, in-home displays, servers, relays	Meter data management system (MDMS)
Electric vehicle charging infrastructure	Charging infrastructure, batteries, inverters	Energy billing, smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies
Transmission enhancement	Superconductors, FACTS, High-voltage direct current (HVDC). Advanced transformers: High-efficiency amorphous transformers, solid state transformers (under development)	Network stability analysis, automatic recovery systems. Advanced transformer asset management systems
Distribution grid management	Automated re-closers, switches and capacitors, remote-controlled distributed generation and storage, transformer sensors, wire and cable sensors, distribution management systems	Geographic information system (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS)
Renewable & distributed generation integration	Power conditioning equipment for bulk power and grid support, communication and control hardware for generation and enabling storage technology; energy storage: advanced batteries, capacitors, fuel cells, compressed air, pumped storage	Energy management system (EMS), distribution management system (DMS), SCADA, geographic information system (GIS), battery management systems
Wide area monitoring & control	Phasor measurement units (PMU) and other sensor equipment	Supervisory control and data acquisition (SCADA), wide-area monitoring systems (WAMS), wide-area adaptive protection, control and automation

Sources: OECD/IEA, 2011 and CGGC, Duke University, 2011

Technology company matrix

Technology companies	Products and Services	Information and communications technology integration	C&I and residential building energy management	Advanced metering infrastructure	EV charging infrastructure	Transmission enhancement	Distribution grid management	Renewable and distributed generation integration	Wide-area monitoring and control
ABB	Energy storage, power products, power systems, discrete automation and motion, low-voltage products, process automation, services	● ■	● ■	■	● ■	● ■	● ■	● ■	● ■
Actua	Software for control of Smart Grid	■					■		
Alcatel-Lucent	Communication networks, e2e systems integration, consultancy services.	● ■		● ■	■		● ■	●	■
Alexandra Instituttet	Research based and user driven IT and process development	● ■							
Alstom Grid	High-voltage products, circuit breakers, power electronics, automation solutions, control room information technology, network consultancy, SCADA systems, power transformers.	● ■		● ■	● ■	● ■	● ■	● ■	● ■
Amplex	Low-voltage network monitoring, metering systems, energy management systems	● ■	● ■	● ■			● ■		
Better Place	EVs and EV infrastructure	● ■	● ■	● ■	● ■		● ■	● ■	● ■
ChoosEV	EV operator, infrastructure, charging stations, EV projects, communications technology, etc.	● ■	● ■		● ■				● ■
Cisco	System networks, IT security etc. - developing standards	● ■		● ■			● ■		
CleanCharge	Smart grid EV infrastructure	● ■		● ■	● ■	● ■	■	■	■
Contech Automatic	Automation solutions, SCADA systems, power control, electricity installation, services and maintenance		● ■	● ■				● ■	
Coromatic	IT-operational dependability		■						
Danfoss	Inverters for photovoltaic installations, heatpumps, refrigeration and air-conditioning	●	●				●	●	

● Hardware ■ Software & other services

Technology companies	Products and Services	Information and communications technology integration	C&I and residential building energy management	Advanced metering infrastructure	EV charging infrastructure	Transmission enhancement	Distribution grid management	Renewable and distributed generation integration	Wide-area monitoring and control
Develco Products A/S	Energy management, building automation, load control, smart metering, grid balancing and energy awareness	● ■	● ■	● ■	● ■				● ■
Eglu A/S	Energy consumption control in hi-tech commercial greenhouses	■	■						
Electrocom	Energy Registration and Smart Metering	● ■	● ■	● ■					● ■
Eltel Networks	Full-service supplier within metering, smart grid, power supply etc.	● ■	● ■	● ■	● ■	■	● ■	● ■	■
EnergyWise	Heat pumps, solar heat pumps							● ■	
Enterprise Green It / EGIT - JouleX	Energy monitoring/data collection, energy scenario simulations, energy policy registration and management within distributed network, DataCenters and facilities.	■	■	■	■	■	■	■	■
Frichs A/S	Engines and power heating systems, biogas sublimation, specialized engines, gas turbines, emergency power stations, maintenance and services							● ■	
Futurecom Business Solutions A/S	IT systems	■	■						
Greenwave Reality	Energy control in buildings	■	● ■		● ■				
Gridmanager	Energy efficiency and management, automatic demand response, load shifting and grid balancing	● ■	● ■	● ■		● ■			● ■
Grundfos	Heat pumps for residential buildings, control and monitoring		● ■					● ■	
HoneyWell	Automation and control solutions	● ■	● ■	● ■					● ■
IBM	Software for EV infrastructure				■				

● Hardware ■ Software & other services

Technology companies	Products and Services	Information and communications technology integration	C&I and residential building energy management	Advanced metering infrastructure	EV charging infrastructure	Transmission enhancement	Distribution grid management	Renewable and distributed generation integration	Wide-area monitoring and control
IEN Consultants	Intelligent buildings, measurement analysis and control for buildings	● ■	● ■						
InoPower ●	Control systems for large scale renewable energy integration into power grids	● ■						● ■	
Juniper Networks ●	System networks, IT security etc.	● ■							
Kamstrup ● ● ● ● ● ●	Advanced metering solutions, smart meters for smart grids, residential meters & industrial meters	●	● ■	● ■			● ■		
Kemp & Lauritzen ● ● ● ● ● ●	Electricity installation, services, power enterprises, engineering, total service, high voltage and supply, transmission	● ■	● ■	● ■			●	● ■	● ■
KK electronic A/S ● ● ● ● ● ●	Control systems	● ■	●			●		● ■	●
Landis & Gyr	Meters for grid, residential and industry buildings		●	●			● ■		
Logica ● ● ● ● ● ●	Full service ranging from consultancy to full business process outsourcing within smart grid services and solutions. Solutions include smart metering, real-time enterprise asset management and running central markets. Implementer of major third party solutions, including SAP.	● ■	● ■	● ■	● ■	● ■	● ■	● ■	● ■
Microsoft Development Center Copenhagen	IT systems	■	■						
Neogrid Technologies ApS ●	Solutions for remote control of consumption, aggregation + activation of flexible power consumption with special focus on controlling heat pumps, grid balancing and energy efficiency and management	■	■		■	■		● ■	
North Q	Realtime metering solutions, energy saving solutions, readers for visualizing power, gas and water consumption etc.	● ■	● ■	● ■					

● Hardware ■ Software & other services

Technology companies	Products and Services	Information and communications technology integration	C&I and residential building energy management	Advanced metering infrastructure	EV charging infrastructure	Transmission enhancement	Distribution grid management	Renewable and distributed generation integration	Wide-area monitoring and control
PowerSense	Supervision and control systems	● ■		●				●	●
Qees	QEES is a global supplier of 'intelligent solutions' or smart home solutions for homes, offices, hotels, schools, etc.	● ■	● ■						
Schneider Electric	Energy management, software, industrial automation, electrical distribution, installation systems etc.	● ■	● ■	■	● ■	● ■	● ■	● ■	● ■
Seluxit ApS	Intelligent buildings, Smart Grids and Meters, Control Electronics	● ■	● ■	● ■					
Semco Maritime A/S	IT systems	■	■						
Siemens Energy	Energy production, transmission and distribution, e-mobility and infrastructure	● ■	● ■	● ■	● ■	● ■	● ■	● ■	● ■
Solarcap A/S	Intelligent buildings		● ■						
Spirae	Active Distribution Management System, smart grid modeling and simulation, cell controllers and smart grid consultancy					● ■	● ■	● ■	● ■
Topsil Semiconductor Materials	semiconductors and components for grid, wind turbines					●	●	●	
Vikingegaarden A/S	Intelligent charging system for vehicles, public charges, parking place solution, domestic charges	● ■			● ■				
Vmware	Virtualization and cloud	■	■						
Wexøe	Electronic hardware		● ■						

● Hardware ■ Software & other services

Consultancy company matrix

Technology companies	Products and Services	Information and communications technology integration	C&I and residential building energy management	Advanced metering infrastructure	EV charging infrastructure	Transmission enhancement	Distribution grid management	Renewable and distributed generation integration	Wide-area monitoring and control
Accenture	Consultancy, technology and outsourcing of smart grid services and software solutions. Accenture has experts on smart grid strategy, business cases, data management and system integration.	■	■	■	■	■	■	■	■
Capgemini	IT and management consultancy services: Smart Energy Services, e.g. energy efficiency, smart metering, transformation of utility companies, grid monitoring etc.	■	■	■			■	■	
Ciber	Consultancy and systems	■	■	■		■	■	■	
Cowi	Consultancy	■	■	■	■			■	
Devoteam consulting	Consultancy and systems	■		■		■	■	■	
EA Energianalyse	Energy consultancy and research				■	■		■	
EKJ	Consulting engineers	■	■	■	■	■	■	■	
Enervision A/S	Consultancy, energy control	■	■	■					■
Exergi	Consultancy	■	■	■	■	■		■	
Grontmij	Consultancy	■	■	■	■	■	■	■	
Niras	Consultancy	■	■	■	■			■	
Ramböll	Consultancy	■	■	■	■	■	■	■	
Teknologisk Institut	Develops, utilizes and communicates research and technology-based knowledge of smart grid.	■	■	■	■			■	
VillaWatt	Test facilities for energy-saving buildings	■	■		■				

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Company contact list

Company	Website	Address	Contact
ABB A/S	www.abb.dk	Meterbuen 33 2740 Skovlunde T: +45 44 50 44 50	Per Rømer Kofod T: +45 21 40 27 33 E: per.r.kofod@dk.abb.com
Accenture	www.accenture.com	Arne Jacobsens Allé 15 2300 København S T: +45 72 28 80 00	Trygve Skjøtskift T: +45 25 28 80 48 E: trygve.skjotskift@accenture.com
Actua ApS	www.actua.dk	Åbogade 15 8200 Aarhus N T: +45 70 27 72 72	Niels Koldsø T: +45 60 35 50 50 E: nko@actua.dk
Alcatel-Lucent	www.alcatel-lucent.com	Islands Brygge 43 2300 København S T: +45 44 80 75 00	Per Dyrhof E: per.dyrhof@alcatel-lucent.com
Alexandra Instituttet A/S	www.alexandra.dk	Åbogade 34 8200 Aarhus N T: +45 70 27 70 12	Jan Horsager T: +45 20 16 66 15 E: Jan.horsager@alexandra.dk
Alstom Grid	www.alstom.com	Strevelinsvej 8 7000 Fredericia T: +45 76 24 53 30	Ole Kaarup Nielsen T: +45 76 20 11 80 E: ole.nielsen@alstom.com
Amplex A/S	www.amplex.dk	Silkeborgvej 2 8000 Aarhus C T: +45 87 30 45 00	Nønne Holm Carlsen E: nhc@amplex.dk
Better Place	www.betterplace.com	Lygten 39 2400 København NV T: +45 70 27 02 47	Mikkel Westenholz E: mikkel.westenholz@betterplace.com
Capgemini	www.capgemini.com	Delta Park 40 2665 Vallensbæk Strand T: +45 70 11 22 00	Michael Holm E: michael.holm@capgemini.com
ChoosEV A/S	www.choosev.com	Vester Farimagsgade 17, 1. sal 1606 København V T: +45 82 30 30 30	Lars Bording
CIBER A/S	www.ciber.dk	Ringager 4C 2605 Brøndby T: +45 44 66 24 66	Lars Damgaard T: +45 24 82 27 76 E: lars.damgaard@ciber.com
Cisco	www.cisco.com	Automatikvej 1, stuen 2860 Søborg T: +45 39 58 50 00	Michael Nielsen E: micniels@cisco.com
CleanCharge Solutions ApS	www.cleancharge.dk	Nytorv 17, baghuset 1450 København K T: +45 22 95 34 42	Nils Dullum
Contech Automatic ApS	www.contech-automatic.dk	Aarhusvej 38 4800 Nykøbing F T: +45 54 88 44 40	Henrik Lundahl T: +45 54 88 44 50 E: hel@contech-automatic.dk
Coromatic A/S	www.coromatic.dk	Agerhatten 5 5220 Odense SØ T: +45 66 17 62 60	Mia Brith Fisker Jørgensen T: +45 63 17 02 17
COWI A/S	www.cowi.dk	Parallelvej 2 2800 Kgs. Lyngby T: +45 45 97 22 11	Stig Christensen T: +45 20 29 51 11 E: spc@cowi.dk

Company	Website	Address	Contact
Danfoss A/S	www.danfoss.dk	Nordborgvej 81 6430 Nordborg T: +45 74 88 85 00	Søren Bækhøj Kjær T: +45 74 88 13 59 E: sbk@danfoss.com
Develco Products A/S	www.develcoproducts.com	Olof Palmes Allé 40 8200 Aarhus N T: +45 87 40 03 70	Dorte Gårdbo Pedersen T: +45 25 38 54 34 E: dgp@develco.dk
DONG Energy	www.dongenergy.dk	Kraftværksvej 53 7000 Fredericia T: +45 99 55 11 11	Peder Dybdal Cajar T: +45 99 55 49 61 E: pedca@dongenergy.dk
EA Energianalyse A/S	www.ea-energianalyse.dk	Frederiksholms Kanal 4, 3.th 1220 København K T: +45 88 70 70 83	Mikael Togeby T: +45 60 39 17 07 E: mt@eaea.dk
EGIT - Enterprise Green IT	www.egit.dk		Lars Carl Holten T: +45 40 35 35 25 E: lch@egit.dk
eglu A/S	www.eglu.net	Petersborgvej 40 8570 Trustrup	Charlotte S. Ladefoged T: +45 29 72 46 36 E: charlotte@eglu.net
EKJ	www.ekj.dk	Blegdamsvej 58 2100 København Ø T: +45 33 11 14 14	Evy Beck Andersen T: +45 33 95 72 11 E: eba@ekj.dk
Electrocom	www.electrocom.dk	Rødeledsvej 95 5700 Svendborg T: +45 88 80 75 80	Kim Brun T: +45 31 11 12 05 E: kmr@electrocom.dk
Eltel Networks	www.eltelnetworks.com	Stationsparken 25 2600 Glostrup T: +45 88 13 50 00	Carlo Lazar E: carlo.lazar@eltelnetworks.dk
Enervision A/S	www.enervision.dk	Præstegårdsvej 9 6534 Agerskov T: +45 73 90 32 00	Ole Dam E: od@enervision.dk
EnergyWise ApS	www.energywise.dk	Metalvej 7A, st. 4000 Roskilde T: +45 20 21 00 99	Göran Wilke T: +45 21 50 55 58 E: gw@exergi.dk
Exergi	www.exergi.dk	Strandgade 94, 1. th 1401 København K	Berg Brix T: +45 61 22 74 03 E: bbr@frichs.com
Frichs A/S	www.frichs.dk	Sverigesvej 16 8700 Horsens T: +45 75 64 72 44	
GreenWave Reality ApS	www.greenwavereality.com	Dr. Neergaards Vej 3 2970 Hørsholm T: +45 69 13 23 33	Bo Lustrup T: +45 22 60 03 80 E: bo@greenwavereality.com
GridManager A/S	www.gridmanager.dk	Livøvej 21 8800 Viborg T: +45 50 77 01 70	Mogens Birkelund T: +45 50 77 01 71 E: mb@gridmanager.dk
Grontmij A/S	www.grontmij.dk	Granskoven 8 2600 Glostrup T: +45 43 48 60 60	Hans-Martin Friis Møller T: +45 27 23 60 90 E: hans-martinfriis.moller@grontmij.dk

Company	Website	Address	Contact
Grundfos A/S	www.grundfos.dk	Poul Due Jensens Vej 7 8850 Bjerringbro T: +45 87 50 14 00	Hakon Børsting E: hboersting@grundfos.com
HoneyWell	www.honeywell.com	Strandvejen 70 2900 Hellerup T: +45 39 55 55 55	
IBM ApS	www.ibm.dk	Nymøllevej 91 2800 Kgs. Lyngby T: +45 45 23 30 00	Kim Oestrup T: +45 28 80 37 98 E: qstrup@dk.ibm.com
InoPower	www.inopower.dk	Stigborgvej 36, st. 9400 Nr. Sundby T: +45 98 16 45 66	Troels Davidsen T: +45 96 32 38 20 E: td@inopower.dk
Juniper Networks	www.jnpr.dk		
Kamstrup A/S	www.kamstrup.dk	Industrivej 28 8660 Skanderborg T: +45 89 93 10 00	Lis Musmand T: +45 89 93 10 09 E: lm@kamstrup.dk
Kemp & Lauritzen A/S	www.kemp-lauritzen.dk	Roskildevej 12 2620 Albertslund T: +45 43 66 88 88	Christian Beiter
KK-Electronic A/S	www.kk-electronic.dk	Bøgildvej 3 7430 Ikast T: +45 97 22 10 33	Erik Gammelgaard
Landis+Gyr A/S	www.landisgyr.com	Dalbergstrøget 5, 1.sal 2630 Taastrup T: +45 70 21 25 30	John Hammeken E: john.hammeken@landisgyr.com
Logica	www.logica.dk	Lautrupvang 10 2750 Ballerup T: +45 44 78 40 00	Christina Jørgensen
Microsoft Development Center Copenhagen	www.microsoft.com/da-dk	Tuborg Boulevard 12 2900 Hellerup T: +45 44 89 01 00	
Neogrid Technologies ApS	www.neogrid.dk	Niels Jernes Vej 10 9220 Aalborg Ø	Henrik Lund Stærmose T: +45 30 65 46 61 E: hls@neogrid.dk
NIRAS	www.niras.dk	Sortemosevej 2 3450 Allerød T: +45 48 10 42 00	Lars Boye Mortensen T: +45 96 30 64 50 E: lbm@niras.dk
NorthQ ApS	www.northq.com	Strandvejen 157, 1.tv 2900 Hellerup T: +45 70 27 18 18	Christian von Scholten T: +45 22 40 80 23 E: cvs@northq.com
PowerSense A/S	www.powersense.dk	Skovlytoften 33 2840 Holte T: +45 76 10 00 17	Martin Speiemann T: +45 76 10 00 17 E: sales@powersense.dk
QEES A/S	www.qees.eu	Naverland 31, 2. tv 2600 Glostrup T: +45 70 23 02 39	Morten Bremild E: mbr@qees.eu

Company	Website	Address	Contact
Rambøll A/S	www.ramboll.dk	Hannemanns Allé 53 2300 København S T: +45 51 61 10 00	Thomas Rand T: +45 51 61 86 10 E: tr@ramboll.com
Schneider Electric A/S	www.schneider-electric.com	Industriparken 32 2750 Ballerup T: +45 44 20 70 00	Joe Andersen T: +45 40 70 33 30 E: joe.andersen@schneider-electric.com
SE Sydenergi	www.se.dk	Ravnevej 12 6705 Esbjerg Ø T: +45 70 11 50 00	Palle Larsen T: +45 75 18 86 10
SEAS-NVE	www.seas-nve.dk	Hovedgaden 36 4520 Svinninge T: +45 70 29 29 29	Kristina Fløche Juelsgaard T: +45 70 29 25 74 E: kfj@seas-nve.dk
Seluxit ApS	www.seluxit.dk	Hjulmagervej 32B 9000 Aalborg T: +45 46 92 27 22	Daniel Lux E: daniel@seluxit.com
Semco Maritime A/S	www.semcomaritime.com	Stenhuggervej 12-14 6710 Esbjerg V T: +45 79 16 66 66	
Siemens Energy	www.siemens.dk	Borupvang 3 2750 Ballerup T: +45 44 77 44 54	Per Roos T: +45 44 77 44 54 E: per.roos@siemens.com
Solarcap A/S	www.solarcap.dk	Breeltevej 18 2970 Hørsholm T: +45 39 57 04 00	
Spirae	www.spirae.com		Julie Zinn Patti T: +1 970 449-8528 E: jzinnpatti@spirae.com
Teknologisk Institut	www.teknologisk.dk	Gregersensvej 3 2630 Taastrup T: +45 72 20 20 00	Frank Elefsen T: +45 72 20 12 50 E: fre@teknologisk.dk
Topsil Semiconductor Materials A/S	www.topsil.com	Linderupvej 4 3600 Frederikssund T: +45 47 36 56 00	
Vikingegaarden A/S	www.vikingegaarden.com	Tinetvej 70 7173 Vonge T: +45 75 80 39 60	Jan Agnoletti Pedersen T: +45 27 60 02 02 E: jap@vikingegaarden.com
VillaWatt	www.villawatt.dk	Hørskætten 5 2630 Taastrup T: +45 77 30 31 51	Birger Hauge T: +45 21 42 05 00 E: birger.hauge@globalconnect.dk
Wexøe A/S	www.wexoe.dk	Lejrvej 31 3500 Værløse T: +45 45 46 58 00	Tom Jappe T: +45 45 46 59 39 E: tja@wexoe.dk

COMPANY CASES

Vikingegaarden: Creating intelligent charging

Vikingegaarden is a market leader in concepts for web-based GPS systems, the process industry, automation and total solutions. Vikingegaarden is well known and has an excellent reputation for highly innovative and user-friendly solutions that can be used anywhere in the world, such as the EV-charger, EVergreen charging.

Company mission

Right from the very beginning, the focus of the Danish Vikingegaarden company has been on the user-friendliness of the advanced solutions which have been developed as part of the web-based CMS system, Vikingegaarden Management System (VMS). The aim has been to create products which are intuitive and easy to use.

Company Background

The company was established in 1996, and the development of VMS began in 1999. As the VMS proved itself to the customers, it became the main focus of the company. Besides VMS, the company's core comprises Citect SCADA solutions.

Products

Vikingegaarden products have been a great success and since the company's clientele is growing geographically as well as businesswise, Vikingegaarden has a desire to strengthen the company's already professional network which handles sales to the end users. The goal is to create a system that makes it easy to charge the batteries of electric cars while using carbon-neutral energy, such as from wind turbines. This will be a big step forward towards a practical solution to the use of electric vehicles.

Innovative projects

Backed by a budget framework of almost DKK 20 million, of which DKK 11.6 million has come in funding from the so-called EUDP Programme, Vikingegaarden A/S has launched a two-year development programme which will result in an intelligent charging station for Electric Vehicles (EVs) being ready for production in 2012.

EVergreen intelligent charging

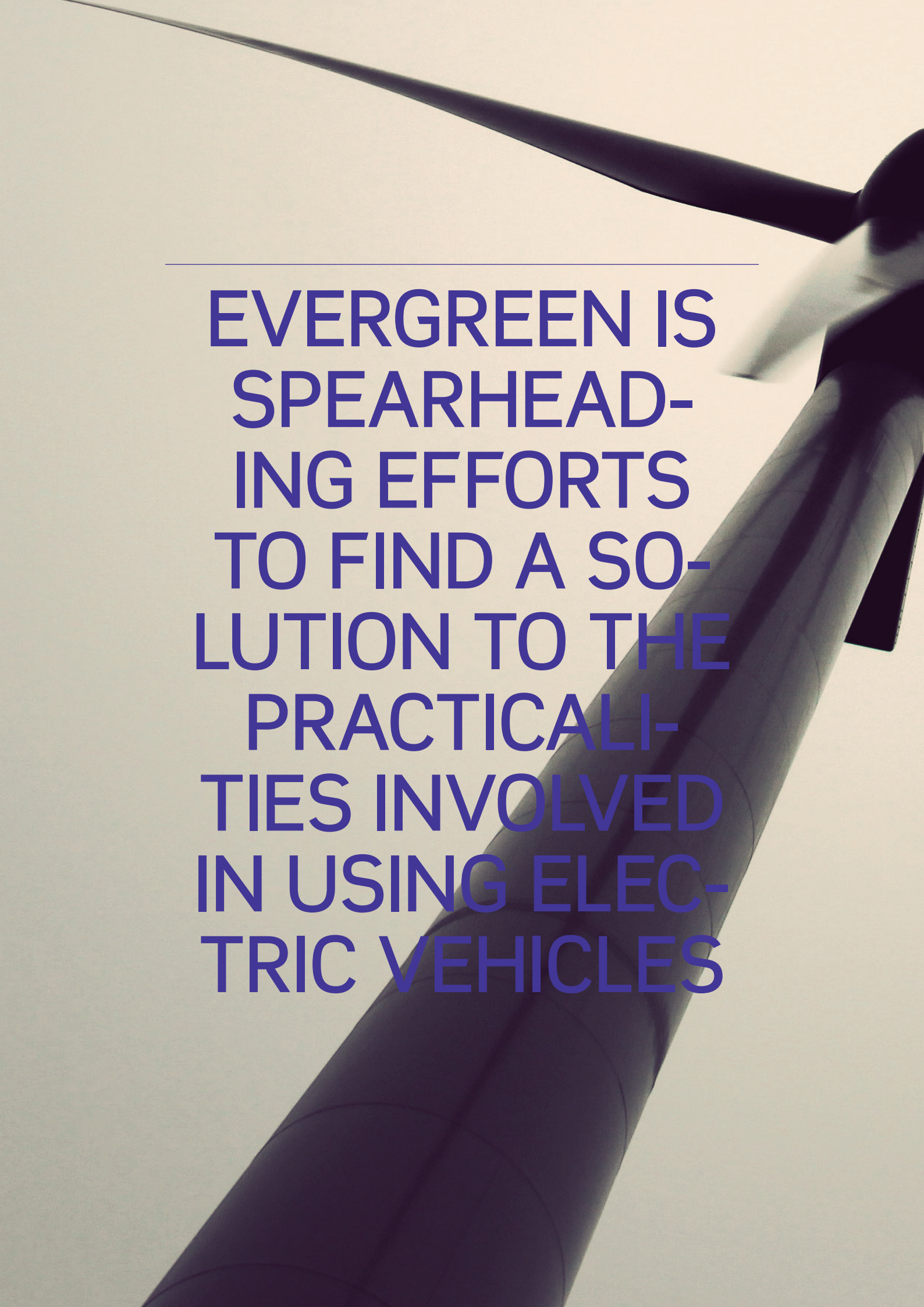
Vikingegaarden has developed the EVergreen charging post that allows the EV owner to choose electricity when it is either cheapest or most CO2 friendly. EVergreen is spearheading efforts to find a solution to the practicalities involved in using electric vehicles. Until now, the challenge has been to find a simple and economical method of recharging electric vehicles, to reduce the barriers facing the wider distribution of electric vehicles and to ensure optimum utilization of the fluctuating electricity supply from wind turbines in particular.

Charging the car when it is windy

EVergreen will make it possible to increase the proportion of wind power and other sustainable energy sources used to power electric vehicles as the system will be able to differentiate charging. For example, it will be possible to program the system to charge the most when the supply of wind energy is greatest. The idea is popular, and Vikingegaarden has already received its first orders from the Moto Mundo company and Thisted Municipality.

VIKINGE GAARDEN

www.vikingegaarden.com



EVERGREEN IS SPEARHEADING EFFORTS TO FIND A SOLUTION TO THE PRACTICALITIES INVOLVED IN USING ELECTRIC VEHICLES

COMPANY CASES

Inopower: Integration of large scale Wind Power into Smart Grid systems

Danish company Inopower has developed a smart grid control system that solves specific Danish challenges and has the potential to assist in the management of smart grids all over the world. The system links large wind power infeeds with the Danish district heating system via a centralized database and the remote control of production/consumption assets.

Since 2006, the Danish-based technology company Inopower has been operating a smart grid control system for the integration of large infeeds of wind power in production. The fact that the wind power infeed is a driving factor behind the power price makes a flexible remote-controlled smart grid system like the Inopower system valuable, as it enables existing assets to be made available to the power system and gives the owner access to new sources of potential income.

The Danish wind challenge

Inopower started developing the control system in response to a specific problem: The integration of large amounts of wind energy into the Danish power grid necessitated a new design of the electricity market so as to enable all decentralized combined heating and power plants to respond to the amount of wind-generated electricity on the grid. The production of energy by wind turbines in Denmark fluctuates from approx. 100% of the country's electricity consumption on some days to them being completely shut down on others. Troels Davidsen, CEO of Inopower, explains: "We wanted to create a solution that could be controlled on grids with large amounts of wind energy or highly decentralized energy production, as this calls for high flexibility and the ability to integrate into different markets."

Storage potential

At present the Inopower control system is handling 250 MW major consumers and 750 MW production units on a daily basis, and the remote-controlled units in the system are CHP plants with controllable production/consumption and thermal storage capability. But the system will also be able to handle power storage units like batteries once battery technology achieves commercialization.

Keeping a balance on the grid

Furthermore, the system is connected to the wind power plants themselves, enabling the wind turbines to respond to situations where direct load control of the wind power production of the turbines is necessary to be able to keep a balance on the grid. By using the Inopower control system, the power system benefits in terms of being able to utilize its existing capacity for grid balancing, and the owners of the assets are able to use their assets to participate in balancing the power grid and thereby achieve a higher profit on their investments.

Intelligent response of assets on power grids with large wind power infeed

The Inopower system links assets to the power market in a way that enables the assets to respond to the actual operation status on the power grid, as they are traded everyday on the Nord Pool power market. In this way, the power grid can use a mixture of assets with different capabilities in the most beneficial way from both a technical and financial point of view. Fast-reacting frequency reserves are available in the Inopower system, where the assets are online controlled according to deviations in the grid frequency down to millisecond deviations. Slow-reacting assets are activated in response to inaccuracies in wind power forecasts, big power cuts or failures on the grid. The assets switch between operating modes throughout the day, and the power grid can utilize capacity in the most profitable way.

Operation of assets through the Inopower system

The assets in the Inopower system are responsive to the power price, and during times of high wind power infeed and low power prices, the large power consumers can benefit if they can make capacity for ancillary services available for the power grid. During low wind power infeed resulting in higher power prices, the production units are more competitive in making capacity available for ancillary services. This functionality is provided by the Inopower system.

“WE WANTED TO CREATE A SOLUTION THAT COULD BE CONTROLLED ON GRIDS WITH LARGE AMOUNTS OF WIND ENERGY”

International prospects

According to Troels Davidsen, there is a specific reason why Inopower is Danish-based: “We see Denmark as an obvious country to implement the solutions, as we have lots of wind energy here as well as large numbers of decentralized power units that we can control remotely and integrate into different markets.” However, Troels Davidsen also sees opportunities to implement Inopower solutions in other countries facing the same challenges Denmark has experienced: “All decentralized production or wind power will demand remote control and systems that enable smaller consumption or production units to act in response to the power grid and support it when necessary. And as we have a lot of experience of operating these solutions at full scale, we see our solutions as possibly relevant in a lot of other countries.”

www.inopower.dk
Source: Troels Davidsen , Inopower A/S

INOPOWER
INNOVATIVE POWER AUTOMATION

COMPANY CASES

QEES: Taps into large market potential

QEES is a global supplier of intelligent or 'smart home' solutions that uses Danish assets as a platform to reach international markets with large potential.

The Danish company QEES was established in 2008 as the successor to Innovus, which dates back to 2005. QEES provides a strong, open and broad infrastructure of energy management/smart home products for its strategic partners, such as energy utilities, telcos and broadband providers. It enables innovative strategic partners to bundle very affordable and attractive value propositions for their customers based on the QEES Green Living SolutionTM. On this platform for collaboration in the industry, QEES is pursuing a strategy to trigger the smart home mass market so that everyone can enjoy the benefits of a 21st century electrical installation and adopt a green lifestyle – at QEES called Green LivingTM.

Partnership building essential

Morten Bremild, Sales and Marketing Director at QEES, explains that the company's key competencies revolve around innovation and the ability to develop business and strategic partnerships. "Obviously, we base that on strong software and hardware design capabilities, which is the reason why we can offer the market the most comprehensive and leading-edge product range to date."

Denmark: the cradle for smart home innovation

To Morten Bremild, there is a natural reason why QEES is Danish: "Denmark was one of the first countries to develop smart home technologies in the early 1990s, and the industry is therefore relatively mature compared to other countries. Add to this the strong design and innovation culture in Denmark and you have a sound environment for developing energy management and smart home business."

Smart homes have market potential

According to Morten Bremild, the Danish market has enormous potential for smart homes, which QEES aims to tap into, offering solutions suitable for the specific Danish electrical standard and small wall and pattress boxes. Furthermore, QEES believes that being based in Denmark gives the company advantages in terms of product development: "Denmark is a relatively mature environment for energy management/smart home solutions, and in this way it constitutes an attractive 'test environment' or 'greenhouse' for the features and functionality of tomorrow," Morten Bremild says, before adding: "however, it is important to note that we think and act globally, as the energy management and smart home demands we meet and the technologies we apply know no bounds."

ww.qees.eu

Spirae: from USA to Denmark

Spirae, Inc., based in Fort Collins, Colorado, USA, develops distributed control systems for the large scale integration of renewables and Distributed Energy Resources (DER) within electric power systems. Spirae's BlueFin™ platform was developed and refined through strategic project activities in the US and Europe over the past eight years – five of which Spirae has worked in Denmark.

Spirae's field-tested multi-layer technology enables network operators to seamlessly incorporate large amounts of DER such as generation, load management and storage. The resulting "Smart Grid" can leverage embedded DER for optimizing distribution network operations, intermittency management and firming for renewables, higher network capacity utilization, voltage regulation, peak load reduction, smart charging and vehicle-to-grid operations, DER aggregation and market participation, and various location-based ancillary services.

Closely linked to university research

Spirae co-owns and operates the InteGrid Test and Development Laboratory at the Engines and Energy Conversion Laboratory at Colorado State University. The InteGrid Lab is a megawatt scale distributed generation and distribution network test facility where Spirae's solutions and third party solutions are installed and tested for performance validation.

Broad range of projects

Notable Spirae projects include the Cell Controller project for Energinet.dk, the Danish Transmission System Operator; renewable and distributed system integration project (RDSI) for Fort Collins Utilities for peak load reduction; multiple US North West Utility demonstration projects for novel market integration; cyber security, remote system management, and microgrid operations for a multinational Smart Grid integration company; and simulation studies for North American Utility for large-scale wind integration, dynamic topology management, and self-healing capabilities.

Spirae in Denmark

Spirae has been working in Denmark for approximately five years on contract with Energinet.dk. As the lead contractor for the Cell Controller project, Spirae has been spearheading a research project that supports Denmark's goal to become a carbon neutral country. The network management technologies that have been developed enable Distributed Energy Resources (DER) to be leveraged for multiple applications such as end-use energy optimization, distribution network management, wholesale market participation, and transmission support services.

Spirae enjoys the Danish innovation-friendly business environment

With the continuing adoption of favorable national energy policies in Denmark and the larger Nordic region, there is a rapid expansion of opportunities for Spirae. Spirae sees Denmark as a central hub of the region's activity with an innovation-friendly business environment making it an excellent choice for our European operations. "With the opening of Spirae.dk, we look forward to collaborating with utilities and cities in the region to help them meet their energy and climate goals," CEO of Spirae, Sunil Cherian states.

For more information, please contact:

Julie Zinn Patti, Chief Operating Officer
jzinnpatti@spirae.dk.com
+1 970 449-8528

www.spirae.com
www.integridlab.com

Spirae

PROJECTS

EcoGrid EU – testing the intelligent power system

A full-scale test site: this is what Bornholm, a Danish island in the Baltic Sea, functions as as part of the EcoGrid EU project, one of the most ambitious smart grid projects in the world. The vision is to create a complete energy system to act as a blueprint for the rest of Denmark and hopefully for other countries.

The key objective of the EcoGrid EU project is to demonstrate the efficient operation of a distribution power system with a high penetration of many and variable renewable energy resources. This requires the active use of new communications technology and innovative market solutions, involving a broad range of companies in different fields. The EcoGrid EU project will combine knowledge from previous EU-funded projects into a large-scale demonstration which will make a substantial contribution to a "Road map for European Smart Grids deployment".

Creating solutions to reduce energy consumption

Finding the balance between fluctuating energy production and consumption is a real challenge. To try to address this, part of the EcoGrid EU project will involve consumers directly by giving them a tool to help solve this problem. This will be in the form of a "smart" meter informing the consumers about real-time prices, which will fluctuate according to production. They will then be able to pre-program their consumption to a certain price. The incentive for the consumers is to save the environment and/or to potentially gain financial benefit.

Bornholm, the lab in the Baltic Sea

Bornholm is the ideal test and demonstration site for power systems. The island is able to operate as an isolated energy system in cases where the connection between Bornholm and the mainland is interrupted. This makes it possible to observe the island as a full-scale model. In addition to this, a high proportion of Bornholm's energy supply is based on wind power and other renewable energy resources which give a degree of instability in energy production. This is a picture of the future for the rest of the world when we will all rely on renewable energy, making Bornholm perfect as a case study of the interaction between production, grid and consumption. This opportunity for research in the area is expected to attract leading international researchers and companies to the project.

Small island, big ambitions

Furthermore, the island's new function as a test site for the EcoGrid EU project echoes its own vision of the future. It is the aim of the municipality of Bornholm that the island will be known as 100 % reliant on sustainable and renewable energy by 2014. Their ambitious vision is not to be a green island, but to be the greenest island in the world.

Contact:
Kim Behnke
kbe@energinet.dk

Source:
energinet.dk/EN/FORSKNING/EcoGrid-EU/Formaal-og-koncept/Sider/Demonstrations-site-Bornholm.aspx

www.brk.dk/Bornholm/site.aspx?p=29

EDISON: Utilizing Danish Expertise to Create Sustainable Solutions

The purpose of the EDISON (Electric vehicles in a Distributed and Integrated market using Sustainable energy and Open Networks) project is to develop system solutions and technologies for EVs and PHEVs that will enable a sustainable, economic, and reliable energy system for global use, and to prepare and provide a technical platform for Danish demonstrations of EVs.

Complex systems are needed

Electric vehicles (EVs) present a unique opportunity to transition our energy consumption in the transport sector from fossil fuels to fuels based on renewable energy.
It should be possible to utilize the full potential benefits of the interaction between EVs and the power grid because of the availability of large amounts of power from fluctuating sources. This implies the need for the development of systems that will enable EVs to charge when there is a surplus of energy in the system and to resupply energy to the grid when there is a shortage of power in the system.

A unique partnership creating solutions

To meet the challenges outlined, Danish expertise can be utilized to develop optimal system solutions for EV system integration, including network issues, market concepts, and optimal interactions between different energy technologies. EDISON is one of the large-scale projects that aims to do exactly this, and in a unique consortium, eight partners consisting of research institutions and major industry enterprises are working together to create and demonstrate such optimal system solutions.

Interdisciplinary

The EDISON collaboration therefore provides an opportunity to work through all the stages of EV development in a comprehensive fashion, from research through concept and technology development to demonstration. Despite incorporating all of these aspects, the project will, however, focus primarily on research, as well as concept and technology development.

The partners in the EDISON project each contribute their special area of competency:

1. **Danish Energy:** Creation of a common knowledge platform for all consortium partners.
2. **DTU-CET:** Development of a system architecture design for EV systems.
3. **IBM:** Development of Distributed integration technology.
4. **Siemens:** Development of a central fast-charging and battery-swapping station design.
5. **Eurisco:** Development and testing of the EV power and communication interfaces.

6a. **Dong Energy:** Laboratory testing of EV-charging control systems and the battery models developed in previous WPs on SYSlab at Risø.

6b. **Østkraft:** Testing of several EVs and charging stations installed in the distribution grid on Bornholm.

7. **Danish Energy:** Formation of a steering group to ensure dissemination of the project results on all levels, and the provision of efficient project management.

Contact:
Project Manager
Jørgen S. Christensen
jsc@danskenergi.dk

Source:
www.edison-net.dk

PROJECTS

Electricity Demand as a Frequency-Controlled Reserve (DFR)

The active control of electricity demand is a key technology in creating a more dynamic, wind-power-friendly energy system. The DFR demonstration project is about using electricity demand as fast reserves. This is an alternative to some of the most expensive reserves in the current electricity system.

Maintaining the power balance between supply and demand is of highest priority in power system operation. If a power plant trips, the system frequency will decrease, and the balance must quickly be re-established by using reserves. Today, the – very costly – reserves are provided mainly by generation side resources, including the extra capacity of generators and interconnection lines.

Refrigerators as energy reserves

Reserves can also be provided by using frequency-controlled demand, which has several advantages, e.g. fast responding speed, low costs and high dispersion at feeder level etc. Most importantly, it can enhance system stability for any future power system for which a high penetration of fluctuating renewable energy is foreseen. There are many demands in power systems that can be used as reserves. In particular, thermostatically-controlled loads such as heaters and refrigerators have cyclic on/off characteristics with considerable volume, which make them ideal to be used as frequency-controlled reserves.

Dfr technology offers many advantages

DFR is a promising technology from several perspectives. From a technical point of view, DFR can be used to provide reserves and enhance power system frequency control, while fulfilling power system requirements such as linear activation. From an environmental point of view, DFR technology is pollution free unlike traditional reserves from generation side resources. And from an economic point of view, the cost of such reserves can be low, and can offer an attractive business model providing benefits for both society and the parties involved.

Technology will spur market advantages

As renewable energy with its fluctuating tendencies is increasingly integrated into power systems, frequency control will become critical in the future where e.g. it has been recommended that 50% of electricity consumption is supplied by wind power in Denmark by 2025. The DFR can facilitate such a trend by providing quality service at need and at a low cost and zero pollution. If implemented, unique advantages in market competition can be gained to realize the business potential for Danish manufacturers.

A project with a possible key role for the future power system

The DFR project is an ongoing research initiative comprising several theoretical projects on the same subject, which has now been granted an extension for practical demonstration. It is being hosted by the power system at Bornholm island, with the local system operator Østkraft having committed their full support. The Bornholm system has encountered serious difficulties in maintaining system frequency during islanded operation periods where wind power has to be greatly reduced. This challenge is also foreseen for future power systems with an increased share of renewable energy. The research outcome from the Bornholm system will be universally applicable and could play a key role in developing new technology for the Danish power system in the future.

Contact:
Mikael Togeby, EA Energianalyse
mt@eaea.dk

Source:
www.ea-energianalyse.dk/reports/927_Implementation_and_practical_demonstration.pdf

PowerLabDK: a world-class research platform

Today we are getting even more of our energy from wind power and other kinds of renewables. The production of energy is therefore fluctuating according to wind and weather. PowerLabDK is an experimental platform established to support the development of technologies that can help maintain the stability of our energy supply and the balance between production and consumption.

The mission of PowerLabDK is to enable different stakeholders to develop intelligent power systems for the future in one of the best research platforms in the world.
Today we are not able to store electricity cheaply enough. This is a challenge that we have to overcome in order to be able to manage the probable imbalance between an energy supply from unstable sources such as wind power, and consumption with its peak periods in demand.

Room for smart grid innovation

PowerLabDK provides laboratory facilities for experimental research, technological innovation and education in electric power and energy with a focus on intelligent power systems and sustainable energy technologies that can enable a low-carbon future in which the power supply system is mainly based on sustainable energy. This experimental platform is expected to give Denmark unique opportunities within business development, export and green growth.

Experimental facilities

The facilities available to PowerLabDK include existing facilities at the four partner institutions as well as others that are currently being established. These range from flexible laboratories at DTU Elektro and IHK, to a large-scale experimental facility at Risø DTU, and a complete full-scale power system at Bornholm (Østkraft). Together they constitute an internationally unique research platform.

Welcoming different partners

The platform is available to researchers from both Danish and foreign universities, companies working in the area and anyone who needs experimental verification of their theories and models. Examples of current projects using PowerLabDK as the research platform are the EDISON Project and More MicroGrids (EU Project). In addition to the institutions mentioned above, PowerLabDK has a number of stakeholders.

Financing

PowerLabDK has a total budget of 19 million EUR., of which 4 million EUR comes from the Energy Technology Development and Demonstration Programme (EUDP) while the rest comes from a number of Danish companies, the Technical University of Denmark (DTU) and the Green Labs DK programme.

Contact:
Professor
Jacob Østergaard
joe@elektro.dtu.dk

Sources:
www.dtu.dk/sites/powerlabdk/English.aspx