Smart Grid Strategy

The intelligent energy system of the future

Danish Ministry of Climate, Energy and Building
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Content

Foreword

The energy agreement of 2012 established broad political support for an ambitious green transition which among other things means significant expansion of the Danish wind turbine capacity. As a result, in 2020, wind power will cover half of Danish electricity consumption and it is expected that a relatively large percentage of overall Danish energy consumption, including for transport and heating, will be electricity-based up to 2020. This is a challenge for the current electricity system. We are used to regulating electricity production according to customers' consumer patterns, but large amounts of wind power, and an increasing amount of solar energy, require more flexible electricity consumption. Therefore the parties to the agreement decided to draw up a strategy for the smart electricity grid.

Work on the smart grid has already been in progress for some years. In autumn 2010 a Smart Grid Network was set up with a number of important players who were to make recommendations for how the electricity sector and the authorities could promote smart grid development. The Smart Grid Network was also asked to describe the business potential in developing smart grids.

In autumn 2011 the Network submitted 35 recommendations and I would like to thank the network for its huge effort in this connection. Work to realise these recommendations has generally gained good momentum, both in the sector and in the political system. The establishment of the Smart Grid Network has also contributed to a broad knowledge network about smart grids that cuts across research institutions, authorities, businesses and sector organisations.

This Smart Grid Strategy presents an overall framework for future work. New technical solutions must be developed along with business models, and efforts in upcoming years must be invested in preparing the electricity market to manage flexible consumer consumption and generation. We must ensure a full roll-out of electricity meters that enable hourly settlement for small electricity consumers, as described in the government's Growth Plan DK.

An important aspect of the Smart Grid Strategy is that the smart grid must extend beyond the electricity system. When we develop a smart grid, we must take the entire energy system into account; we must promote smart energy. A future smart grid therefore has to be included in the analyses of the energy system, launched as a consequence of the energy agreement. It will still be some years before a cohesive and smart energy system is a reality, however the energy sector and the political system must ensure the right solutions are developed in time. The government has therefore decided to establish a partnership for smart energy in the context of its innovation strategy from December 2012. This partnership will gather sector players and will support demonstration activities and systematic knowledge acquisition. It is my anticipation that the partnership will provide support for the many ongoing initiatives and activities in the energy sector, the business community, research communities and development and demonstration projects, so that we can meet the future challenges for the energy system through concerted efforts.

Incorporating the energy systems into a single smart grid has also been a key for the government's growth team for energy. In its recommendations on 28 February 2013, the team recommended promoting development of a smart grid and smart energy. I will follow up on all these recommendations this spring.

Martin Lidegaard
Minister for Climate, Energy and Building

Summary of the strategy and key initiatives

As a consequence of the energy agreement, half of electricity consumption in 2020 will be met by electricity from wind turbines, and at the same time new electricity consumption is expected. An energy system with a smart grid design requires greater exploitation of the energy from wind as soon as it is produced, for example by heats pump and electric cars. This will allow for greater exploitation of cheap wind turbine electricity, and it will mean less need to expand the electricity infrastructure to meet new electricity consumption.

This Strategy sets the course for development of a smart grid which can make this green transition cheaper, provide savings on electricity bills and help promote new services and products to the benefit of consumers. The Strategy describes a number of specific initiatives, to be performed by the central government as well as by the energy sector. The energy sector has an important role, since among other things development of a smart grid must be encouraged by market forces through development of consumer electricity products which make it attractive for households and businesses to make their flexible electricity consumption available to the electricity system.

There is already some potential to move electricity consumption to off-peak hours and to coordinate the energy systems, however this potential will increase considerably in the years to come. Efforts up to 2020 must therefore be channelled into developing new solutions and to establishing the right framework for developing the electricity system, in order to promote the green transition and make it as cheap as possible, including managing the emerging growth in solar energy and large amounts of wind energy from 2020 and onwards. Some of the key initiatives and activities for developing the smart grid are shown in the figure below.

The development of a smart grid depends primarily on whether consumers see a value in making their flexible consumption available. There are several ways to encourage consumers to do so. Firstly, consumers want a financial incentive, however flexible electricity consumption also makes it possible for consumers to become involved actively in the green transition and it allows for the development of a host of new services for the more high-tech consumers.

The most important condition for successfully activating consumers is to provide them with the option of settlement by the hour instead of the fixed-price settlement (known as template settlement) used today, according to which the consumer pays the same price for electricity, regardless of which time of the day they use the electricity. To enable hourly settlement, consumers need to have hourly meters installed that can be accessed remotely. The grid companies have already installed remotely-read hourly meters at 50% of consumers, who together account for 75% of electricity consumption. However, it is expected that hourly settlement will not have been fully rolled out until all consumers have had remotely-read hourly meters installed. In connection with its 2013 Growth Plan DK, the government has therefore taken steps to ensure roll-out of the remaining remotely-read hourly meters.

Due to the adoption in spring 2012 of the wholesale model, electricity-trading companies will be the only players in future with direct access to consumers. One of the intentions of the wholesale model is to make for greater competition in the electricity market. Greater competition can lead to tailored smart grid products and, ultimately, savings on electricity bills for consumers. The development of such products requires that the Danish Energy Association and Energinet.dk develop a model for how hourly settlement of consumers can be made much cheaper than is the case today for the larger, hourly-settled customers. The Danish Energy Association has taken upon itself to do this before entry into force of the wholesale model in October 2014. The wholesale model and hourly settlement will be underpinned by the DataHub, which is to provide consumers with easier access to their own data and make it easier to change electricity supplier.

Electricity consumers will have increased incentive to move their electricity consumption to off-peak hours if there is a stronger price signal from the actual price of electricity. One way of ensuring a stronger price signal is to have net tariffs vary so that the tariff is higher when power is expensive and the grid is under pressure, and lower when power is cheap and grid capacity is plentiful. The Danish Energy Association has taken upon itself to develop a model for variable tariffs. This model must also be ready upon entry into force of the wholesale model.

Another way of ensuring a stronger price signal is to develop new 'flexibility products' in the electricity market. If Energinet.dk were able to use flexible electricity consumption as regulating power to a greater extent, and if the grid companies were able to reduce congestion in the distribution grid, the costs of running the electricity system could be reduced. Part of this cost reduction could fall to consumers who make their flexible consumption available to the electricity system. The Danish Energy Association and the Danish grid companies have taken it upon themselves to develop solutions and products for the retail market, and Energinet.dk, in collaboration with the other Nordic system operators, has taken it upon itself to improve the uptake of small consumer units in the wholesale market, in particular the regulating power market.

In the short term, experience from concrete market solutions will probably have to be collected, primarily from large energy consumers. This could be in the form of agreements about disconnection when the distribution grids are overloaded or agreements related to regulation of ventilation and heating plants. The Danish Energy Association and the grid companies have committed to developing market platforms for such solutions. Furthermore, the Ministry of Climate, Energy and Building will help draw attention to the potential for flexibility in connection with the coming mandatory energy audits and for flexibility in the energy agreements with large electricity consumers. In the long term, the small electricity consumers may be included on market terms in line with the roll-out of remotely-read hourly meters to all consumers, and as potentials increase. It is expected that all consumers will have had remotely-read hourly meters installed by no later than 2020.

However, development of the energy system will not stop with the electricity grid. The next step is to utilise and store wind energy in other energy sectors and thus render the entire energy system smart. Primarily with regard to wind energy and, in future, solar energy, fluctuating electricity production in the district heating system may be exploited via heat pumps and electric cartridges (electricity cartridges). In the gas system, wind energy can be stored seasonally in connection with production of hydrogen, which can be used either directly in the gas grid or to upgrade biogas to natural gas quality.

In order to include a future coherent and smart energy system in the smart grid agenda, the Ministry of Climate, Energy and Building is establishing a partnership with broad participation from the energy sector. In collaboration with other sector players, this partnership will help Denmark to exploit the considerable export potential for the smart grid and smart energy solutions. Denmark has more smart grid projects than any other country in the EU, and it is crucial that this competitive advantage is translated into growth and employment in the future.

Figure 1. Key initiatives and activities

1.

A smart grid can manage more wind power and new electricity consumption

Denmark has a long tradition for the promotion of energy efficiency improvement. In future, energy must be used more efficiently and effectively as well as more intelligently so that the increased share of wind energy and emerging growth in solar energy can be used to the widest possible extent to cover the new energy consumption. In order to achieve this, consumers will have to use power more flexibly and the entire energy system must be designed to meet the demands of fluctuating solar and energy generation.

1.1
Development of the smart energy system of the future is already in progress

The Danish energy system is already considered a smart system by many, due to its integration of a large number of decentralised plants, the large amounts of wind energy already included in the grid, and the widespread use of combined heat and power. Denmark must add further to these strongholds and a smart grid should therefore be considered a development rather than a final condition. Figure 2 shows the various elements involved in a smart grid.

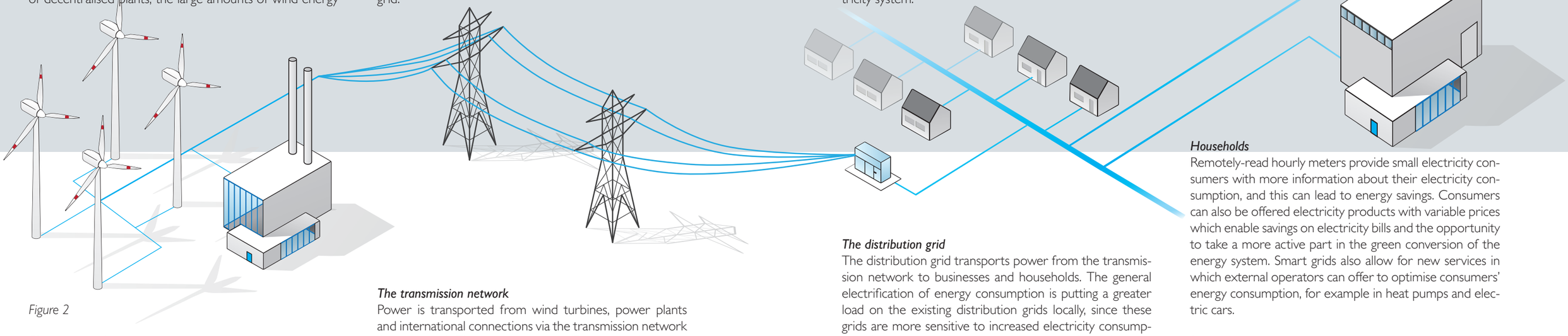


Figure 2

Electricity production
The massive wind energy expansion up to 2020 following from the March 2020 energy agreement must be properly integrated into the Danish electricity grid. This will assist Denmark's green transition and contribute to enhancing the value of wind power.

The transmission network
Power is transported from wind turbines, power plants and international connections via the transmission network (high-voltage). The system operator (Energinet.dk) ensures overall balance between electricity production and energy consumption by regulating the thermal power plants and international connections upwards or downwards. In a smart grid, this balance between demand and supply can also be ensured by flexible electricity consumption and by using wind energy in the district heating and gas systems.

With the wholesale model, which enters into force on 1 October 2014, the electricity-trading companies will become key players in the market in relation to consumers. The electricity-trading companies must supply a single collected product to consumers: supplied electricity, consisting of both electricity, transmission and system services. The grid companies, on the other hand, will no longer have contact with consumers. The wholesale model is expected to give the electricity-trading companies incentive to increase competition for customers, which could result in the development of tailored smart grid solutions that give consumers savings as well as lower expenditures for the electricity system.

The distribution grid
The distribution grid transports power from the transmission network to businesses and households. The general electrification of energy consumption is putting a greater load on the existing distribution grids locally, since these grids are more sensitive to increased electricity consumption than the transmission network. In particular in areas with high risk of overloading, the grid companies may utilise the existing grid more effectively and closer to the fullest of its capacity by installing intelligent metering, which will allow them to receive real-time data about the status of and load on the grid. In combination with efforts to move consumption to off-peak hours, this may prevent or postpone the need for further grid investments.

Households
Remotely-read hourly meters provide small electricity consumers with more information about their electricity consumption, and this can lead to energy savings. Consumers can also be offered electricity products with variable prices which enable savings on electricity bills and the opportunity to take a more active part in the green conversion of the energy system. Smart grids also allow for new services in which external operators can offer to optimise consumers' energy consumption, for example in heat pumps and electric cars.

Businesses
Businesses, like consumers, can save money on their electricity bills with hourly settlement. Hourly settlement is expected to entail increased price competition in the electricity market and lower electricity prices. Businesses that are able to move some of their electricity consumption, for example for heating and ventilation plants, to off-peak hours, can save additional money on their electricity bills.

Incentives for grid companies to promote smart grid solutions should also be considered. The regulation review committee set up in pursuance of the energy agreement is therefore analysing whether financial regulation of grid companies provides the right incentives for investment in the smart grid.

In their "Smart Grid in Denmark" report from 2010, based on calculations, the Danish Energy Association and Energinet.dk concluded that the deployment of a smart grid in Denmark can lead to significant socio-economic savings. Since a number of conditions have changed since 2010, including a smaller increase in the number of electric cars than anticipated, the Danish Energy Association and Energinet.dk have been called upon to update their calculations and assess the smart grid potential in both the short and the long terms.

1.2
The smart grid potential

The potential for moving electricity consumption to off-peak hours is limited today. However, this potential will increase in step with the general transition from fossil fuels to renewables and in step with an increase in electricity consumption due to the spread and development of a number of technologies. These include technologies such as heat pumps (central heat pumps in heating systems and individual heat pumps in households), electric cartridges in district heating, electric cars, larger electricity-consuming household appliances, houses heated by electricity, and control of air-conditioning and ventilation plants, e.g. in industry, trade and services.

Individual heat pumps are relevant in areas which are currently outside the collective district heating and natural gas supply.

Central heat pumps and electric cartridges are used to heat water in the district heating system. Electric cartridges can heat water in district heating when the price of electricity is low. This means that wind power can be used to heat water when the electricity price is low, and electric cartridges can also help to balance consumption with generation in the electricity system. Electric cartridges are already being used, whereas the use of central heat pumps still needs to be demonstrated in a Danish context. Both these technologies have great potential for flexibility because of storage capacity, in the form of the heat storage tank of the district heating plant.

Electric cars and plug-in hybrid cars are expected to gain higher market shares in the upcoming decade. During recharging, both of these technologies can contribute to more flexible electricity consumption and can be used to even out imbalances in the electricity system. It is likely to be some years before the batteries of electric cars can also supply electricity to the grid.

Cooling, freezing, ventilation and air-conditioning plants, night lighting and large IT systems in the industry, trade and service sectors hold huge potential for flexible consumption.

Household appliances are expected to hold some potential for flexible consumption in the long term, for example from electric water heaters and from freezers and refrigerators. However, the individual appliances are also likely to become more energy-efficient.

Below is a description of a scenario for development in the theoretical potential for flexible electricity consumption for a number of these technologies up to 2035. The theoretical flexible potential is an expression of the percentage of the individual technologies' total electricity consumption that can be made flexible. This figure has been calculated on the basis of an expected scenario for the spread of the technologies.

The theoretical potential for flexible consumption (GWh/year) is an expression of the percentage of annual electricity consumption that can potentially be moved in order to even out periods with a high or low share of fluctuating energy. All electricity consumption by large heat pumps and electric cartridges is considered flexible. A large percentage of the consumption by electric cars and individual heat pumps is also considered flexible, since the cars and heat pumps in principle can be coupled to and from the grid via external control most of the time. Around 20% of the industry and service sectors' energy consumption is considered flexible, see a report from 2011 by EA Energy Analyses mapping the potential for flexible electricity consumption in industry, trade and services ("Kortlægning af potentialet for fleksibelt elforbrug i industri, handel og service").

Electricity consumption – example of development of potential flexible consumption

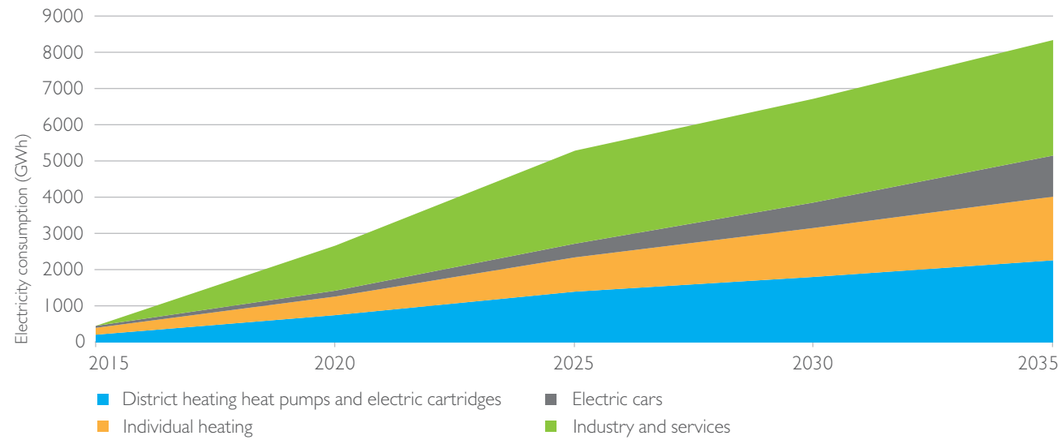


Figure 3

If fully realised in the markets, the theoretical potential of approx. 2,700 GWh in 2020 would correspond to about two-and-a-half times the electricity generated at the Horns Rev 2 Offshore Wind Farm. This would meet the demand of 500,000 normal households.

Some technologies may be promoted through favourable taxation schemes. For example, the tax on electric heating, which covers electricity consumption above 4,000 kWh for heating purposes (including electricity for heat pumps) has been increased from DKK 0.145/kWh to DKK 0.352/kWh, cutting off more than one-sixth of the total electricity price, which for private households is typically just above DKK 2/kWh, including tariffs and fees (DKK 1 approximately equals EUR 0,13).

Other technologies will not be relevant until at a later stage, because aggregation of a large number of units in total market products is required, including electric cars and individual heat pumps. Furthermore, it is also important that consumption by the units can be controlled automatically, for example through price signals or via external control, as only few consumers and businesses can be expected to turn power on and off manually.

It should be stressed that this is potential flexible consumption. Realisation of this potential depends on whether the market barriers can be reduced and whether products can be developed which encourage consumers and businesses to make their flexible consumption available to the electricity system. For more about this, see section 2.

Initiatives

Political

› The electricity-regulation review committee is analysing whether financial regulation of the grid companies has been organised to provide the right incentives to invest in the smart grid.

Sector

› Energinet.dk and the Danish Energy Association have been called upon to update their socio-economic calculations concerning exploitation of the smart grid potential, including up-to-date forecasts on the spread of key technologies such as photovoltaic solar modules, heat pumps and electric cars.

2.

Energy markets must be prepared for smart grid solutions

Flexible consumption can help resolve future challenges in the electricity grid. Here it is important to distinguish between challenges in the transmission system and challenges in the distribution systems. The system operator responsible for the transmission system must balance an electricity system with considerably greater amounts of wind power, while the grid companies responsible for distribution will have increasing problems with congestion in local grids, and they will have to incorporate local electricity production from e.g. photovoltaic solar modules. If flexible consumption is to become a reality and help meet these challenges, the electricity market must be able to manage the new flexibility services as alternatives to e.g. regulating power in connection with thermal power plants in the transmission system and grid reinforcement in the distribution system.

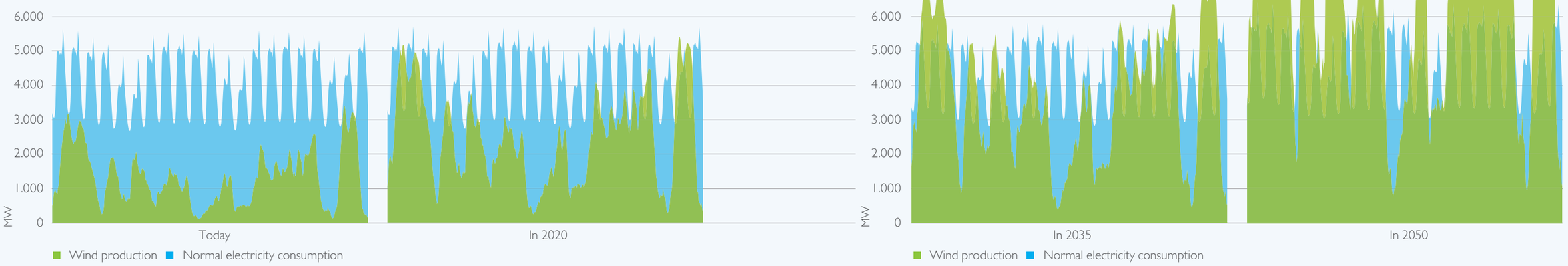
2.1
The transmission system – balancing wind power production and electricity consumption

The primary challenge of the transmission system is that wind energy will meet 50% of traditional annual electricity consumption in 2020. Figure 4 shows fluctuations in traditional electricity consumption and wind power production today and in the future. As is evident from the figure, there are no major changes in traditional electricity consumption up to 2050, because the increased electricity consumption following from a greater number of household appliances is balanced out by these appliances being more energy efficient. The new electricity consumption from heat pumps and electric cars, in particular, has not been included in the figure, because the consumption pattern of these technologies depends on whether the potential for flexible consumption is utilised.

On the other hand, wind power production increases considerably in 2020 and beyond. It will exceed traditional electricity consumption to a far higher extent than today. However, there will remain periods when wind power cannot meet the full demand. Energinet.dk is responsible for maintaining a balance between supply and demand in the transmission system. Large-scale and small-scale CHP plants and international connections help ensure this.

In future, flexible electricity consumption can help spur the development of new, cheap services for balancing the electricity system, including regulating power. Today, regulating power is primarily delivered via international connections. Adjusting electricity consumption relative to wind power production can also enhance the market value of wind power at times when demand would otherwise be low.

Figure 4



The spot market

On a daily basis, balance responsible parties (consumption) collect purchase bids from electricity-trading companies; while balance responsible parties (production) collect sales bids from electricity generators. A purchase bid could be a bid to purchase 100 MWh between 17:00 and 18:00 hours at a certain price, and a sales bid is the price at which the electricity in question can be produced. The spot price is where production bids and consumption bids match. The electricity exchange determines the prices for 24 individual hourly rates for the subsequent 24-hour period. Denmark is divided into two price areas: eastern and western Denmark (east and west of the Great Belt).

The real-time market

The spot market establishes a schedule for the day of operation (24-hours), however several factors may interfere with production and consumption forecasts, for example, if a plant has an outage or if inaccurate weather forecasts mean that electricity consumption and production turn out differently than expected. In this context, uncertainty of forecasting wind power production constitutes a special challenge. Energinet.dk therefore uses its regulating power to adjust the balance in the electricity system within the operating hour. The price of regulating power services is notably higher than the spot price. An ever greater percentage of turnover in the wholesale market is expected to be transferred from the spot market to the balance and real-time market.

The actual price of electricity accounts for about a quarter of the electricity bill, while grid company and Energinet.dk tariffs as well as the renewable energy PSO (public service obligation) contribution together account for a quarter of the total price as well. VAT and taxes account for the remaining half of the total price.

It is anticipated that fluctuations in the spot price will increase in future as a consequence of an increased share of wind energy in the system and due to phase out of coal-fired base load plants. Larger spot price fluctuations will increase the financial incentive towards hourly settlements, however the price signal may be further strengthened by offering flexible consumption in the market for regulating power. The financial benefits of making flexible electricity consumption available are greater here, although there are greater technical requirements.

The need for regulating power will increase with the increase in the share of wind energy. The price of regulating power is expected to be high in periods when wind power covers all electricity consumption, because it is more cost-intensive to start up thermal power plants than to regulate production at plants that are already up and running. As can be seen from figure 4, compared with today, it is expected that there will be more periods of this type in 2020 and beyond.

The use of flexible consumption in the real-time market could reduce transmission network operation costs. In their Smart Grid in Denmark report, the Danish Energy Association and Energinet.dk calculated that savings on procurement of regulating power and reserves account for almost one third of total socio-economic benefits.

The real-time market therefore has to be better prepared to manage companies with considerable flexible energy consumption and, in the long term, flexible, aggregated consumption from small units such as heat pumps and electric cars. For example, an operator of a fleet of electric cars must collect 10,000 electric cars, and an operator in the heat pump market must collect a corresponding number of heat pumps in order to generate the 10 MW flexible electricity consumption required to make a bid on the real-time market today. One option is for fleets of electric cars, or many heat pumps in union with larger units, to make a bid together. However, it would be easier to offer such products if e.g. the requirements for bid size were to be relaxed.

A clear statement of separate activation of Danish regulating power is not available, however a conservative estimate is that Danish power plants supplied around a quarter of the power in 2011, while the remainder was supplied from Norway and Sweden. Although flexible consumption could potentially cover part of the need for regulating power, in future the major part will probably still have to be supplied through larger electricity markets. Therefore, there is a need for collaboration with other Nordic system operators to improve adaptation of small consumer units to the real-time market, e.g. through looking at the possibility of changing the bid size, adjusting requirements for metering, and relaxing requirements for communication, so that flexible consumption can contribute to a greater extent to balancing a system with an ever greater share of energy from wind power. These concerted efforts can be seen as a pilot project in which the Nordic system operators allow bids from flexible consumption units at more favourable terms.

2.2
The distribution grid – local congestion in the electricity grid

The around 70 grid companies are responsible for ensuring that power is transported from the transmission network to consumers through the distribution grids. The distribution grids are sensitive to large and sudden loads, for example, if a great number of electric cars simultaneously recharge on the same residential street, or if households in an entire housing area replace their oil-fired boilers with heat pumps. Increasing electricity production at mid-day from small photovoltaic solar modules may also be a challenge for the electricity system locally.

The challenge facing grid companies is moreover that a large part of the new electricity consumption will generally be added to the current absolute peak period at around 19:00 hours, when people come back from work and turn on their electric appliances. Typical variation over a day, with existing consumption patterns, is indicated in grey in figure 5. If the absolute peak load (the green area) is moved to other periods during the day, when consumption is lower, the electricity grid will no longer be subject to loads greater than it can manage (the dotted line).

Transition of the distribution grids to the smart grid involves two fundamental elements, as shown in figure 6. One element is that grid companies can utilise the existing capacity in the distribution grid more optimally, as they can allow for greater loads by improving their monitoring of the grid. Therefore, a coherent system of metering, forecasting, and communication systems must be established in order to map grid loads and optimise the utilisation rate.

The other element involves reducing the load on the distribution grid through flexible electricity consumption and production. This will allow grid companies to ask for help to reduce the load in high-demand situations, which requires the active involvement of consumers. Consumers with large electricity consumption would be relevant here.

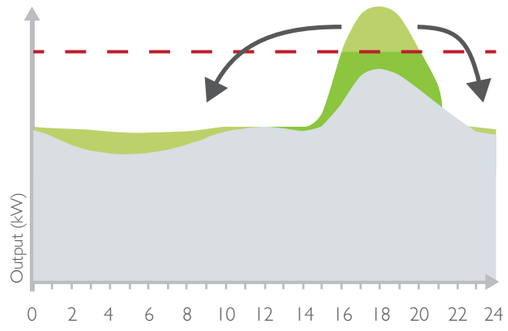


Figure 5

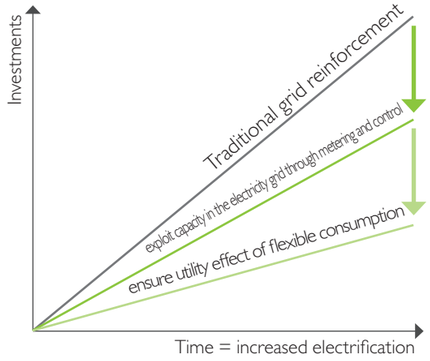


Figure 6

The grid companies can increase consumers' incentives to move consumption to off-peak hours through tariffs varying with demand and supply. The wholesale model makes it possible for grid companies to differentiate the tariffs clients pay via their supplier for use of the distribution grid. In other words, these tariffs vary according to certain periods of the day or according to the actual load on the grid. Variable tariffs will strengthen the price signal from the hourly settlement, as the grid tariff will typically be high when the electricity price is high, and vice versa. The gap between the most and the least expensive hourly rates is thereby increased. Variable taxation is also an option, however this is more difficult. As a result of the energy agreement, it was decided to examine the need to make adjustments to the existing subsidy and tax system, including possibilities to secure the right incentives for conversion to a green, cost-effective and flexible energy system. This could underpin the smart grid development.

2.3.
Phases of the smart grid market

Flexible consumption must be a competitive alternative to the current method of balancing the electricity system, as well as to reducing and postponing expansion of the distribution grid. An important condition for this is that the current electricity markets are developed and adapted so that commercial players can combine and offer flexibility services. There is, so to speak, a window of opportunity for deciding between developing a smart grid or expanding the grid in the traditional fashion; if the distribution grid's capacity is expanded, the incentive to develop a smart grid will be reduced.

In autumn 2012, Energinet.dk and the Danish Energy Association developed a smart grid concept, Smart Grid in Denmark 2.0, for establishing a well functioning market for trade in flexible electricity consumption and production. The concept is based on the wholesale model, which determines the future distribution of roles in the electricity market, including that grid companies will no longer have direct contact to the individual customer. Smart Grid in Denmark 2.0 splits the development of a smart grid in Denmark into a number of phases. These are described in brief below. Arrows indicate trade in flexible consumption.

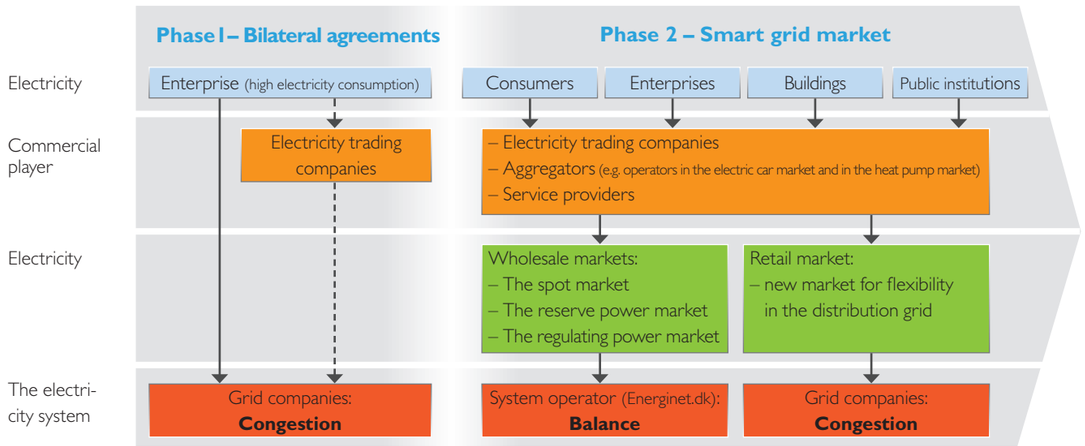


Figure 7

In phase 1, trade in flexibility will take place bilaterally between enterprises that can interrupt their electricity consumption periodically and grid companies, possibly via electricity trading companies. Such an agreement will be on the basis that parts of the distribution grid are overloaded for some hours during the year. Rather than investing in grid expansion, via a market agreement, the grid company can pay one or several large electricity customers in the area, e.g. a nursery or a shopping centre with an air-conditioning and ventilation plant, to reduce its/their consumption during the hours in question in order to avoid overloading of the grid. This option is provided for in the wholesale model in relation to customers with consumption of at least 100,000 kWh, and it serves as a take-off for proper market development in phase 2.

In phase 2 of the development of a smart grid in Denmark, a smart grid flexibility market will be developed in the retail market, in which flexible electricity consumption is traded both in existing wholesale markets and in a new retail market for grid companies. Here, electricity-trading companies, external aggregators (such as operators in the electric car market and in the heat pump market), and service providers will play key roles in promoting concrete flexibility products and services that involve external, flexible control of the electricity consumption of customers against savings on these customers' electricity bills.

Grid companies' concrete experience with flexible consumption in phase 1, and, thus, with the value of avoiding or postponing grid reinforcement investments, is vital to establishing a flexibility market. The Danish Energy Association is therefore called upon to test a local market platform for flexibility services for grid companies as follow up to its Smart Grid in Denmark 2.0 report. Energinet.dk and the Danish Energy Association will also work to ensure coupling between markets, so that flexibility services can be made available on both the retail and wholesale markets. This would increase the value of the flexibility offered and it would increase the incentive provided by the varying spot price.

When the electricity-trading companies, aggregators and service providers are able to offer new services with external control of customers' electricity consumption, there would be greater demand for communication between electricity-consuming units and electricity meters. In this context, aggregators and service providers must be given opportunity to act on an equal footing with the electricity-trading companies, which already operate as commercial players. For example, it is essential that electricity meters can be connected to the existing grid for use in separate settlement of power for, for example, an operator in the electric car market. The Danish Energy Association is currently preparing a model for how to enable third party metering by connecting a separate meter to the existing installation. The objective is to enable separate metering and settlement of part of the consumption at the place of consumption.

2.4
Metering and settlement by the hour

Even though the smart grid is initially expected to include the flexible consumption of enterprises, in the years to come market-based solutions for small consumers should also be developed and tested. To achieve this, consumers must be given possibility for hourly settlement. Today, consumption by small consumers is settled as a fixed price, a so-called load profile settlement: they pay the same electricity price regardless of which time of the day they consume the electricity.

To enable hourly settlement, consumers need to have remotely-read hourly meters installed. The grid companies have installed remotely-read hourly meters at 1.6 million consumers, corresponding to 50% of consumers with load-profile settlement. Furthermore, remotely-read electricity meters have also been installed at the 50,000 enterprises that consume more than 100 kWh annually and that together account for around half of the total electricity consumption. This means that around 75% of the total electricity consumption in Denmark is already being remotely metered.

In connection with its Growth Plan DK, the government has taken steps to ensure roll-out of the remaining remotely-read hourly meters. By stipulating requirements for installation of remotely-read hourly meters, the benefits of hourly settlement will be increased, because a full roll-out will reduce the costs of hourly settlement and boost competition in the electricity market. The Danish Energy Association and Energinet.dk are in the process of developing a model for hourly settlement for small consumers. This model must be ready by introduction of the wholesale model on 1 October 2014.

An electricity meter will cost an estimated average of DKK 1,325. Since it is likely that the old electricity meters will have to be replaced within a number of years anyway, consumers will only have to pay the additional cost of installing a remotely-read meter instead of a simple electronic meter. This additional cost amounts to around half the price of the electronic meter, typically distributed across a 10-15 year-period. The price may vary depending on the price of the new meter and on whether or not the existing meter is close to replacement. Whether this additional cost will lead to higher tariffs for the consumer depends on finances in the individual grid company.

Furthermore, there will also be greater operating costs associated with services by grid companies for hourly settlement for small consumers. The common assessment in the energy sector is that the additional costs of hourly settlement can be reduced to an average of DKK 10 per consumer per year, if remotely-read hourly meters are installed at all consumers and the existing fixed-price settlement is phased out. The reason this is possible is that electricity-trading companies and grid companies only need to communicate through the DataHub in one rather than two settlement systems. The additional costs of remotely-read hourly meters therefore consist of both investment costs and increased operational costs.

The savings gained from hourly settlement are multi-faceted. Firstly, increased price competition is expected in the electricity market, which will provide for lower electricity prices. This is primarily because the current fixed-price customers will no longer have to pay a premium for a guaranteed a fixed electricity price if they transfer to an electricity product with variable prices. For a household with an annual consumption of 4,000 kWh, a conservative estimate is that increased price competition will save the consumer around DKK 100 annually. Moreover, consumers will be able to save around DKK 40 annually on their electricity bill by moving their consumption to off-peak hours. Finally, consumers will receive better information about their electricity consumption, which is likely to lead to energy savings for the individual customer, regardless of whether or not the customer has hourly settlement. However, these energy savings rely on grid companies providing consumers feedback on their electricity consumption. Overall, it is expected that savings for consumers who choose to exploit the benefits of hourly settlement, and who have an average electricity consumption, will be higher than the additional costs of installing remotely-read electricity meters and of converting from the current fixed-price settlement method to hourly settlement. If the electricity meters generate only 1% energy savings, and consumers do not exploit the benefits of hourly settlement, the additional costs and savings will balance out.

Jointly with the Danish Energy Association, Energinet.dk and the Danish Energy Agency have prepared a socio-economic analysis of roll-out of the electricity meters. This analysis reveals a positive result of DKK 10 million for the base scenario in the analysis, and DKK 60 million for the progressive scenario. In the progressive scenario the number of electric cars and the life span of the meters are higher than in the base scenario. Furthermore, the analysis also includes a conservative scenario in which energy savings, moving consumption to off-peak hours, and savings on reserves/regulating power have not been included, and in which the price per meter has been increased. The result of the conservative scenario is a socio-economic cost of DKK 138 million.

A number of the benefits of remotely-read meters, including the possibility of moving consumption, will not take effect in earnest until around 2020 when hourly settlement and the smart grid products in the electricity market become more widespread, whereas energy savings can be promoted immediately.

Remotely-read hourly meters

In 2011, only around 10% of households in the EU had had one or other form of intelligent metering system installed. The ambition is that 80% of consumers in the EU have remotely-read hourly meters by 2020, provided this is financially viable. A number of EU countries have set out targets for the roll-out of intelligent meters, including Finland up to 2014, France up to 2016, Spain up to 2018, and the UK up to 2020.

2.5
Need for security in the electricity system

Control of flexible consumption will entail a need for increased automation, remote control, and exchange of data with other IT systems. Ultimately it will also entail new security-related challenges for the electricity system as a whole. Risks and possibilities of attacks on the electricity system as a critical infrastructure, as well as risks of misuse and distortion of data will increase and the traditional understanding of security in the electricity system therefore has to be expanded, with extra focus on cyber-attack threats and IT security and their associated risks, vulnerabilities and implications. Both in Denmark and internationally, great attention is being afforded to these issues which are strongly connected to the generally increased scope of digital solutions, and the use of online services in society, as well as the fundamentally changed threat scenario.

Smart grid is included in emergency management work in the energy area. This applies in particular to protection against cyber attacks and managing such attacks to reduce their effects on society. As responsible authority in the energy area, the Danish Energy Agency has overall responsibility for emergency management and preparedness in the energy area, while Energinet.dk manages coordination of relevant enterprises and their emergency preparedness in the electricity sector. Emergency management and preparedness work involves all threats that can potentially lead to power failure, as well as preventing and managing such situations.

Flexibility products and services associated with external, flexible control of electricity consumption will require third-party access and increased communication over the internet between electricity-consuming units and electricity meters. Within personal data protection, it is important to ensure consumer protection as a part of efforts to standardise smart grid data models, through promoting EU standards for data exchanged. In Denmark, Energinet.dk is working closely with the Agency of Digitisation to develop a software application which, via the DataHub, can give third parties secure, delegated access to data, with the consent of the user, in order to develop services in the energy area. Furthermore, the DataHub can be utilised to deliver aggregated data void of personal information. In December 2012, the Danish Safety Technology Authority, which is the authority responsible for electricity and metering security, published an analysis of the security-related challenges identified in connection with the smart grid.

Initiatives

Political

- As a result of the energy agreement, it was decided to examine the need to make adjustments to the existing subsidy and tax system, including possibilities to secure the right incentives for conversion to a green, cost-effective and flexible energy system.
- The government will stipulate requirements that remotely-read hourly meters be rolled out throughout Denmark.

The sector

- The Danish Energy Association and Energinet.dk are called upon to develop a model for hourly settlement. The Danish Energy Association is called upon to prepare a model for variable tariffs reflecting the potential benefits of moving electricity consumption to off-peak hours. Both models should enter into force with the wholesale model in 2014.
- Energinet.dk must work together with the other Nordic system operators to improve adaptation of small consumer units e.g. through looking at the possibility of changing the bid size, adjusting requirements for metering, and relaxing requirements for communication, so that flexible consumption can contribute to a greater extent to balancing a system with an ever greater share of energy from wind power.
- Energinet.dk is working to develop the electricity markets nationally as well as internationally, with a view to enabling more players to offer their flexibility services.
- The Danish Energy Association is called upon to test a local market platform for flexibility services for grid companies as a follow up to its concept of a Smart Grid in Denmark 2.0.

3.

Activation of the consumption potential

A crucial requirement for realisation of the smart grid potential is that consumers, including private households, enterprises, industry and public institutions, are ready to be flexible. Therefore, it must be easy for consumers to be flexible; they must not experience any loss of service and there must be real financial incentives. Furthermore, consumers must be informed about the advantages of flexible electricity consumption; both for themselves and for the green conversion of the energy system. In the short term, initiatives should be aimed at the businesses and institutions that have the greatest potential for flexible electricity consumption, but in the longer term there must also be targeted information campaigns for private consumers.

3.1
The potential in industry, trade and services

As can be seen in figure 3, today there are good flexibility potentials within industry, trade and services. There are also possibilities to activate flexible electricity consumption at large electricity customers, as all large customers with annual consumption of more than 100,000 kWh are charged hourly. There are currently about 50,000 such customers, and together they account for around one-half of electricity consumption.

In order to activate flexible consumption at enterprises, they must have a better incentive to move electricity consumption to off-peak hours. A survey has shown that large electricity consumers (more than 100,000 kWh per year), which are currently charged hourly on the basis of the spot price, do not move consumption according to the price of electricity, as the variations in the spot price do not in themselves provide adequate incentive to do so. In order to increase the incentive, the grid companies could use variable tariffs to reinforce the price signal. Another significant reinforcement of the price effect would be if it was possible to aggregate large enterprises' flexibility which matches the market requirements (currently 10 MW) and can be offered on the regulating power market, as mentioned in section 2

There is also a need to demonstrate enterprises' potential flexible consumption and what they could save by making this available. In this context, the Danish Energy Agency's agreements on energy-efficiency improvements with the 100 most electricity-intensive enterprises are relevant instruments and these can require that the enterprises themselves incorporate their possibilities to move electricity consumption to off-peak hours.

The recently adopted Energy Efficiency Directive also means that an energy audit of large enterprises must be performed every four years. The energy audit is to identify and quantify cost-effective savings possibilities. In connection with this, in the same way cost-effective potentials for moving consumption can also be identified. There is no requirement that enterprises follow the recommendations in the energy audit, but they can help establish more awareness of the financial benefits of flexible electricity consumption. The Directive makes it possible to replace the energy audit with energy management, and Denmark has good experience with this. The Energy Efficiency Directive is a minimum directive and this makes it possible to stipulate higher national requirements such as the requirements for an energy audit, including identifying potentials for flexible electricity consumption.

3.2
Involvement of private consumers

The smart grid is not just about the needs of the electricity system. A number of solutions and services will also be able to satisfy consumers' wishes and needs to manage energy consumption, also called home automation. There is alrea-

dy a number of Danish companies specialised in various solutions within home automation, for example that the heating system automatically turns down the thermostat on a radiator when a window is open, or that a message is sent to the consumer that a light is on or there is unusually high water consumption, even though there should not be anyone at home, which could indicate a break-in or burst pipe.

Apart from boosting energy savings, security and monitoring of a household, these solutions can also be utilised by the electricity system, either if appliances themselves are able to react to signals in the electricity grid, or if their consumption is controlled by an aggregator or service provider. As home-automation solutions often have several functions, it will not be necessary for an aggregator to collect as many consumer units as if savings on electricity bills were consumers' only incentive.

However, in the context of the needs of the electricity system, the larger consumer units will supply most flexibility, and in this context electric cars and plug-in hybrid cars are particularly relevant in the longer term and a number of initiatives have already been launched to promote the use of these.

In connection with the energy agreement, a pool of DKK 70 million has been earmarked for 2013-2015 to support roll-out of recharging stations for electric cars, infrastructure for hydrogen as well as infrastructure for gas in heavy transport, In January 2013, the parties to the agreement accepted allocation of the pool as DKK 40 mill. for electricity, DKK 20 mill. for gas and DKK 10 mill for hydrogen. In addition, DKK 15 million has been earmarked in 2013-2015 for continuation of the electric-car pilot scheme. Finally, in December 2012 tax reductions were adopted which will almost halve the price of electricity used by charging stations and by battery changing stations up to 2015.

The DataHub can also support settlement conditions for electric cars and thus the business models of aggregators and service providers. In the recent versions of the DataHub, Energinet.dk considers enabling electric car roaming, i.e. that the owner of an electric car can recharge at a neighbour's recharging station, but pay for the electricity himself. Further to work by the Danish Energy Association on a model for how to enable third party metering by connecting a separate meter to the existing installation in order to enable separate metering and settlement of part of the consumption at the place of consumption, Energinet.dk is also considering how the DataHub could manage data from several meters in a household. Both initiatives will make it easier for an electric car aggregator to sell a package service in the form of "supplied electricity" to owners of electric cars.

As stated in figure 3, it is expected that electric cars will only be able to move a relatively limited amount of energy in terms of GWh, as fewer electric cars are now expected than previously However, electric cars are different from other technologies in the figure in that they can recharge at very high wattage and they can be plugged in and out of the electricity grid instantly. Therefore, they can balance consumption and production of electricity very effectively for short periods at very short notice. Therefore, in addition to acting as regulating power, electric cars can also be used as spinning reserves, i.e. capacity which Energinet.dk reserves to secure balance in the electricity grid close to the operation moment. The value of these reserves is even higher than the value of regulating power. As with regulating power, there are high technical requirements to participate in the balance markets. Like the real-time market, the balance market must be made ready for smaller consumer units as the potential for flexible consumption increases.

3.3
Intelligent management of the energy consumption of buildings

Between 30% and 40% of total Danish energy consumption is used for heating, ventilation and lighting in buildings. The percentage of electricity consumption will increase in line with phasing-out fossil fuels. Therefore, there is considerable potential in activating flexible electricity consumption in buildings. This primarily applies for buildings with high electricity consumption, e.g. with electric heating, electric hot water, heat pumps, charging stations for electric cars, air-conditioning, etc. As stricter energy requirements for buildings are introduced, there will be incentives for buildings to have their own electricity production. For example, enterprises, public buildings and housing associations will be able to establish large photovoltaic solar modules and thereby actively contribute to electricity supply in the middle of the day.

As with activating flexible consumption by private consumers and enterprises, managing consumption by buildings requires an open, easy-to-access and secure communication structure so that small plants and different consumer equipment can be coupled to the electricity grid. The challenge is, on the one hand to ready buildings so that they can manage and control appliances, and on the other hand to ensure that appliances are controllable and that they 'talk the same language'. In this connection, open international standards must ensure that buildings and appliances are made ready for the smart grid so that different appliances can smoothly be coupled together. Internationally and in the EU, work is continuing to promote such standards and Denmark is actively supporting this, through the Danish Standards Association and others. Danish business representatives are in demand for international standardisation work because Denmark is a good way ahead with knowledge about renewable energy. Therefore, Denmark has good opportunity to influence work towards supporting Danish interests. As production by Danish companies is very much for export, international standards will also contribute to investment security for the business community in developing smart grid products, solutions and consultancy services.

The advantage of open standards is that consumers can easily change supplier and equipment without being tied to specific producers. This also ensures the most cost-effective access for component developers and operators of the systems. In "Smart Grid in Denmark 2.0", the Danish Energy Association and Energinet.dk recommend two main standards for data exchange between players in a smart grid. In addition, the Danish Standards Association's Forum for Smart Grid and Renewable Energy is in the process of drawing up a road map for the data in the electricity grid and the types of product which have yet to be standardised. This work is expected to be completed before the end of 2013, with a view to incorporating it into international standardisation work.

Until now there has been great interest in reducing energy consumption by private and public enterprises. If control equipment is installed to reduce energy and electricity consumption by lights, pumps, heating, cooling, ventilation, IT servers and other electricity consumption, it will be relatively easy to add an additional facility for automatic control so that appliances etc. can be switched on or off according to price signals or some other remote control. However, this will require that products and appliances such as heat pumps, electric cars and household appliances are made ready for the smart grid. The Building Act and the building regulations contain requirements for the energy-efficiency of heat pumps and ventilation equipment, etc. in connection with new building and renovation of existing buildings.

It should be examined whether in the same way there could be requirements that it should be possible to automatically control products using smart grid communication solutions, although this will require financial benefits for building owners, for example as a result of hourly settlement and dynamic tariffs. In this context there is a need for international clarification of the requirements for smart grid readiness so that in the longer term a common labelling scheme for smart grid products and solutions can be developed, for example under the EU energy labelling scheme. After this, requirements can be incorporated in the Danish building regulations, for example for the ability of heat pumps to communicate with the smart grid.

In order to ensure that installation of smart grid equipment does not lead to inappropriate increases in energy consumption, Denmark is encouraging the European Commission to commence work on eco-design requirements for smart appliances and electricity meters in early 2013. This work is expected to be completed at the end of 2015 with adoption of requirements for electricity meters as well as other possible cross-sectoral component requirements for various categories of appliances.

Initiatives

Political

- Potential to move electricity consumption to off-peak hours incorporated in electricity-savings agreements with the largest Danish energy consumers and implemented in the mandatory energy audit for large enterprises where relevant.
- Investigations into how requirements can be included in the building regulations that heat pumps installed in connection with new building and renovation of existing buildings should be controllable. Such requirements will require financial benefits for building owners, for example through hourly settlement and variable tariffs.
- In the EU, Denmark will support development of a European labelling scheme for smart grid readiness, possibly as part of the current energy labelling.
- In the EU, Denmark will support the European Commission in making "smart appliances" subject to the eco-design requirements in order to avoid them leading to inappropriate increases in energy consumption.

4.

Smart Energy – wind power in the district heating and gas sectors

The smart grid agenda has so far primarily focussed on intelligent electricity systems, but in future the smart grid should also be incorporated into the gas and district heating grids as part of an integrated smart energy system. Denmark has extremely well developed district heating and gas grids and therefore there is a good basis to exploit the synergies between the different types of energy and grid. For example, the district heating and gas systems can be used to store electricity from wind power in other types of energy for later use when the price of electricity is low. The alternative to storing electricity is to export electricity abroad. However, this is not necessarily always appropriate as better integration of the electricity, heating and gas sectors can help reduce the use of fossil fuels and make up a supplement to biomass in the district heating sector.

As part of the government's innovation strategy, in December 2012 the Ministry of Climate, Energy and Building launched a pilot partnership on smart energy with broad involvement from the energy sector. There is already considerable activity within the smart grid and there is a fledgling interest from the energy sector, RDD institutes and the business community in developing towards smart energy. However, a fundamental challenge for development of smart energy is that the solutions involve many players and sectors which do not usually work closely together. The overall objective of the partnership will be to help open up narrow thinking within the electricity, heating/cooling and gas sectors. In addition the partnership is to promote and disseminate the results of demonstration activities in smart energy.

Figure 8 illustrates how the interplay between the electricity, district heating and gas systems can be utilised because of the different processes and technologies which are explained in the following section.

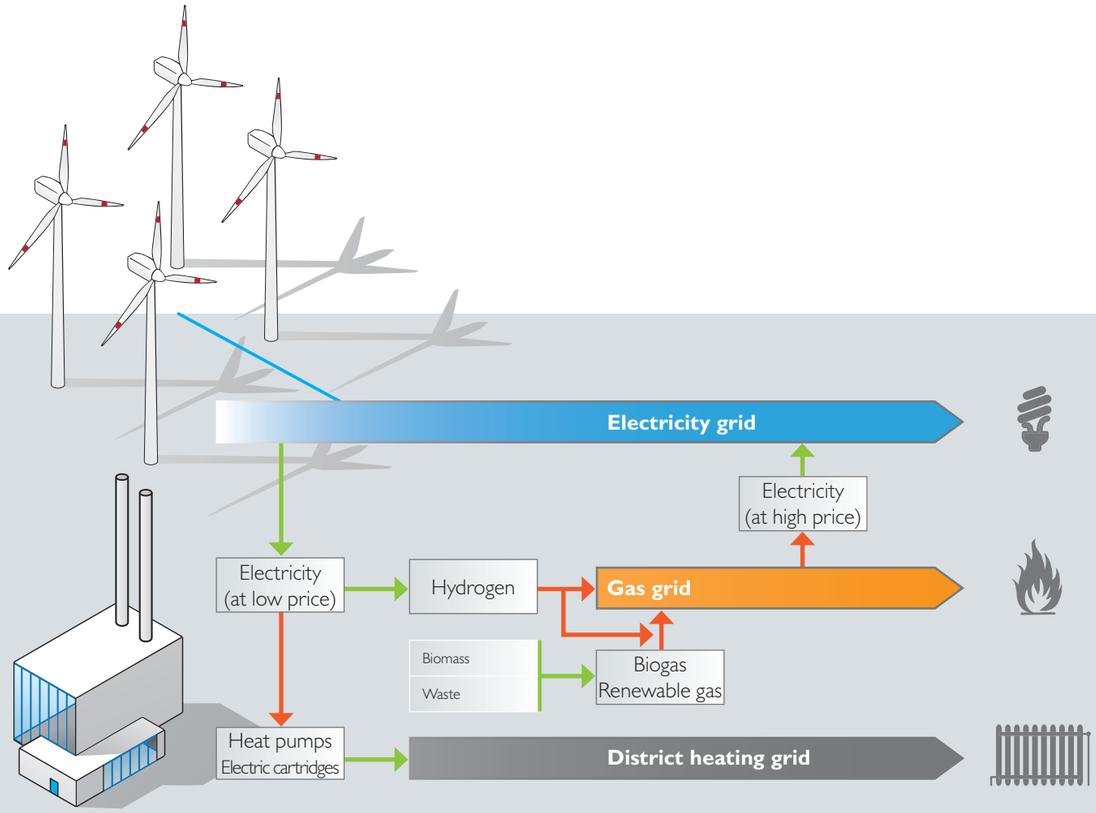


Figure 8. When there is a lot of wind turbine electricity in the grid and the price of electricity is low, hydrogen and district heating can be produced.

4.1
The district heating system

Denmark has a well developed district heating grid in which different technologies can be used in interaction with the electricity grid. With extensive combined heat and power and integration of large amounts of wind energy, Denmark has already come a long way in relation to an integrated system solution. However, there is significant potential to increase synergy effects in the energy supply of the future, especially with regard to how electricity from wind turbines can best be integrated into the heating system in the long term, for example through using electric cartridges, heat pumps and district cooling.

Electric cartridges can heat water in district heating when the price of electricity is low. This means that wind power can be used in heating when the electricity price is low, and electric cartridges also help to balance consumption and production in the electricity system. There are currently particularly low tax rates for electric cartridges in the district heating sector, and about 300 MW electric cartridges have been installed amounting to more than the maximum production at a given instant from a large wind farm. The electric cartridges have only a few operating hours and therefore they do not convert so much energy to heat, as they are installed to provide regulation services in the electricity system. Therefore electric cartridges are most suitable as peak-load units for the district heating sector.

In addition to electric cartridges, central heat pumps can be utilised by the district heating sector where they can use electricity over a longer period of time and thereby use large amounts of wind power. Heat pumps work best for long periods of operation, in contrast to heating elements, which can be turned on and off instantly. Heat pump technology is more expensive that heating elements, but heat pumps are more energy efficient as they can produce 3-4 times more heat per kWh electricity consumed. Once the heat pump has been established, using it is therefore less sensitive to the price of electricity than heating elements. Today there is only limited experience with central heat pumps in the district heating system, and therefore there is a need for analyses of how and under what conditions large heat pumps work best with the growing amount of renewable energy collected in the overall energy system. Furthermore there is a need to demonstrate large heat pumps in Denmark, and resources have been earmarked for this in the geothermal energy pool under the energy agreement.

District cooling, in which cold water is distributed in a closed system of pipes in the same way as district heating, also has possibilities for storage in storage tanks, either when the price of electricity is low (compressors), or for surplus heat in connection with electricity production (absorption). Energy consumption for district cooling is about half that of traditional cooling. Demand for district cooling is increasing, especially in offices and service buildings (hotels, shopping centres, hospitals, airports and server rooms) and new buildings, which often have large internal loads from many computers and machines, as well as better insulation and greater incoming natural light. It is particularly relevant during the summer months to store energy as cooling instead of as heating. By being able to store energy from one day to the next, the absolute peak period can be reduced if the cooling has already been produced and stored.

The synergy effects of integrating district heating and district cooling can involve energy, climate and economic aspects and therefore there is a need to examine whether it is relevant in socio-economic and energy contexts to regulate district heating and district cooling equally and whether municipal investment in district cooling can be made in accordance with EU regulations on subsidies. These issues will be included in the district heating analysis initiated in connection with the energy agreement.

4.2
The gas system

The gas system is different in that it is possible to store large amounts of energy for longer periods by utilising the existing gas storage facilities and gas transmission grid. Denmark has a well developed gas grid and a large part of the small-scale CHP sector comprises gas-fired motor and turbine plants, which to a greater extent than coal and biomass-fired plants can adjust production depending on the amount of wind power in the electricity system. Therefore, gas can act as storage for both the electricity and heating sectors, as the gas-fired plants can be started up if wind power production is unable to cover electricity consumption and heating consumption via heating elements and large heat pumps.

As appears in figure 8, using electrolysis, electricity can be converted to hydrogen which can be stored and used later for electricity production or for other purposes. Hydrogen can be stored directly or converted to methane and stored in the gas grid. Pure hydrogen must be stored under high pressure to keep storage space small, but it can also be mixed with natural gas to a limited extent (up to 5%) and stored in the gas grid. By adding CO_2, hydrogen can be converted to methane (similar to natural gas) and stored in the gas grid. In contrast to the storage technologies in the district heating sector, conversion of electricity to hydrogen gives possibilities to store energy over several seasons, for example from the summer for use in winter months, when energy consumption is higher. Another important difference is that gas can be converted back to electricity on days with inadequate wind to cover consumption, e.g. by burning in large or small-scale CHP plants or exploitation in fuel cells, depending on the type of gas. However there are considerable energy losses in converting electricity to gas, and gas back to electricity, even though technological advances are expected to improve efficiency. Therefore such production can primarily be relevant when there is large production of electricity from wind power and low demand.

If wind power displaces the need for biomass and waste in the combined heat and power sector, this biomass could be used instead to produce renewable energy gas. However, this requires that renewable energy gas can be produced on commercial terms. In connection with the energy agreement, an analysis was initiated of the gas infrastructure in a transitional phase in which natural gas continues to be used, and in the future, when biogas and other renewable energy gas take over.

Initiatives

Political

- The Ministry of Climate, Energy and Building establishes a partnership with broad involvement of the energy sector on development of an intelligent energy system.
- The parties to the agreement have earmarked DKK 17.5 mill. under the pool to promote new renewable technologies to elucidate framework conditions and investment needs for large heat pumps and storage technologies and for a demonstration project within the EUDP.
- The analysis of the role of district heating in future energy supply will examine how in the long term wind power can best be integrated into the heating system as well as the possibilities to promote district cooling.
- An analysis will be made of future use of the gas infrastructure, both in the transitional phase in which natural gas continues to be used, and in the future, when biogas and other renewable-energy gas take over. The analysis is related to other analyses in the electricity area and the analysis of the role of district heating in future energy supply.

5.

Denmark as a regional energy hub

Denmark has a long tradition of exchanging electricity with neighbouring Sweden, Norway and Germany, and the exchange capacity is continuously being expanded. Denmark is strategically and centrally located in relation to integration between Nordic hydropower, the European continent, and the large offshore wind power resources in the North Sea. Many of Denmark's neighbouring countries, including the Nordic countries, are planning for large expansion of renewable energy sources in coming years as a result of the EU target of 20% renewable energy by 2020. Incorporating the large amounts of energy from fluctuating energy sources will therefore also raise challenges for Danish neighbours.

5.1
An important agenda in the EU and the Nordic countries

Many other EU Member States are experiencing capacity problems and congestion in their transmission grids, and the European Commission is actively seeking to promote development of smart grids as part of modernisation of energy systems in EU Member States.

The existing wholesale markets (the spot market and the real-time market) for trading electricity set the framework for the EU's Third Energy Liberalisation Package with the overall political ambition of common European liberalised and integrated electricity markets by 2014. As the latest step in implementation of the Third Energy Liberalisation Package, the European Commission has prepared a Communication on the internal energy market. One of the European Commission's focus areas is the smart grid, in which hourly settlement, use of intelligence in the electricity grid and remotely read meters are highlighted as instruments to help the market develop towards the smart grid. Within the Council, Denmark will work to promote the smart-grid agenda in the EU by focussing on an ambitious follow-up to the Communication, among other things by proposing preparation of action plans for a smart grid in Member States.

There is a need to continue development of the wholesale markets in order to establish a solid foundation for the smart grid. The international and flexible market places which support effective incorporation of wind power and other renewable sources will contribute to realising the flexible resources and thereby set the framework for socio-economically efficient exchange of energy. The spot market has been changing in recent years from primarily being based on the Nordic market system, with the NordPool Nordic Electricity Exchange as the hub, to increasing market coupling towards the south. Similarly, there is a need to develop the markets for reserves and regulating power in order to balance the electricity system. Energinet.dk is collaborating with Denmark's neighbouring countries to the north and south on increasing market opening and market coupling so that balancing services can also be traded freely between electricity systems, thus ensuring socio-economic optimisation.

In order to ensure development of the infrastructure, the European Commission has delegated much of the work to the European Network of Transmission System Operators for Electricity (ENTSO-E) and the European Electricity Grid Initiative (EEGI), including preparation of regulations for the common market, ten-year grid development plans and annual action plans for developing the transmission system and the distribution system. Through participation by Energinet.dk in both these fora, Denmark can influence the development and has good opportunities to promote Danish views on the wholesale market.

The Nordic countries are traditionally a good way ahead in market development for both the wholesale market and the retail market compared with the rest of the EU, although while the development of the wholesale market is

characterised by international market solutions, the situation for the retail market is more sluggish due to the differences in regulations between the Nordic countries and the absence of trade across national borders.

Nordic cooperation is therefore crucial and common Nordic solutions which do not cause unintentional market obstacles for development of a smart grid are extremely important.

The Danish market design is based on DataHub and the wholesale model enables Denmark to contribute to accelerating market development and thus development of a smart grid on the retail market at Nordic level. Possible elements and solution models in a future common Nordic retail market could be important hubs for developments in the retail market in the same way as NordPool has been the hub for market development in the wholesale market. An important locomotive for the retail market is Nordic collaboration under the Nordic Council of Ministers on a common Nordic retail market for electricity in 2015 as well as the desire to support development of an intelligent electricity system via the retail market. This will primarily be through promoting initiatives and incentives which can be instrumental to enabling electricity market players to use the potential to move consumption as described in section 2.

5.2 International connections incorporated in the smart grid

Today, the balance in the electricity system is very much secured by international connections to the Nordic countries and to Germany. As the potential for flexible electricity consumption by consumers and businesses grows, these flexibility services can also help secure balance in the system. This could reduce the need for international connections, but international connections will continue to be a vital element in the array of options to balance the Danish system.

At European level, there is a growing challenge that many important electricity and gas transmission connections will not be expanded in time. This is partly because the benefits from the connections lie outside the geographic areas affected by the connections and because investment decisions are often made on the basis of a national or micro-economic mindset rather than a larger regional, socio-economic mindset. The European Commission has estimated that there is a total EU investment requirement of EUR 200 bn., of which current investment plans cover only half.

The EU has recently adopted an infrastructure regulation, which will ensure coupling of the European energy infrastructure. The primary aim is to secure investment for infrastructure projects with larger regional and European benefits than national benefits and which would not be realised with the current national planning initiatives. This will be through selection of projects with common European interest and which are crucial to coupling the European energy system. At this time, Denmark has submitted four projects as potential projects of common European interest: The COBRA connection to the Netherlands and the Kriegers Flak electricity-exchange connection to Germany as well as two projects to increase trading capacity between Jutland and Germany.

Challenges to investing in grid reinforcement

In Denmark, as the organisation responsible for transmission, Energinet.dk decides grid expansion on the basis of socio-economic analyses. In Denmark, the costs of grid expansion can be financed through increasing the transmission tariffs paid by consumers. It is not possible for other EU countries (e.g. Germany) to base investments on the macro-economy and financing via transmission tariffs, so decisions on grid expansion can only be made on the basis of company finances (congestion rent).

In order to promote collaboration between governments, the energy sector and investors, and to pave the way for private financing for the energy infrastructure in the region, the Danish government has taken initiative to gather the northern European countries in the Northern European Energy Dialogue (NEED), which held its first meeting in Copenhagen on 21 November 2012. In 2013, NEED will be held in the UK and will continue to promote dialogue on important energy-policy issues which promote the competitiveness of the region, including political support for the northern European infrastructure projects prioritised as part of implementation of the infrastructure regulation. In parallel with this, initiative has been taken for a North European Business Dialogue which includes the energy sector's contribution to NEED.

Initiatives

Political

- Denmark will work to promote the smart grid agenda in the EU through ambitious follow-up to the Communication on the internal market, including encouraging preparation of action plans for smart grids in Member States.
- In the Nordic Council of Ministers, Denmark will encourage expansion of a common Nordic retail market, which enables free choice to buy electricity from electricity trading companies in the Nordic countries.
- Energinet.dk is called upon to enter into cooperation with relevant authorities in the other Nordic countries in order to spread the DataHub model.

6.

A growing market

Smart grids represent a growing market with great commercial potential in Denmark and elsewhere. The Danish energy system already has a high percentage of renewable energy, well developed connections to surrounding countries and electricity trading via NordPool, and this makes it very suitable as a platform to develop future smart grid solutions. Denmark has many strongholds and a high degree of expertise in the energy sector and these are crucial for developing smart grid solutions. Moreover, the March 2012 energy agreement sent a clear signal to investors that there is political consensus on a green conversion of the energy system and thus stable development in the Danish energy market for many years to come.

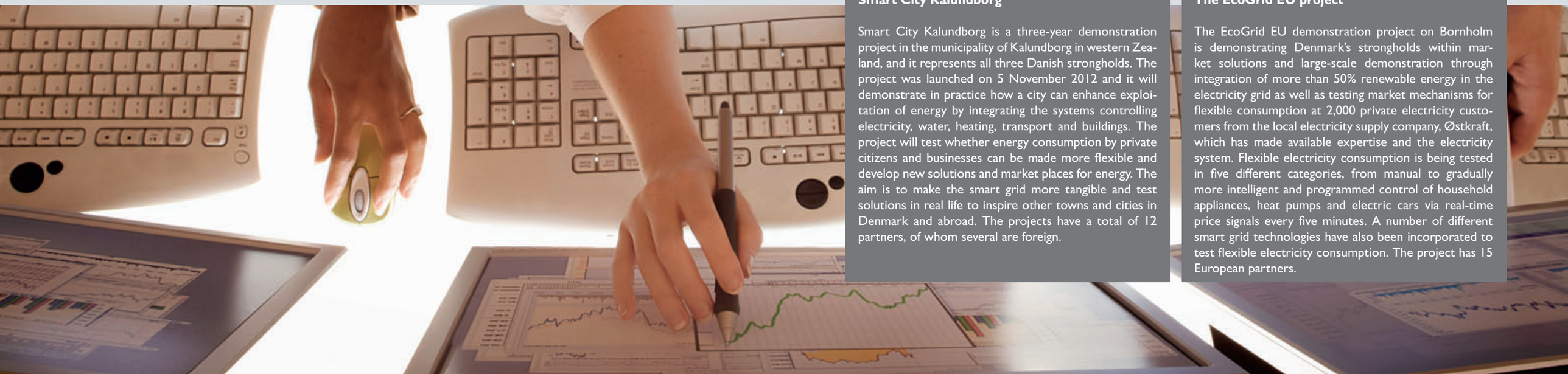
6.1 Danish strongholds

The Smart Grid Network has pointed out three Danish strongholds which are important for development and expansion of smart grid solutions. On the one hand, these strongholds make it attractive for foreign enterprises to invest in Denmark, and on the other hand they make Danish enterprises attractive for foreign markets.

› *System solutions*
Smart energy is about the interplay between different energy systems such as electricity, district heating/cooling and gas. Denmark has an advantage here because of the extensive combined heat and power development, a nationwide natural gas system and experience managing a high proportion of wind power; examples of system solutions which can secure interplay and optimal exploitation of different types of energy as well as temporary storage of renewable energy. Internationally there is demand for technology and know-how in this area in order to optimise the interplay between different energy systems and types.

› *Market solutions*
NordPool is one of the most efficient electricity exchanges in the world, and this gives Denmark a good basis to establish market-based smart grid solutions. Many of Denmark's neighbouring countries, including the Nordic countries, are planning large expansion of renewable energy sources in coming years and efficient markets are important building blocks in realising this green transition. Denmark can contribute with expertise in step with integration of electricity markets across borders in the EU, with NordPool as a model for a cohesive European market. In addition, as described in section 2.3, the electricity sector has developed a market model for trading with flexible electricity consumption.

› *Large-scale demonstration environments*
In Denmark, Energinet.dk and the grid companies have invited enterprises to use the Danish grid to test solutions on real customers. As it is difficult to have electricity supply companies assist in demonstration projects in many other countries, there is positive interest internationally in Danish projects being implemented with real customers on real grids, and this creates better opportunities for businesses to test and complete development of their products, solutions and services. In the short term there are opportunities to attract investment in research projects, while in the longer term there are opportunities for actual development and production of components, software for control systems, development of grid infrastructure in Denmark and creation of new market products. Furthermore there may be potential in larger international firms choosing to establish development centres or similar in Denmark with knowledge-demanding specialist jobs.



Smart City Kalundborg

Smart City Kalundborg is a three-year demonstration project in the municipality of Kalundborg in western Zealand, and it represents all three Danish strongholds. The project was launched on 5 November 2012 and it will demonstrate in practice how a city can enhance exploitation of energy by integrating the systems controlling electricity, water, heating, transport and buildings. The project will test whether energy consumption by private citizens and businesses can be made more flexible and develop new solutions and market places for energy. The aim is to make the smart grid more tangible and test solutions in real life to inspire other towns and cities in Denmark and abroad. The projects have a total of 12 partners, of whom several are foreign.

The EcoGrid EU project

The EcoGrid EU demonstration project on Bornholm is demonstrating Denmark's strongholds within market solutions and large-scale demonstration through integration of more than 50% renewable energy in the electricity grid as well as testing market mechanisms for flexible consumption at 2,000 private electricity customers from the local electricity supply company, Østkraft, which has made available expertise and the electricity system. Flexible electricity consumption is being tested in five different categories, from manual to gradually more intelligent and programmed control of household appliances, heat pumps and electric cars via real-time price signals every five minutes. A number of different smart grid technologies have also been incorporated to test flexible electricity consumption. The project has 15 European partners.

6.2
Commercial potentials in Denmark and globally

In the long term, the smart grid is likely to involve substantial investment in Denmark, in the EU and on global markets. However, it is difficult to compare developments in the smart grid area between countries and to estimate the scope of job-creation, exports and investment as there are different interpretations of what are actually smart-grid-related products and services, and there are different assessments of the international market. Jobs will be created as the smart grid develops and supplies services which create added value for consumers, while tasks in some areas will primarily replace jobs in the traditional energy system. The size of exports and investment will depend on the maturity of the market and demand, and it is very likely that these will increase progressively on the basis of broad international agreement that smart grids are a necessary step towards modernisation and expansion of the energy systems.

The domestic market
Both the 2010 report by Energinet.dk and the Danish Energy Association entitled "Smart Grid in Denmark" and the 2011 report by the Copenhagen Cleantech Cluster entitled "Denmark: A European Smart Grid hub" stated that in the long term there will be considerable socio-economic benefits from establishing the smart grid. Development and expansion of smart grid solutions is likely to lead to a larger domestic market, but the pace of development is uncertain. Investment will primarily be necessary within monitoring and balancing of the electricity grid, transmission and distribution of electricity, sale and consulting services with energy services, as well as development of components and IT services. The greatest growth potential for the domestic market is therefore likely to be in the electricity sector as well as within IT and communications solutions and consultancy.

In Denmark there is a high degree of research, development and demonstration (RDD) to develop future smart grid solutions, while installation of intelligent meters is claiming by far the majority of investments at European level. In 2011, according the European Commission's report entitled "Smart Grid projects in Europe", Denmark led the way by taking part in 80 registered smart grid projects, or 22% of all smart grid projects in the EU with a demonstration budget of at least EUR 1 bn., while Germany was in second place with involvement in around 40 projects.

So far, Denmark has managed to attract investments from leading international companies and these consider Denmark as an attractive market for testing new technologies, partly because the Danish market is homogeneous and of manageable size, and partly because the electricity system is based on a robust and well managed grid. Increased investment in research and development can in future help create growth through collaboration with Danish localised companies and research institutes, and furthermore, such clusters and test environments can form a strong foundation for spin-off businesses which will often be set up in the immediate vicinity of the research institutes and development projects. In this context it will be important to facilitate cooperation with smaller players and foreign collaboration partners.

Establishment of Danish smart grid test scheme

As a follow-up to the recommendation from the Smart Grid Network on establishing an impartial test scheme to help bring Danish industry to the forefront and contribute to development of a common European type-approval and labelling scheme for electricity-producing and electricity-consuming appliances, the Danish Technological Institute and the Confederation of Danish Industries have developed a concept for a Danish smart grid test scheme. Launch was prioritised for support under the ForskEL programme in 2013, and the test scheme will make it possible to test and demonstrate smart grid products and solutions in accordance with international standards. Establishment of the test scheme will initially also contribute to defining the criteria for smart grid readiness.

The global market
A strong domestic market can also form the basis for Danish enterprises to be involved in projects abroad and thus lay the foundation for new export markets. In Europe, North America and in global growth markets, the investment need up to 2030 has been estimated at hundreds of billions of Danish kroner. A survey carried out in November 2012 among members of the Danish sector organisation, Intelligent Energy, shows that enterprises operating in smart grid markets expect significant growth in both the short and medium terms. More than 70% of this growth is expected to be realised in local markets, i.e. in Europe, but there are also indications of greater growth in the US and BRIC countries.

International smart grid trends

In the EU, the smart grid agenda is primarily driven by ambitious targets for uptake of renewable energy and climate challenges, as well as technological developments such as smart meters, electric cars and heat pumps. The European Commission's 2011 report, "Smart Grid projects in Europe" calculates that, at European level, smart grid projects totalling almost DKK 40 bn. have been launched and that this market is expected to grow to more than DKK 400 bn. by 2020. Germany and the UK in particular, like Denmark, are focussing on wind power, storage technology and increased electrification of the transport and heating sectors. In addition, the smart grid is also being promoted by the possibility to reduce losses and theft from the grid, especially in eastern and southern Europe.

In the US, the savings potential of smart grids is assessed as much greater than in the EU because of the high energy consumption and more frequent power failures. There is a great need to modernise and expand the electricity grid, and the size of investment is estimated at between DKK 1,800 and 2,600 bn. up to 2030 according the European Commission's 2011 report "Smart Grid projects in Europe". In 2007, about DKK 25 bn. was allocated to modernising the electricity grid, smart grid training programmes and pilot projects which are being implemented in cooperation with electricity companies and the private sector with a minimum of 50% private financing, and the smart grid is high on the political agenda.

In the BRIC countries, development of a smart grid is being bolstered by increasing energy demand to drive growth. In China, the State Grid Corporation of China is planning to establish a national smart grid with investment in capacity development in the transmission grid of DKK 3,459 bn. from 2009-2020, of which DKK 581 bn. has been earmarked for smart grid technology and installation of 360 million smart meters up to 2030. There is increasing demand from the Chinese market, and China has expressed a wish to strengthen cooperation with Denmark on a smart grid, especially within Danish system solutions.

Even though many countries are moving forward with the smart grid agenda, there is a tendency to only focus on individual technologies. Therefore, Denmark can exploit strongholds within system and market solutions as well as energy efficiency improvements, where consulting services are in demand in many countries. However, it is vital that Denmark does not merely remain a test country for international players, without moving on itself from the demonstration phase, and Denmark must actively develop solutions with export potential and reap first-mover advantages and export benefits from the comprehensive RDD efforts, perhaps as subcontractors for larger foreign players. Denmark has already made several international smart grid offensives, e.g. in Silicon Valley and in Japan, and there will be a basis for further investment and export promotion.

6.3
Research, development and demonstration

Research, development and demonstration (RDD) within new technological, regulatory and market-based solutions should support the development of smart grid solutions and increased interplay between types of energy in the energy system. In Denmark there is a tradition for cooperation between research institutes, grid companies, energy companies and the energy industry, and within the existing support schemes a number of ambitious smart grid projects have already been launched, ranging from basic research to large-scale demonstration.

According to the European Commission's "Smart Grid projects in Europe" report, in a European context Denmark has a strong leading position with regard to demonstration initiatives within the smart grid due to targeted political efforts in which the development of Danish electricity supply is supported by prioritised RDD funding to develop smart grid solutions. One of Denmark's strengths is that there are a number of energy research programmes which each provide support for the various stages in the RDD process – from basic research to demonstration and commercialisation, so that the entire development chain is covered. In 2012, a number of the energy research programmes (DSF, the Danish National Advanced Technology Foundation, ForskEL, ELforsk, EUDP) had a common priority of three focus areas, including the smart grid and energy storage.

As follow-up to the recommendations in 2011 by the Danish government's Smart Grid Network related to RDD, a number of players from the research field and energy sector have formed a network for RDD and smart grids, and together they have prepared a road map for RDD efforts up to 2020. The recommendations focus on areas to solve central issues in the Danish energy system as well as areas on which Danish research institutes and knowledge centres have extensive knowledge which can make a difference both nationally and internationally, create new jobs, attract investment and make for growth opportunities. The road map by the research network is a strategic addition to the various research programmes and it can therefore contribute to application prioritisation by the programme committees The network is also considering whether the road-map activities should be taken further in an actual partnership.

The energy sector can benefit from the experience in development and demonstration activities already in progress in order to identify future focus areas. In order to support this work, and further to the research network's road map, the energy research programmes are being encouraged to assess the results of smart grid projects they have supported, and are supporting, in order to clarify the conditions yet to be developed and demonstrated to promote optimal exploitation of resources with 50% wind energy in the electricity system. International project results could be included if they supplement the Danish RDD results. This issue will also be relevant for the smart partnership on development of an intelligent energy system, see section 4.

6.4
Easier access to data

Access to data creates new and better opportunities for growth and innovation in the private business community, as data can be used to develop new types of digital products, services and business models. Therefore, it is important that there is transparency across the entire energy sector and that barriers to establishing solutions are reduced by access to data.

Compared with most other countries, Denmark stands out, as it already has many open, central registers in the public area, of which some can be utilised commercially. At first there will be a need to clarify which data is in demand in connection with development of smart grid solutions as well as an overview of available data and barriers to access to public and private data. With this background, in the long term, examinations could look at which type of public and private data can be made available for use in developing smart grid solutions. Energinet.dk is already working on making available more and relevant non-confidential data about the electricity market and electricity system as special web services which can be used to develop new services, and the Danish Meteorological Institute has initiated a pilot period in which location-specific weather forecast data for individual addresses is made available, with the consent of the owner. In addition it will be important to establish a practice among private players in the energy sector of making data available in accordance with relevant legislation, e.g. the Act on Processing of Personal Data. Finally, as described in section 2, individual consumers should have easy digital access to forward their consumption data to third parties, e.g. an electricity trading company, aggregator or service provider, as this will promote development of the retail market and competition on the electricity market.

Initiatives

Sector

› The energy research programmes are called upon to initiate an interdisciplinary assessment of the conditions yet to be developed and demonstrated to promote optimal exploitation of resources with 50% wind energy in the electricity system.

7.

Cementing the agenda for the future

In autumn 2011, the Minister for Climate and Energy's Smart Grid Network submitted its recommendations for initiatives to prepare the electricity system for managing up to 50% wind energy and since then work has progressed well. The recommendations were aimed at both authorities and other players in the sector, and they cover everything from research, development and demonstration, to expansion of the electricity grid, regulatory initiatives, new services and on to data security for the commercial potentials in smart grid development.

Both the sector and the political system are well on the way to establishing the foundation for a smart grid on the basis of these recommendations. The Smart Grid Network has played an initiating role in establishing an environment that cuts across research institutes, authorities, businesses and sector organisations. As a result of this work, two sector associations and a research network have been established focussing on the smart grid. The research network is considering whether activities in connection with the road map for research, development and demonstration should be continued in a formal partnership. Furthermore, the Danish Standards Association has a forum for smart grids and renewable energy.

The smart grid agenda is therefore solidly cemented with key players with the electricity sector and the business community. Further work on developing and expanding the smart grid will primarily be in these fora, in parallel with the energy research programmes, which have prioritised the smart grid and energy storage as two of three overall focus areas.

The Danish Intelligent Energy Alliance

The Danish Intelligent Energy Alliance was set up at the initiative of the Danish Energy Association and it gathers 128 energy companies, industrial companies, knowledge institutes, consultants, communication companies and IT companies. The Alliance seeks to build a solid technical platform and exploit international knowledge on among other things standards in order to ensure that Danish solutions can be sold on international markets and that international experience is utilised in development of a Danish intelligent energy system.

Smart Grid Research Network

The Smart Grid Research Network comprises representatives from research institutes as well as sector organisations and authorities. In December 2012, the Research Network submitted a report which identifies areas related to smart grids, in which there is a need to focus efforts within research, development and demonstration up to 2020. The Research Network focuses on areas in which Danish research institutes and knowledge centres have considerable knowledge, which can attract foreign investment and thereby support the growth agenda.

The Confederation of Danish Industries' Smart Grid Network

The Confederation of Danish Industries' Smart Grid Network gathers about 100 supply companies, technology companies, energy consumers, researchers and authorities. The Network focuses on development of technological and commercial solutions for the overall energy infrastructure, intelligent exploitation of the distribution system and automatic energy management for buildings. An important issue for the Network is the international perspective, in relation to regulation, standardization, and business development with foreign partners.

The Danish Standards Association's forum for smart grids and renewable energy

The Danish Standards Association's forum focuses on development and implementation of products and services with smart grids and practical implementation of standards for these. The forum is a network of experts within standardization.

Although the players and enterprises in the electricity sector will be promoting smart development of smart grids in new and existing electricity markets, the political system will have to ensure the right framework for such market development.

The energy agreement and adoption of the wholesale model in 2012 were the first political steps for the first phase of the development of a smart grid, and with the government decision to roll out remotely-read hourly meters for all consumers, the framework has been set for the market for flexible electricity consumption to develop. Furthermore, the DataHub of March 2013 will collect consumption data from all electricity customers and thereby make it easier for electricity-trading companies and new commercial smart grid players to develop smart grid services, and it will become easier for electricity customers to change between different suppliers.

However, there are a number of challenges to be addressed politically in order to ensure the correct incentives for full exploitation of smart grid potentials in the long term. In particular, the agenda must be expanded to include other energy areas.

As can be seen in figure 9, further to the energy agreement, a number of analyses relevant for development of a smart grid will have to be completed. The tax and subsidies analysis will examine how the tax and subsidies system can most effectively promote development of a smart grid. The regulation review committee will be responsible for detailed examination of regulation of the electricity supply sector. In the autumn of 2012 an external committee was set up to investigate whether the financial regulation of grid companies provides the right incentives to secure cost-effectiveness and that the necessary investments in the grid are made, including in profitable smart grids.

In addition, the smart grid and smart energy will be part of a number of analyses, in particular the analysis of the future role of district heating, the analysis of the future use of the gas infrastructure and the broader analysis of the future functionality of the electricity grid, including use of small-scale combined heat and power.

In order to promote development of a smart energy system, as follow-up to the smart grid strategy a partnership was established with broad participation from the energy sector. The partnership is part of the government's December 2012 innovation strategy. The overall goal of the partnership is to be the hub for a cross-sectoral collection of experience on implementing the smart grid and developments towards an intelligent energy system in Denmark.

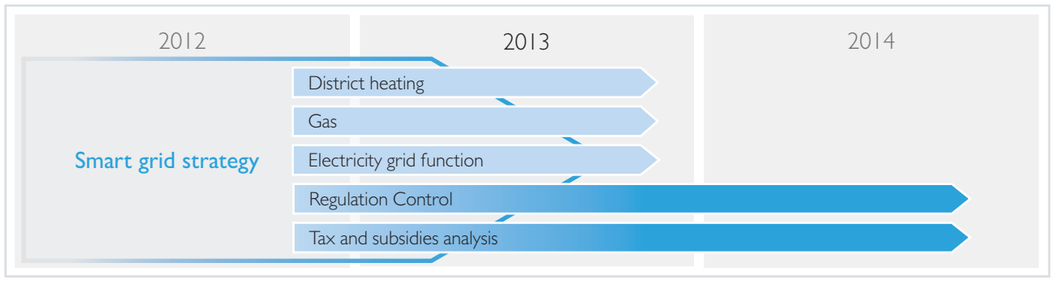


Figure 9

Smart Grid Strategy

The intelligent energy system of the future

DANISH MINISTRY OF
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