ENERGINET.DK

DANISH ENERGY ASSOCIATION

SMART GRID IN DENMARK 2.0

IMPLEMENTATION OF THREE KEY RECOMMENDATIONS FROM THE SMART GRID NETWORK

- SMART GRID CONCEPT
- INFORMATION MODEL FOR DATA COMMUNICATION
- ROAD MAP FOCUSING ON THE ROLE OF THE GRID COMPANIES

DanGrid

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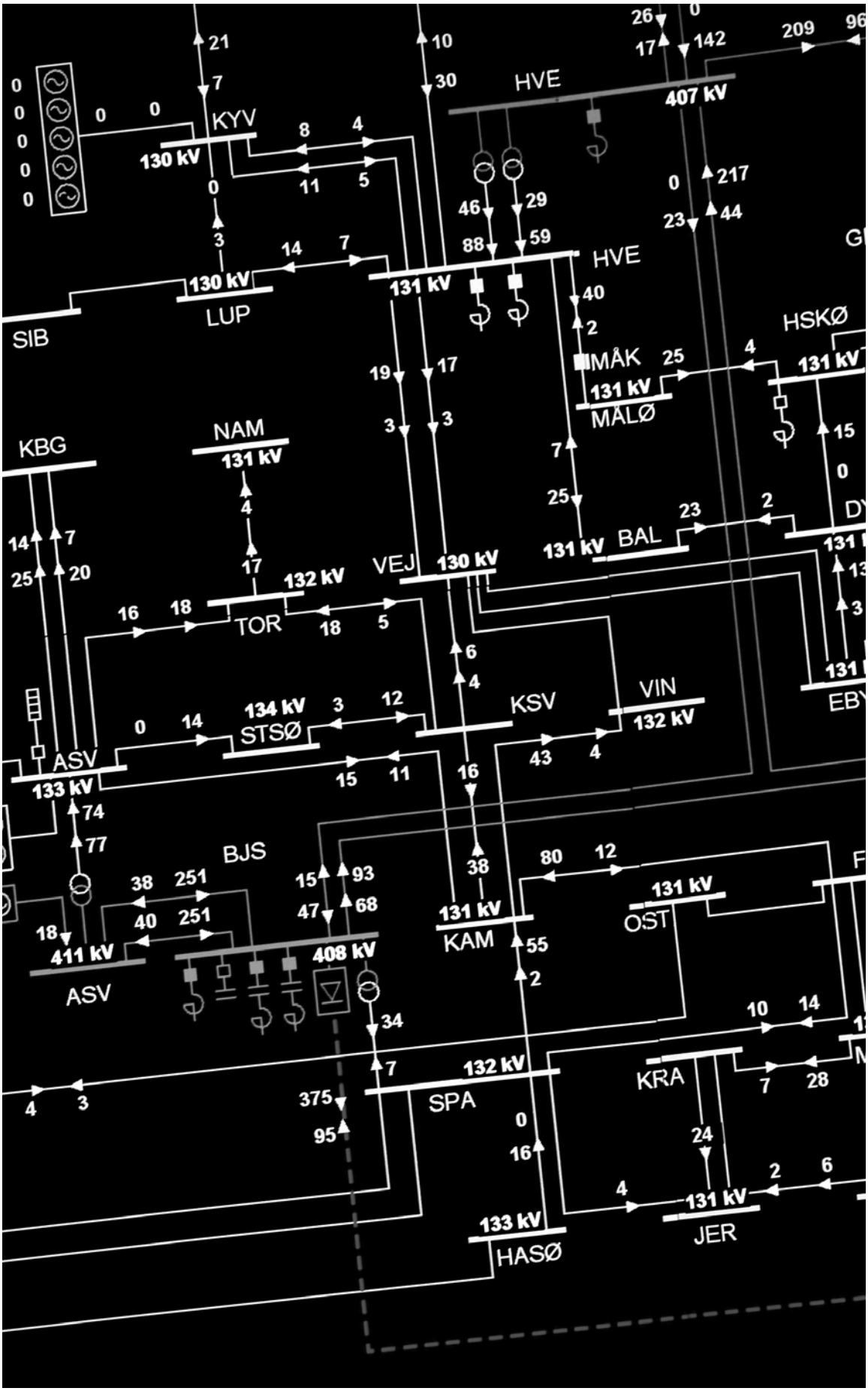
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// SUMMARY

In 2011, the Smart Grid Network, set up by the Danish Minister for Climate and Energy in 2010, published a report that points to 35 recommendations which each contribute to establishing a Smart Grid in Denmark. This report has been prepared by the Danish Energy Association and Energinet.dk and looks at three of these recommendations in greater detail:

Concept for power system operation (Smart Grid Network recommendation no. 22)
Information model for data communication (Smart Grid Network recommendation no. 23)
Road map for roll-out of the Smart Grid (Smart Grid Network recommendation no. 24)

SMART GRID CONCEPT

Energinet.dk and the Danish Energy Association have jointly developed a Smart Grid concept which can be used to mobilise and activate flexible electricity consumption and production from small customers – flexibility that would otherwise have remained unutilised in the power system.

With the establishment of a Smart Grid concept comes an invitation to suppliers and other players to develop new solutions and products to support the concept.

The concept mobilises and activates flexible electricity consumption and production from small customers. This happens through customers or appliances connected to the power system changing their behaviour – as and when requested – to fulfil the needs of the power system. For example, a heat pump might stop because a power line is overloaded, or an electric car adapts its charging pattern to balance out fluctuating wind power or solar energy levels.

This flexibility is sought by grid companies to reduce and defer investments in the distribution grids and by Energinet.dk (the transmission system operator, TSO) to balance the entire power system.

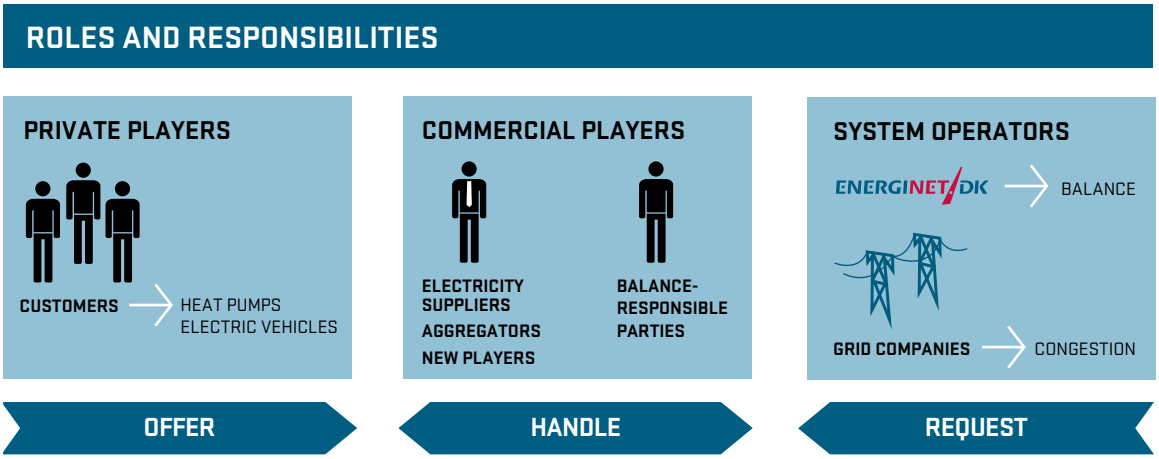
Commercial players handle the flexibility, and compete on equal terms to deliver the most efficient and innovative product. The commercial players will probably gather a sufficient volume of flexibility and offer it to grid companies and Energinet.dk, which are expected to only want to contact a limited number of places in order to mobilise and activate the flexible electricity consumption and production.

The concept distinguishes between two different mechanisms for activating flexibility. The first is the use of price signals (variable grid tariffs and electricity prices), which give customers a financial incentive to shift their electricity consumption and production to times of day when it is less inconvenient for the power system. The second is flexibility products, where a pre-arranged and clearly specified service – for example reducing the load in a particular grid area – can be activated as required by the grid companies and/or Energinet.dk for an agreed price.

The use of price signals is an important element in releasing the value of flexible electricity consumption and production, but it is not enough on its own as the response to the price signals cannot be guaranteed in advance. Trading in flexibility products is the supplementary measure which ensures that specific needs for flexibility can be met at all times.

The aim of the concept is, therefore, the establishment in the long term of a fully functional market for trading in standardised flexibility products. To begin with, the trading in flexibility is expected to take place bilaterally, and for a transitional period via a simple market place acting as a display window for confirmed flexibility agreements.

The concept ties in well with the act which has recently been passed on the so-called wholesale model, which defines the future distribution of roles in the electricity market where the grid companies are not in direct contact with individual customers. The proposed concept therefore does not require a direct business connection between grid companies and customers as the flexibility will be exploited via the commercial players.



THE PRIVATE PLAYERS offer flexibility, which is handled by the commercial players to Energinet.dk and the grid companies

INFORMATION MODEL FOR DATA COMMUNICATION

Tomorrow's power system is complex, with numerous physical units, businesses and private individuals actively involved in the power system. Likewise, the volume of necessary information which must be gathered, communicated and processed will grow dramatically, and it is therefore crucial that a fully functional IT infrastructure is in place.

A central element is a harmonised information model in the Danish power system. The concept therefore points to using international standards to define an information model. The choice of standards has taken account of international developments in the area, and ensures an efficient way of integrating different players, components and customers. It means, for example, that the cost of mobilising flexible electricity consumption and production is reduced if individual appliances are, from the outset, designed so they can be monitored and remotely controlled in standardised ways.

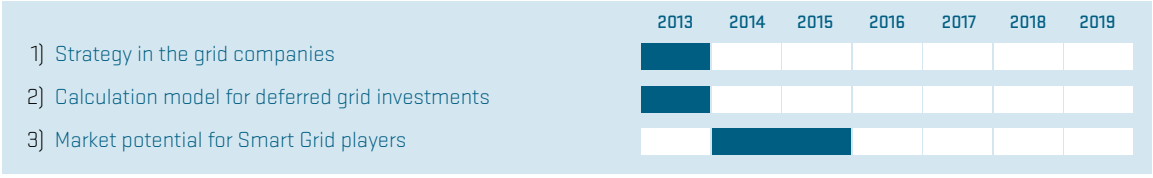
ROAD MAP FOCUSING ON THE ROLE OF THE GRID COMPANIES

The challenges to the distribution grid resulting from new electricity consumption and decentralised production can be handled via traditional grid expansion or by exploiting the possibilities offered by flexible electricity consumption and production. In a report published in 2010 (Smart Grid in Denmark), Energinet.dk and the Danish Energy Association concluded, based on their analyses, that a Smart Grid – compared with traditional expansion – is, from a socio-economic perspective, the most efficient method of addressing future challenges.

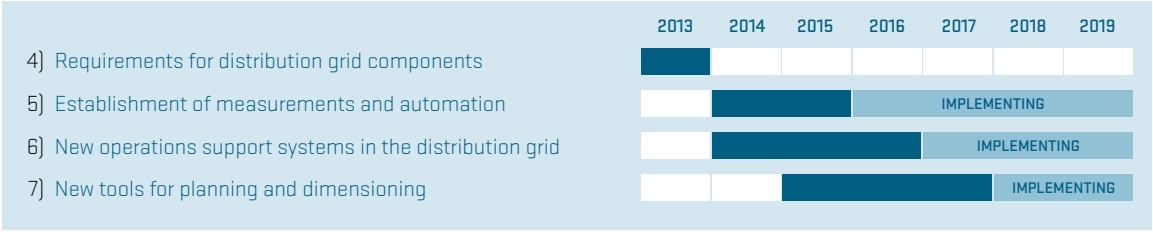
The present report points to a need to remove two key barriers. The first barrier is constituted by the fact that the existing regulation does not support grid companies using Smart Grid technology in the electricity grid. The second barrier is that, at present, grid companies do not have a real option of using price signals as a means of activating customers' flexibility. Today there are 3.2 million electricity customers who are not subject to hourly settlement and therefore do not have a financial incentive to respond to price signals.

In preparing this report, a road map has been developed that focuses in particular on the role of the grid companies, describing the key steps towards establishing a Smart Grid. The road map sets out a number of measures which must be implemented as well as when they should be implemented. Section 8 describes the individual measures in detail.

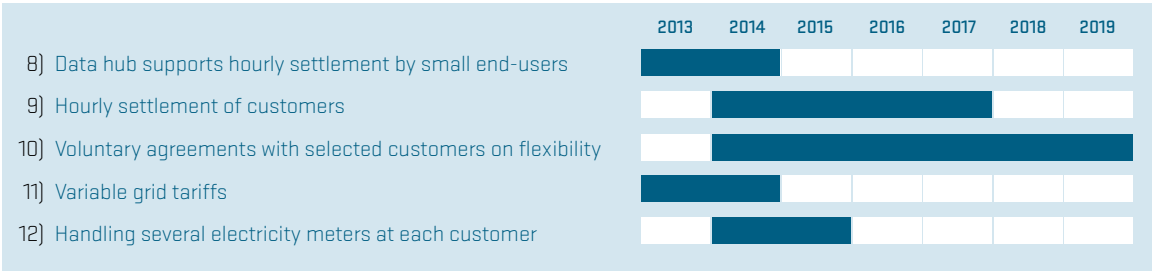
ROAD MAP FOCUSING ON THE ROLE OF THE GRID COMPANIES – MEASURES AND SCHEDULE



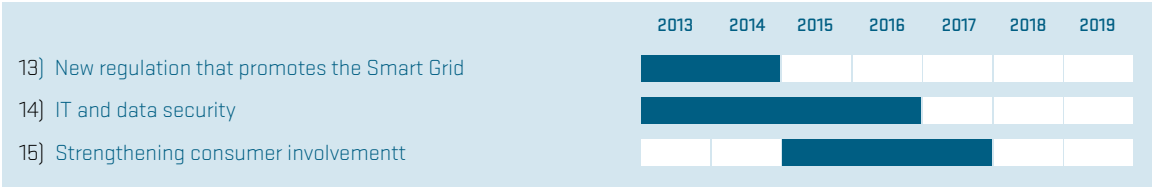
DECIDING BUSINESS CASE AND STRATEGY: Measures which support the individual grid companies in preparing a business case and deciding on a strategy for establishing a Smart Grid.



NEW TECHNOLOGY IN THE POWER GRID: Measures concerning the introduction of new technology in the electricity grid. For example, establishing technological solutions for automation and for monitoring grid loads as well as setting up further measurements at strategic points in the distribution grid.



ACTIVATING CUSTOMERS' FLEXIBLE ELECTRICITY CONSUMPTION: Measures which support the grid companies in actively involving end-users via price signals or through entering into agreements on regulating or shifting electricity consumption to periods with spare power grid capacity.



OTHER MEASURES: Other measures that support the grid companies in developing a Smart Grid.

1 // INTRODUCTION

In 2010, the Danish Minister for Climate and Energy set up the Smart Grid Network involving representatives from the entire energy sector. The network was tasked with preparing recommendations for future measures and initiatives that would make it possible to handle up to 50% wind power in the power system in 2020. In 2011, the Smart Grid Network published a report which points to 35 recommendations, which each contribute to establishing a Smart Grid in Denmark

The Danish Minister for Climate, Energy and Building Martin Lidegaard has commissioned the preparation of a strategy for establishing a Smart Grid in Denmark. This strategy will be published before the end of 2012. The Smart Grid Network's recommendations are a key element in preparing the strategy.

This report has been prepared by the Danish Energy Association and Energinet.dk in a partnership called DanGrid and looks at three recommendations from the Smart Grid Network. "Concept for power system operation", "Information model for data communication" and "Road map for roll-out of the Smart Grid".

A detailed description of the individual recommendations can be found in three subreports which can be seen on the Energinet.dk and the Danish Energy Association websites (Danish only).

1.1 // THE FUTURE HOLDS NEW CHALLENGES FOR THE POWER SYSTEM

The Danish government's goal is for Denmark's entire energy needs to be met by renewable energy in 2050. The government's goal assumes the phasing-in of renewable energy on a massive scale, and by 2020 half of Denmark's traditional electricity consumption must come from wind power.

At the same time, consumers are expected to replace their oil-fired boilers with electric heat pumps, install solar cells on their roofs and replace their petrol or diesel-powered vehicles with electric cars.

This development will pose significant challenges to both the power system and the power grid. For Energinet.dk (the TSO), the main challenges include balancing consumption and production and maintaining voltage stability to ensure the stability of the power system. For the grid companies, the main challenges consist of handling increased loads in the distribution grid due to higher electricity consumption and increased local production capacity, while at the same time maintaining high-quality deliveries to consumers.

So far, the electricity sector has been adapting the power system by investing in traditional grid installations, i.e. laying more and larger cables underground and constructing more transformer stations, and ensuring access to sufficient production capacity. Consumers have primarily been regarded as "passive" customers with predictable and regular consumption patterns. An intelligent power system – a Smart Grid – would see consumers interacting with the power system and production by means of automatic and intelligent control of their electrical appliances, thereby realising socio-economic benefits.

1.2 // SMART GRID CHEAPER THAN TRADITIONAL TECHNOLOGY

In a joint report published in 2010 (Smart Grid in Denmark), Energinet.dk and the Danish Energy Association analysed how the power system – within the framework of an increasingly open and international market – can be efficiently converted to meet future challenges. Based on the report's economic analyses, the conclusion was that a Smart Grid, improved market coupling and strong transmission connections to neighbouring countries together represent the best socio-economic method for handling the future challenges inherent in using large volumes of wind power for e.g. transport and heating.

The report is available on both the Energinet.dk and Danish Energy Association websites.

2 // THE COURSE IS SET

Energinet.dk and the Danish Energy Association have together developed a Smart Grid concept that focuses on involving commercial players and mobilising flexible electricity consumption and production from smaller customers

The concept must be seen as a further development of the existing power system where primary and local power stations and major consumption units today contribute ancillary services for controlling and balancing the power system.

With the establishment of a joint Smart Grid concept comes an invitation from the electricity sector (Energinet.dk and the grid companies) for suppliers and other players to develop new solutions and products to support the concept.

ELECTRICITY INDUSTRY AGREES ON A JOINT SMART GRID CONCEPT

- This report, which has been prepared by Energinet.dk and the Danish Energy Association, presents a concept for a Danish Smart Grid.
- The concept is based on the mobilisation of currently unused and potentially cheaper resources, i.e. flexible electricity consumption and production, leading to socio-economic benefits. Mobilisation involves using the properties of electricity-consuming and electricity-producing resources to control active power output as well as activating their potential voltage-control properties.
- The concept creates a framework which will allow all the players involved to create additional value by activating what is today an unused resource, i.e. the flexibility of the electricity consumption and production of even smaller customers.

ELECTRICITY SECTOR INVITES PLAYERS TO DEVELOP SOLUTIONS AND PRODUCTS AIMED AT SUPPORTING THE JOINT CONCEPT

- With this joint concept, the electricity sector is providing the direction for a Danish Smart Grid, and players in the electricity sector are hereby invited to develop new solutions and products to support the concept.
- The concept describes a market-based method for mobilising the potentially flexible properties of both electricity consumption and production in the power system. Priority is being given to ensuring that the resources' flexibility is made available to markets voluntarily and, in so far as is possible, to maintaining the power system's stability and security of supply.
- Where participation in markets is voluntary, it is still necessary to comply with relevant technical regulations. This will ensure that units which are technically capable can actually also contribute to, for example, frequency stability and voltage quality in the power system.

3 // ROLES AND RESPONSIBILITIES IN TOMORROW'S POWER SYSTEM

The proposed Smart Grid concept will involve the power system's current players, but new players will be added, and the roles of existing players will change to match the new situation

One of the concept's main ideas is to mobilise and activate flexibility from distributed units. This section describes the players which are central in requesting, handling and offering flexibility in tomorrow's Smart Grid.

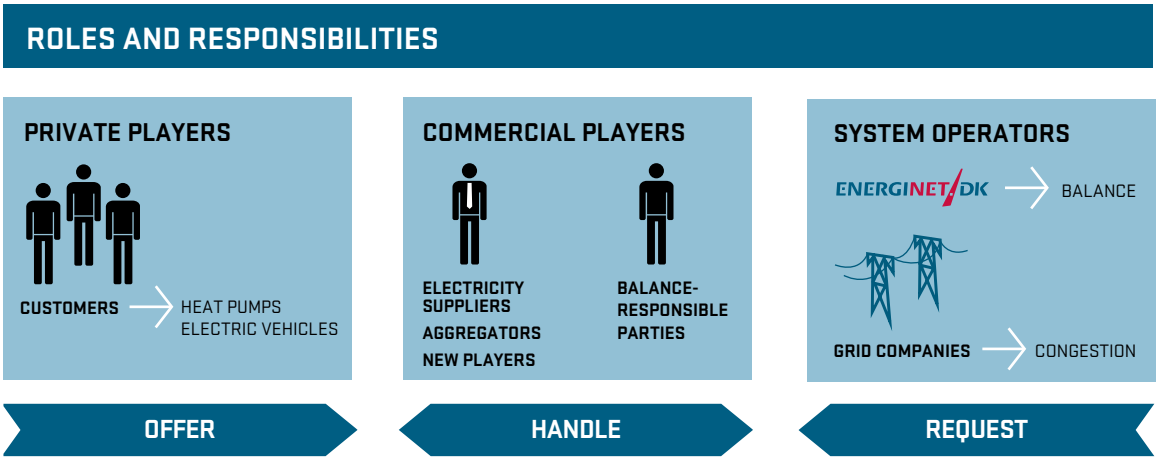
3.1 // WHO REQUESTS FLEXIBILITY?

The primary players requesting flexibility are the system operators, i.e. the grid companies and Energinet.dk. The grid companies want the flexibility to reduce and defer investments in the distribution grids, while Energinet.dk will request flexibility to ensure system balance throughout the entire power system.

To handle the task of ensuring balance in the power system, well-established markets already exist where Energinet.dk procures the required flexibility, for example the joint Nordic regulating power market (NOIS). In the proposed Smart Grid concept, this will not change, just as Energinet.dk's role in general will not be significantly modified. Energinet.dk will, however, be given access to new ways of ensuring system balance by buying the new flexibility products which are mobilised by the concept.

WHAT IS "FLEXIBILITY"?

- In this context, flexibility means that a customer, or an appliance connected to the power system, changes its behaviour to meet a need from the power system. For example, a heat pump that stops because a power line is overloaded, an electric car that adapts its charging patterns to balance out fluctuating wind power or solar energy levels, or a customer choosing to use their tumble-dryer later than planned.



THE PRIVATE PLAYERS offer the flexibility which is handled by the commercial players to Energinet.dk and the grid companies.

SYSTEM OPERATORS – GRID COMPANIES AND ENERGINET.DK

- The system operators are natural monopolies that handle the operation and development of the power system.
- **ENERGINET.DK** owns and runs the transmission grid (>100 kV). Its primary task is to ensure the generally stable operation of the power system, in other words maintaining balance between consumption and production, second by second – also in the event of major outages, for example the outage of large power stations. In addition, Energinet.dk has the task of ensuring a well-functioning transmission grid and a well-functioning electricity market.
- **THE GRID COMPANIES** own and run the distribution grids (<100 kV). Their primary tasks are to ensure as few disruptions to the electricity supply to customers as possible, to ensure that the electricity which Danish customers receive is of sufficiently high quality, and to ensure valid measurements for settling production and consumption. In Denmark, there are approx. 70 grid companies which are often customer-owned cooperatives, municipal businesses or privately and/or publicly owned limited companies.

It is the task of the grid companies to expand and reinforce the distribution grids to safeguard future supplies. The reinforcements are usually made when the loads on individual sections of the distribution grid are approaching their capacity limits. With the proposed Smart Grid concept, the grid company will also be able to procure flexibility products which can be used to minimise the load on individual sections of the distribution grid in critical situations when the load is very high. In this way, the grid company is able to reduce and defer its grid reinforcement costs.

This means that the future responsibilities of the grid companies will not, generally speaking, change, but the way in which they discharge their responsibilities will be different. The grid companies must, to a far greater extent than is currently the case, trade with commercial players to use flexibility products as an alternative to grid reinforcements. Moreover, monitoring and operating the grids will be a significantly bigger task for the grid companies than is the case today.

3.2 // WHO OFFERS FLEXIBILITY?

The basic idea of the concept is to mobilise flexibility from units which would otherwise be unused. The DER units (distributed energy resources) are the physical sources of the flexibility which can be mobilised in the Smart Grid concept and thus play a very important role. The most significant difference compared to today is that these units will be mobilised so that their mode of operation is flexibly adapted to demand from the power system.

In addition to the physical units, customers also play a key role. They are not necessarily directly active in delivering flexible electricity consumption as they cannot be expected to derive sufficient benefits from being active 24 hours a day, or to even want to be continually active. However, many customers are expected to have active control systems (for example intelligent building automation) for activating flexible consumption.

PRIVATE PLAYERS

- The private players are usually small and large customers, industrial customers and electricity producers.
- **DER** (distributed energy resources) covers several different types of resources which can benefit from making flexibility available to the power system. Examples of DER include local CHP units, wind turbines, electric vehicles, heat pumps, solar cells, emergency generators etc.
- **CUSTOMERS** are also important; these may be traditional electricity customers (homes, offices and industry) – with or without their own local production (for example from solar cells) – which potentially have flexible resources that can be made available to the power system.

COMMERCIAL PLAYERS

- The commercial players operate freely on commercial terms in the power system – typically balance-responsible parties (BRPs), electricity suppliers and aggregators.
- The BRPs have a formal legal role and are responsible for supplying the expected and reported products in the electricity markets such as Elspot, regulating power and the reserve capacity markets. This means that all electricity production and consumption in Denmark must be registered with the BRPs.
- An important role in tomorrow's power system is that of the aggregator, which on the one hand handles flexibility at the retail level by offering solutions that make it interesting for customers to offer flexibility, and on the other gathers and administers (aggregates) individual flexibility in sufficiently large volumes for it to be procured and activated as a combined service via the wholesale markets. The aggregator role can overlap with that of the BRP or be an independent commercial function which is offered by new or existing players in the market.

Finally, the central electricity-generating units, such as power stations and wind farms, will carry on playing an important role in maintaining stability in tomorrow's power system. A significant proportion of the flexibility sought by Energinet.dk will probably still be supplied by these units.

3.3 // WHO HANDLES FLEXIBILITY?

In the concept, flexibility will be handled between those offering it and those requesting it by a number of commercial players who will compete on equal terms to be the most efficient and innovative.

Today, the BRPs already serve as the link between the wholesale and retail markets for electricity, and they are, among other things, responsible for submitting plans for total electricity production and consumption. In the Smart Grid concept, it is therefore natural, once the market for trading in flexibility has achieved a sufficiently large volume in the future, that the BRPs also become responsible for registering and reporting the flexibility products.

Energinet.dk and the grid companies are expected to still only want to have to contact a limited number of places to mobilise and activate a flexibility product.

The BRPs will probably gather a sufficient volume of flexibility products via their own aggregator functions, via other commercial aggregators or directly via local production units.

The aggregator role is also expected to be key to mobilising and activating DER and customers. Via the active marketing of good business offers and concepts, the aggregators must make it interesting for private players to be flexible in their electricity consumption and/or own production. Moreover, either they themselves or their business partners will supply systems to the private players to ensure that they will not necessarily have to take any active steps when a flexibility product is activated. It is important that the flexibility can be activated without the active involvement of the customer, but always taking account of the customer's preferences and comfort requirements.

Today, the aggregator role is already being performed by some BRPs in relation to, for example, smaller CHP units which supply different types of ancillary services. However, in future, this role will involve far more customers and appliances which can be activated, and the assumption is that new players will emerge as a result. These might specialise in, for example, recharging electric vehicles or controlling heat pumps, with their business solely concentrating on the special properties of selected technologies.

EXAMPLE – AN AGGREGATOR OFFERS TO CONTROL A CUSTOMER'S HEAT PUMP

- In tomorrow's power system, an aggregator can, for example, be a player who specialises in controlling heat pumps for customers and activating the flexibility which the heat pump can deliver.

- A customer with a heat pump wants to maintain an indoor temperature which satisfies his comfort requirements (for example 20-22°C during the day and 16-18°C at night). The heat pump uses 3,000 kWh of electricity a year, and the customer pays DKK 2/kWh, corresponding to an annual cost of DKK 6,000.

- The aggregator offers to supply the electricity and assume control of the heat pump while guaranteeing a temperature which lies within the customer's comfort zone. The customer pays DKK 5,500 a year for the service and thus saves DKK 500 relative to what he paid previously.

- Using controls and automation, the aggregator switches off the heat pump for short periods when electricity prices are high without the temperature in the house falling outside the customer's comfort zone, and reduces the annual cost of powering the heat pump by DKK 500 a year. The aggregator also switches the heat pump on and off when it benefits the power system, earning a further DKK 250 by selling these services on market terms. The aggregator has thus reduced the cost of operating the heat pump to DKK 5,250 a year. He receives payment of DKK 5,500 from the customer and thereby earns DKK 250 a year.

- This is a fictive example, but it shows that both the customer and the aggregator stand to gain from the heat pump's flexible electricity consumption being utilised by the power system. The customer is offered an attractive solution (maintaining a comfort zone temperature and a cheaper electricity bill), which makes it interesting for him to offer his flexibility to the market (by handing over control of the heat pump to the aggregator).

4 // FOCUS ON MARKET ACCESS

It is central to the concept that mobilising and activating flexibility must be market-based. This means that the private players must be free to decide to whom and to what extent they offer their flexibility, and it must be ensured that the flexibility is priced and sold transparently

TWO DIFFERENT MECHANISMS – PRICE SIGNALS AND FLEXIBILITY PRODUCTS

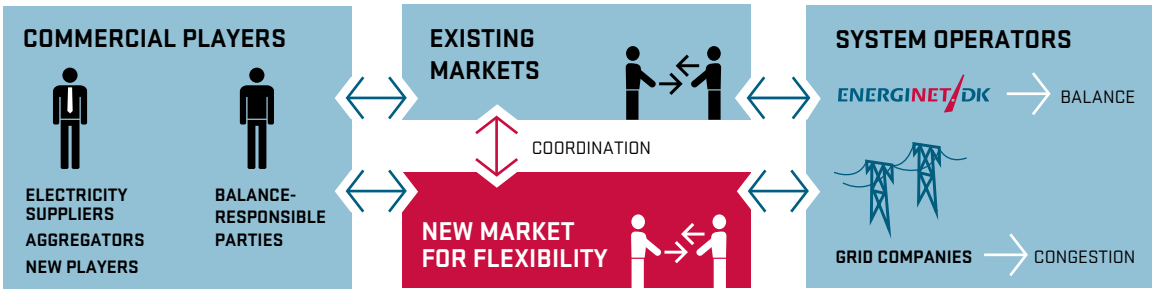
The concept basically distinguishes between two different mechanisms for activating flexibility:

- **PRICE SIGNALS** (variable grid tariffs and electricity prices), providing a general incentive for customers to shift their electricity consumption and production to times which are less inconvenient for the power system.
- **FLEXIBILITY PRODUCTS,** where a service which has been clearly agreed and defined in advance – for example reducing the load in a specified grid area – can be activated as and when needed by grid companies and/or Energinet.dk at an agreed price.

The use of price signals is central to releasing the value of flexible electricity consumption and production. However, price signals are not sufficient on their own as the response to the price signals cannot be guaranteed in advance. Trading in flexibility products is the supplementary measure which ensures that specific needs for flexibility can be met at all times. The aim of the concept is therefore, in the long term, to establish an efficient market for trading in standardised flexibility products.

Today, markets have already been established where Energinet.dk procures flexibility products, for example the common Nordic regulating power market (NOIS). However, there is no similar trading platform which allows the grid companies to utilise flexibility products as an alternative to grid reinforcements.

MARKETS FOR FLEXIBILITY



A NEW MARKET for flexibility makes it possible for the grid companies to purchase flexibility products as an alternative to grid reinforcements. The new market will be coordinated with the existing markets for flexibility, for example the regulating power market.

GRID COMPANIES AND ENERGINET.DK HAVE DIFFERING NEEDS

- Energinet.dk needs flexibility services in order to meet its obligation to guarantee system balance. The grid companies' demand for flexibility primarily springs from their need to counter situations of local overload in the distribution grid. Energinet.dk therefore demands relatively large volumes of power, but can, on the other hand, use resources from all over northern Europe, except in cases of congestion in the transmission grid. By contrast, a grid company will usually demand significantly less power which, however, must be very precisely localised in relation to the overloaded grid area – perhaps down to the level of an individual district or street, or concentrated on a single major consumption or production unit.

Flexibility products targeted at grid companies are, initially, expected to be traded via bilateral agreements, then via a simple market place for flexibility products (display window) and finally via a formal market for trading in standardised flexibility products. This will introduce new ways for the grid companies to procure flexibility products as an alternative to grid reinforcements.

It is important that trading in flexibility to overcome situations of local overload in the distribution grid is coupled with existing markets for flexibility for balancing purposes, especially the joint Nordic regulating power market (NOIS). This ensures synergies so that flexible services which are available to the grid companies are also available to Energinet.dk, so that activating resources on the part of Energinet.dk takes account of the operational status of the distribution grid, and so that a given resource only has to be offered in a single place. This means that resources can be activated for different purposes in the power system for the benefit of both private earnings and the economy at large.

ESTABLISHING A NEW MARKET FOR FLEXIBILITY

- **PHASE 1 – BILATERAL AGREEMENTS**
  The flexible customers are not yet mobilised and are not aware of the possibility for and value of supplying flexibility. Thus, there will only be a few customers offering flexibility to begin with, and the agreements will be individually tailored rather than being standard contracts.

- **PHASE 2 – MARKET PLACE**
  In phase 2, a simple market place is established where the grid companies will, from the outset, be able to announce their flexibility needs, knowing that there are flexible customers who will respond out of a desire to supply flexibility.

  In the traditional electricity markets, the players submit purchase and sales bids to a central body, for example the joint Nordic power market (NordPool), which then matches supply and demand and calculates a marginal settlement price. The market place for flexibility, on the other hand, is conceived as a place where sellers and buyers can find each other and agree deliveries of various flexibility products without the need for a central coordinating function – i.e. a broader interpretation of the word "market place".

  The market place for flexibility services will increase transparency, but it will still be necessary to enter into individual agreements that specify the service.

- **PHASE 3 – MARKET**
  In phase 3, a formal market for well-defined and uniform flexibility services is established. This can only happen once the use of the simple market place has led to the consolidation of well-defined products and a certain market volume.

COUPLING MARKETS AND SERVICES

- It is important that new forms of trading which focus on the grid companies are integrated with the existing markets where system-balancing products are currently being traded, in other words with Energinet.dk. This is because these products are physically linked so that if a grid company, for example, activates a reduction of the electricity consumption (output) in a specific area, this affects the system balance. On the other hand, Energinet.dk could have used exactly the same resource for balancing the system, which would not have been possible if the markets were completely separate.

4.1 // THE MARKET DOES NOT SOLVE EVERYTHING

The market-based approach is expected to be able to cover the need for Energinet.dk and the grid companies to procure the products which are necessary for them to meet their obligations in situations of normal operations. However, it must still be possible to accommodate critical situations, and to handle and relieve outages in particular grid areas or actual blackouts quickly and efficiently.

In these cases, the flexibility services which are available in the markets may be insufficient, and so-called alert state or emergency state is necessary to avoid system or supply failure. Likewise, there may be technical characteristics or functionalities which are not offered on market terms, but which are necessary for the technical operation of the power system, for example voltage regulation. For this purpose, the concept, like the present power system, ensures that technical regulations can introduce the necessary requirements to be met by components in the power system with a view to ensuring the requisite properties.

NORMAL OPERATION AND ACTIVE MARKETS – ALERT STATE AND EMERGENCY STATE ARE RARE

- The Danish power system operates normally most of the time. The so-called non-normal operating conditions, alert state and emergency state, can occur temporarily, and here it is a question of all players contributing to restoring normal operations as quickly as possible so that as few people as possible are affected given modern society's dependence on stable electricity supplies.

- Under normal operating conditions, the market is working and ensures that electricity is traded between electricity generators and consumers as well as offering balancing capacity down to the so-called delivery hour.

- In their efforts to reinforce and maintain the local electricity grids, the grid companies occasionally need to temporarily cut off supplies to some areas. This is not an alert state, just as bad weather, for example, can lead to electricity supplies being interrupted in local areas. Here, the markets will still be working even though individual electricity customers or producers may experience disruptions.

- As the TSO, Energinet.dk is responsible for ensuring that a coherent power system is available for electricity producers, customers and the market players. Problems and incidents in the overall power system can lead to a risk of system failure. Major disruptions mean considerable losses for individuals and society as a whole. Energinet.dk is therefore obliged and able to step in when the power system is in an alert state and, for example, order power stations to regulate upwards or downwards and cut off large electricity consumers etc. In emergency state, Energinet.dk can disconnect wind turbines and large areas and order that emergency supply units are used to quickly restore normal operations. In these rare cases, the normal market and commercial agreements will be overruled as the alternative is widespread collapse.

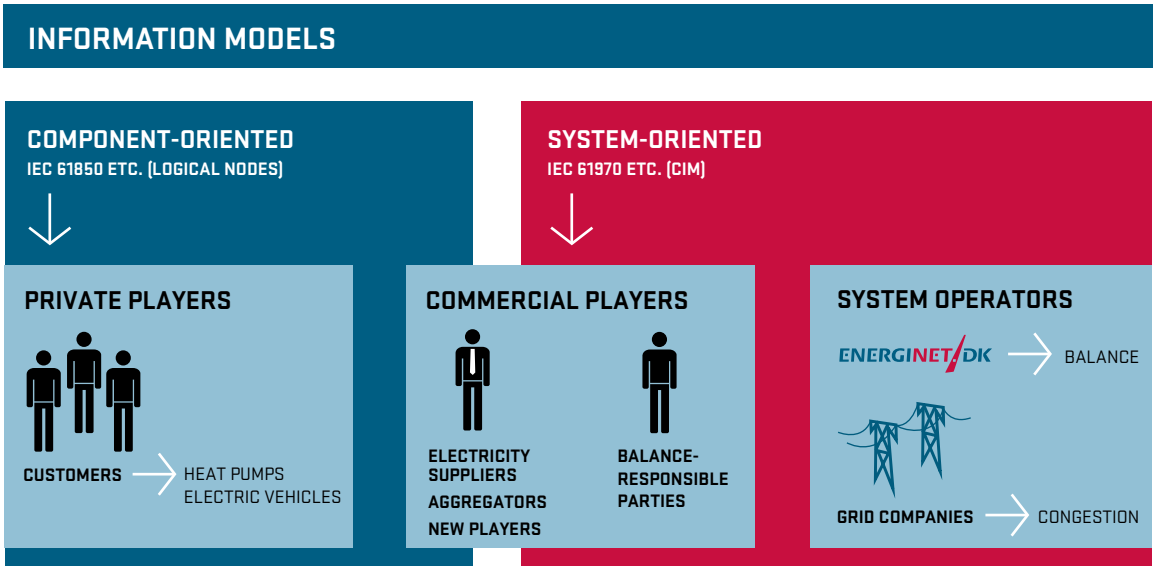
5 // DATA COMMUNICATION

The power system of the future will be extremely complex. The number of physical units, businesses and private individuals actively involved in the workings of the power system will multiply many times over. Likewise, the volume of information that needs to be gathered, communicated and processed will grow dramatically

Therefore, an effective IT infrastructure is vital. The aim is to ensure the efficient integration and exchange of information between all the various components and players involved. To utilise the flexibility from DER units and flexible customers, easy market access is necessary – problems with the exchange of information must not act as a barrier. A key element is a harmonised information model in the Danish power system. The concept therefore points to using various international standards that define such an information model. The standards have been selected based on a number of international announcements from, for example, the USA, Europe and China that the use of these standards will be promoted, especially in a future power system. Following international trends ensures the availability of innovative products for a Dan-

THE MOST IMPORTANT STANDARDS

- Internationally, two standards for Smart Grids are singled out in particular, each including a number of part-standards and related standards. One is the IEC 61850 standard, which was originally developed for substations but which has today been developed to cover a wide range of other areas, e.g. DER units. The information model in IEC 61850 is based on the so-called Logical Nodes, whereby information can be structured in a harmonised way. The other standard is the IEC 61970 standard, which was originally developed for control centre environments, but which today, via related standards, covers a wide range of system activities in the power system, for example electricity markets. The information model in IEC 61970 is called the Common Information Model - CIM. The two information models are being harmonised with a view to defining a combined information model for the entire power system and its associated components and processes.



COMPONENT-ORIENTED STANDARDS (IEC 61850 etc.) are used when communicating with the customer's DER units, for example with an aggregator. The system-oriented standards (IEC 61970) are used among commercial players and in relation to the system operators.

ish Smart Grid, just as Danish businesses are able to develop solutions for a far larger market.

To ensure the cost-efficient implementation of the standards, they should primarily be applied in connection with the development of new solutions, markets and products. However, in future, the entire power system and all involved players should move towards using the recommended standards.

Moreover, the standards are not "static", and it is important that Danish players become involved in their future development. Here, it is important to ensure that the ongoing process is coordinated with the Smart Grid Network recommendations, for example "Communication standards for smaller power-generating units" (part-recommendation 18) and "Interoperability of Smart Grid solutions" (part-recommendation 20).

STANDARDISATION MAKES ECONOMIC SENSE

- Using a harmonised concept for exchanging information is an efficient way of integrating different players, components and customers. It means, for example, that the cost of mobilising a DER unit is reduced if, from the outset, it is designed so that it can be monitored and remotely controlled in a standardised way by, for example, an aggregator – the appliance must be "smart grid-ready". Moreover, it reduces the cost of changing aggregators, which improves competition in the market.

IMPLEMENTATION IS A JOINT PROJECT

- To promote Danish solutions for implementing and supporting the widespread use of the international standards, a number of projects will be launched with the broad support of the industry. For example, the Danish Energy Association, the Danish District Heating Association, the Association of Danish CHP Enterprises and Energinet.dk have launched the CHPCOM project which involves implementing new standards at the CHP plants. This will produce valuable experience and industry recommendations which can pave the way for further implementations.

6 // BENEFITS OF THE CONCEPT

The proposed concept paves the way for new and economically efficient tools for handling the challenges posed by greater electrification and a higher proportion of fluctuating RE production for Energinet.dk and the grid companies

The concept creates a framework for mobilising flexible electricity consumption and production, which today is a largely untapped resource.

The main benefit for the grid companies is that the concept allows flexible resources to be mobilised and used as a real alternative to grid reinforcements without the grid companies needing to engage in direct commercial relations with customers. The concept thus ties in with the future wholesale model in which customer relations in connection with the settlement of transported energy through the power grid are handled by the electricity trading companies.

At the same time, Energinet.dk is able to use the mobilised flexibility for balancing purposes. The concept supports this by coupling the new market for flexibility with existing markets for balancing services, thereby increasing the range of services on offer. This ensures the optimum coordination and utilisation of resources from a socio-economic point of view.

The concept increases transparency and boosts competition via an open market place. The need for bilateral contracts is thus expected to be reduced, while the transaction costs of trading in flexibility are expected to be lowered.

CONCEPT MATCHES FUTURE DISTRIBUTION OF ROLES IN THE ELECTRICITY MARKET

- The concept matches the recently adopted act which determines the future distribution of roles in the electricity market*). It is not required that the grid companies have direct commercial relations with the customers offering flexibility as commercial players will act as intermediaries.

  *) Act no. 575 of 18 June 2012 (promoting competition in the electricity market etc.)

- Internationally, the concept is in line with legislation on liberalising the electricity market, including the separation of grid companies and electricity suppliers. Via freely competing commercial players, both grid companies and Energinet.dk are able to benefit from flexible electricity consumption and production.

CONCEPT OFFERS GRID COMPANIES A REAL ALTERNATIVE TO GRID REINFORCEMENTS

- Price signals can be used as an incentive for customers to plan their electricity consumption or production to suit the needs of the power system. However, it means that their response cannot be guaranteed in advance, which in certain situations is unfortunate.

- Through trading flexibility products, it is, however, possible to enter into fixed agreements that a specific service is supplied when – via the commercial players – it is activated by either a grid company or Energinet.dk. The quality of the service is ensured in that the players bringing flexibility to the market must be accredited in order to be active in the market place.

- The market place is thus a supplementary measure, which means that the grid companies in particular can be sure that their need for flexibility can be met at all times, and that they can thus use flexibility products as a real alternative to grid reinforcements.

THE CONCEPT ENSURES FLEXIBILITY IS USED WHERE IT OFFERS MOST VALUE

- The concept is an extension of the existing market design, where Energinet.dk – via international markets for regulating power and reserves – already meets its needs for flexibility in order to maintain system balance. The concept means that the flexibility from customers and DER can be offered to these markets and thus increase what is on offer. At the same time, a new market is established where the grid companies can trade in flexibility. Coupling the new market to the existing markets ensures that the flexibility is used where it offers most value.

THE CONCEPT OPENS UP THE POSSIBILITY OF ESTABLISHING NEW PLAYERS IN THE ELECTRICITY MARKET THAT CREATE ADDITIONAL VALUE

- Electricity customers and DER are able to supply flexibility to the power system by responding to price signals. However, to be able to supply formal flexibility products, it is expected that a new role will be needed in the electricity market which can combine flexible electricity consumption and production from smaller customers and DER and actively offer it to the market.

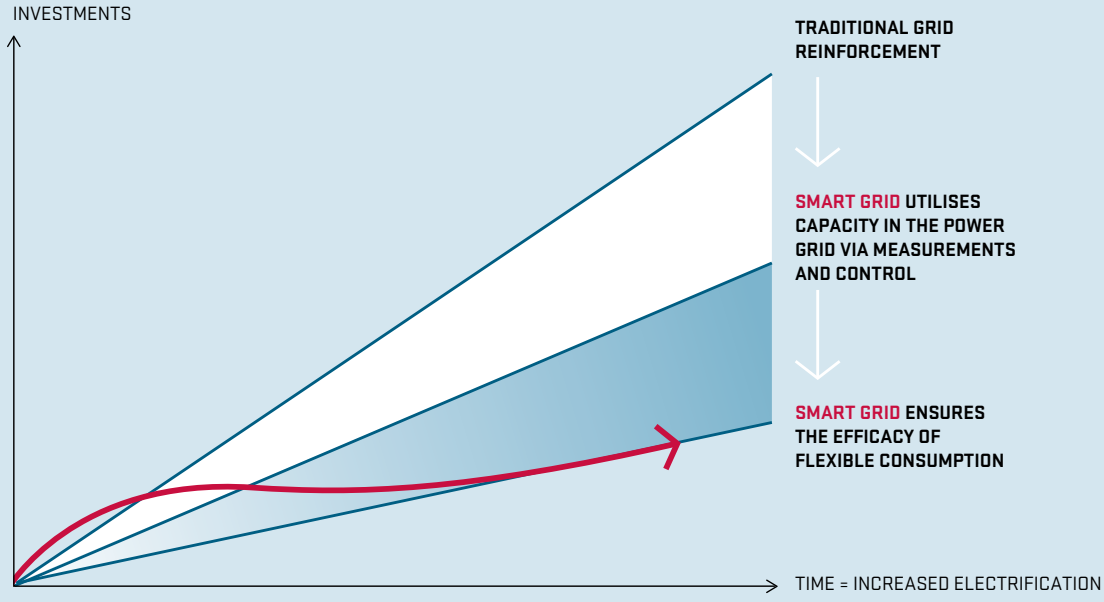
- These aggregators will operate in open competition with each other and can create added value by offering the most innovative and effective solutions.

7 // CONVERTING THE POWER GRID TO A SMART GRID

The challenges facing the power grid as a result of the expected load increase from new electricity consumption and local production can be handled via conventional grid expansion or by using the possibilities for increasing capacity utilisation in the power grid which new technology and flexible electricity consumption and production offer

In general, converting the power grid to a Smart Grid can be regarded as a two-stage development process. First, the grid companies need to establish technological solutions for automating grid operations and monitoring capacity utilisation in the power grid. Then, customers' flexible electricity consumption and production can be used to optimise capacity utilisation in the grid.

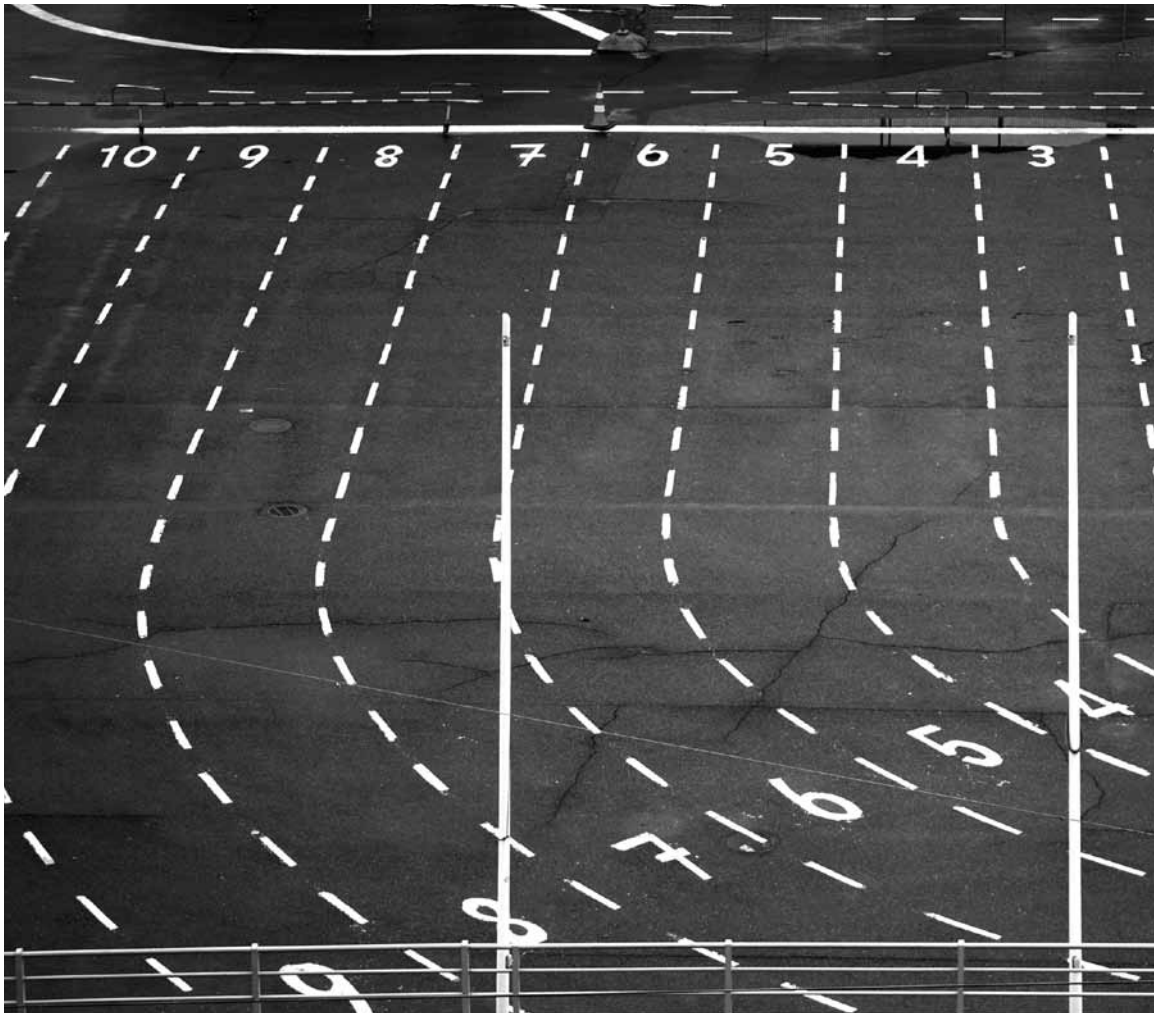
In practice, the grid companies can choose to start both steps simultaneously to reduce the cost of traditional grid expansion as much as possible.



CONVERSION IN TWO STEPS

- **STEP ONE** involves increasing the utilisation of existing capacity in the distribution grid by using new technology in the power grid. By improving the monitoring of the state of the distribution grid, it is possible to reduce safety margins and thereby permit higher loads. An integrated system of measurements, prognoses and communication systems therefore needs to be established to map grid loads and boost the degree of utilisation.

- **STEP TWO** consists of further increasing utilisation of existing capacity in the distribution grid by using flexible electricity consumption and production. This will make it possible for the grid companies to seek help with, for example, load reduction in very difficult operating conditions. Here, the grid company steps outside the physical power grid and actively involves the customers.



8 // ROAD MAP FOCUSING ON THE ROLE OF THE GRID COMPANIES

This section presents a road map which constitutes a recommendation for grid companies to develop a Smart Grid

Based on the road map, it is clear that there is a need to remove two central barriers in order to promote the conversion of the power grid to a Smart Grid. The first barrier is constituted by the fact that the existing regulation does not support grid companies using Smart Grid technology in the power grid. The regulation assumes that all costs and investments are driven by traditional grid components, and that companies wanting to pursue the Smart Grid path are put at an economic disadvantage.

The second barrier concerns the grid companies' access to using variable grid tariffs to shift electricity consumption to times with the greatest availability of capacity in the grid. This is not a real option today where there are 3.2 million electricity customers who are not subject to hourly settlement and who therefore cannot be billed using variable grid tariffs. While 1.4 million of these customers have already had remote-read electricity meters installed, none of them can be offered hourly settlement and thereby lack an individual financial incentive to be price-flexible.

NEW ECONOMIC REGULATION NEEDED OF GRID COMPANIES' SMART GRID ACTIVITIES

- Converting to a Smart Grid requires considerable investments in new technology. However, the present regulation of the grid companies assumes that all costs and investments are driven by traditional grid components. Companies wanting to use a Smart Grid are automatically put at an economic disadvantage, which discourages grid companies from converting their distribution grids to a Smart Grid.

- Thus, it is necessary to devise a new and modern regulation of the grid companies which prioritises the establishment of balanced and positive investment incentives for rolling out Smart Grid solutions in the distribution system. The regulation must therefore provide a robust incentive and make it possible for grid companies to introduce new technology in order to optimise and utilise grid capacity (for example via improved measurement, monitoring and automation).

- The grid companies must also be encouraged to effectively weigh up hardware-based solutions against operating solutions which entail the active involvement of players on commercial terms.

- It is assumed that this barrier will be overcome following the review of the regulation of the Danish electricity supply sector which was decided following the energy agreement of 22 March 2012 as well as via temporary administrative measures.

NEED TO ENCOURAGE CUSTOMERS TO ADOPT FLEXIBLE ELECTRICITY CONSUMPTION VIA PRICE SIGNALS

- To provide an economic incentive to shifting electricity consumption to times of the day and night with available capacity in the power grid, it is imperative that customers are exposed to price signals (variable grid tariffs and electricity prices) that reflect the actual cost of electricity consumption at any given time. By giving customers the option of adjusting their electricity consumption in response to price signals, it will be possible to use capacity in the power system more efficiently while offering customers real financial benefits if they optimise their electricity consumption according to varying electricity prices over the 24-hour period.

- With a new act (on the so-called wholesale model), legislation is in place which permits the design of variable grid tariffs, but the fundamental market design for establishing hourly settlement systems which will make this possible is still not in place. The following measures must be introduced before customers can be encouraged to activate and shift their flexible electricity consumption.

  - Frameworks and regulation must be adapted to support the establishment of hourly settlement systems for all customers.

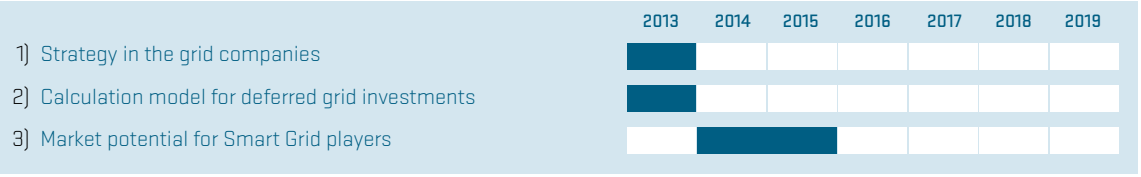
  - Introducing the type of hourly settlement system which is currently used for large electricity customers will entail high additional costs for customers with a lower electricity consumption. The electricity market regulations should therefore specify a new independent settlement group (flex settlement), where revised requirements as regards validation and deadlines can reduce the additional costs of an hourly settlement system.

- It is assumed that this barrier will be overcome as part of the energy agreement of 22 March 2012, which states that an agreement is sought with the grid companies on rolling out remote-read hourly electricity meters.

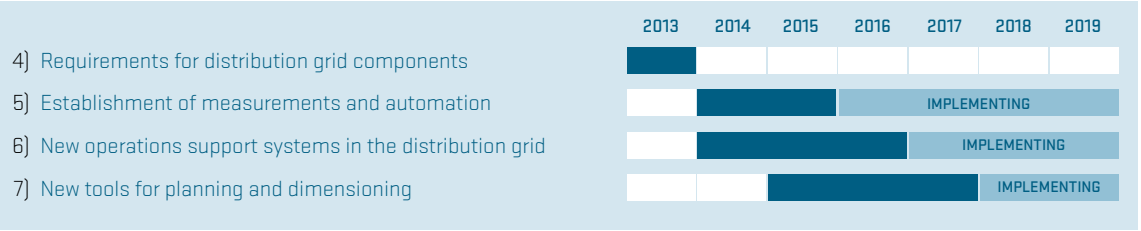
The following is a road map which constitutes a recommendation for the grid companies to develop a Smart Grid. The two above-mentioned barriers are reflected in the proposed measures no. 8, 9 and 13. In addition, a number of other measures which are necessary are listed, stating when the individual measures should be implemented.

The individual measures are divided into four categories which concern "Establishing business case and strategy", "New technology in the power grid", "Activating customers' flexible electricity consumption" and "Other measures". The categories and measures are described in sections 8.1-8.4 and are explained in subreport no. 3 "Road map for a Smart Grid in Denmark with special focus on the role of the grid companies" (Roadmap for Smart Grid i Danmark med særlig vægt på netselskabernes rolle) – available in Danish only.

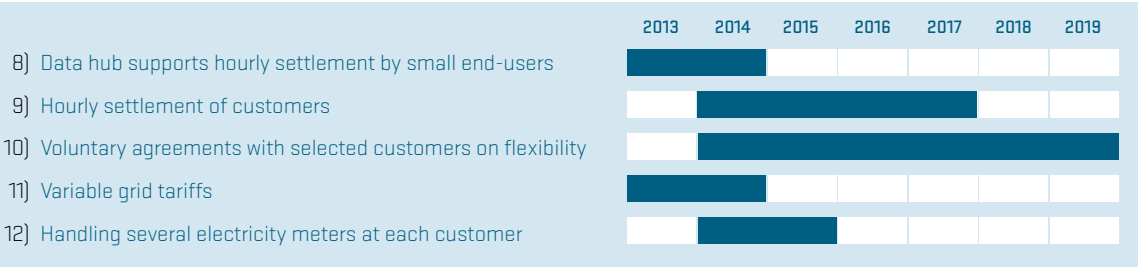
ROAD MAP FOCUSING ON THE ROLE OF THE GRID COMPANIES – MEASURES AND SCHEDULE



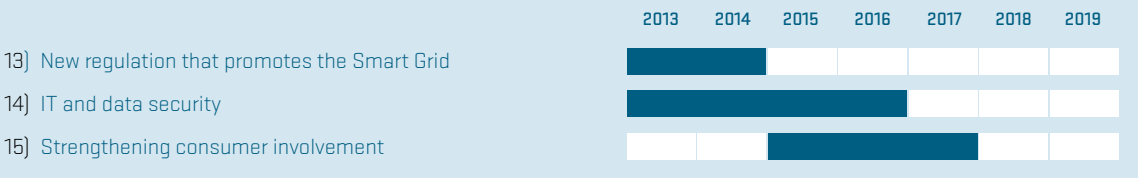
DECIDING BUSINESS CASE AND STRATEGY: Measures which support the individual grid companies in preparing a business case and deciding on a strategy for establishing a Smart Grid.



NEW TECHNOLOGY IN THE POWER GRID: Measures concerning the introduction of new technology in the electricity grid. For example, establishing technological solutions for automation and for monitoring grid loads as well as setting up further measurements at strategic points in the distribution grid.



ACTIVATING CUSTOMERS' FLEXIBLE ELECTRICITY CONSUMPTION: Measures which support the grid companies in actively involving end-users via price signals or through entering into agreements on regulating or shifting electricity consumption to periods with spare power grid capacity.



OTHER MEASURES: Other measures that support the grid companies in developing a Smart Grid.

8.1 // DECIDING BUSINESS CASE AND STRATEGY

The first step for the grid companies is to evaluate the business case for a Smart Grid and to assess how a Smart Grid is able to benefit the individual company.

MEASURES RE BUSINESS CASE AND STRATEGY

■ **MEASURE 1 – STRATEGY IN THE GRID COMPANIES**

Embarking on the Smart Grid route starts with a vision. The management must have a vision for how a Smart Grid can create value for the company and thereby for its customers. Possibilities, business cases and technology must be considered in relation to company-specific factors, for example grid elements already established.

Subsequently, a strategy must be decided upon to realise the vision. It is necessary to prepare a concrete business case, and decide on the path ahead by devising an action plan with milestones.

Implementation: 2013
Responsible: Grid companies

■ **MEASURE 2 – CALCULATION MODEL FOR DEFERRED GRID INVESTMENTS**

At industry level, a calculation model for deferred grid investments is prepared which contributes to clarifying the financial impact of a Smart Grid for the individual grid company. The calculation model must show the value of deferred grid investments for the company, and help the individual company to assess the value which the Smart Grid can create for the company and thereby for customers.

Implementation: 2013
Responsible: Grid companies

■ **MEASURE 3 – MARKET POTENTIAL FOR SMART GRID PLAYERS**

To realise the full benefits of a Smart Grid, it is necessary to allow commercial players room to effectively help activate and utilise customers' flexible electricity consumption. With a view to creating a market, it is necessary to quantify the combined value which the grid companies believe a Smart Grid can realise for the industry as a whole. This will provide a starting point and help players to assess the Smart Grid business case.

Implementation: 2014-2015
Responsible: Grid companies

8.2 // NEW TECHNOLOGY IN THE POWER GRID

Technological solutions for automation and for monitoring grid loads must be established. In so doing, the grid companies will acquire new knowledge about the rate of utilisation of the power grid, which can then be optimised by operating closer to the technical limits for current and voltage, for example.

The grid companies should therefore establish further measurements at strategic points in the distribution grid and also set up operations support systems which, based on the measurements, can facilitate greater capacity utilisation in the existing grid. The measurements must be used by future planning and dimensioning tools. At the same time, increased awareness of load levels can be used to define new specifications for components and protective equipment.

MEASURES RE NEW TECHNOLOGY IN THE POWER GRID

■ MEASURE 4 – REQUIREMENTS FOR DISTRIBUTION GRID COMPONENTS

When the Smart Grid is used to defer grid reinforcements, it means an increase in both the average load and, in most cases, also the maximum load on the individual components. It is necessary to analyse how the different grid components are affected by the new mode of operation, and the consequences for component specifications. Likewise, it is necessary to examine how substations can be suitably adapted to house the new equipment which needs to be installed as part of a Smart Grid solution. Also, an assessment should be carried out of the possibilities for correcting the voltage quality in the low voltage grid using equipment installed in the substation.

Implementation: 2013
Responsiblen: Grid companies

■ MEASURE 5 – ESTABLISHMENT OF MEASUREMENTS AND AUTOMATION

It is necessary to examine how the grid can be monitored to a sufficient degree for it to be possible to increase capacity utilisation. At the same time, it should be analysed whether power rerouting and grid monitoring can relieve problems with overloading. Analyses as well as technologies and communication should be tested in pilot projects by the grid companies.

Implementation: 2014-2016
Responsible: Grid companies

■ MEASURE 6 – NEW OPERATIONS SUPPORT SYSTEMS IN THE DISTRIBUTION GRID

To operate the power grid closer to its capacity limit while electricity consumption and production become more unpredictable, a higher degree of monitoring and estimation is required. Operations support systems must, in the long term, perform state estimations, operational simulations, short-term prognoses and the activation of regulating services. The individual grid companies have different needs and requirements regarding their operations support systems; for example, data availability will differ.

Implementation: 2014-2017
Responsible: Grid companies

■ MEASURE 7 – NEW PLANNING AND DIMENSIONING TOOLS

New models for calculating distribution grid loads must utilise the extra information provided by the hour meters and on-line measurements in a smart grid. Dynamic line ratings may be used for temporary overloading of the grid components. The various options and consequences must be studied further. At the same time, new methods must be developed for planning the distribution grid incorporating new possibilities for reducing safety margins during operation, for precise modelling of grid loads and operational restructurings as well as the purchasing of regulating services.

Implementation: 2015-2018
Responsible: Grid companies

8.3 // ACTIVATING CUSTOMERS' FLEXIBLE ELECTRICITY CONSUMPTION

The existing capacity utilisation in the distribution grid must be further increased by using flexible electricity consumption and production. With new measuring systems, the grid companies are able to ask for help to, for example, reduce loads in very difficult operating conditions. Here, the grid company steps outside the physical power grid and actively involves the customers.

It is essential that customers are exposed to price signals that provide an incentive for them to shift their electricity consumption to times of the day or night when there is less load on the power grid. This results in better grid capacity utilisation while customers enjoy financial benefits.

However, it must still be possible to request flexibility in the local power grid in the form of flexibility products, allowing the grid companies to control the load in a particular area of the grid at any given time.

MEASURES RE ACTIVATING CUSTOMERS' FLEXIBLE ELECTRICITY CONSUMPTION

■ MEASURE 8 – THE DATA HUB SUPPORTING HOURLY SETTLEMENT FOR SMALL END-USERS

Introducing the type of hourly settlement which is currently used for large electricity customers (over 100,000 kWh per year) would entail disproportionately high extra costs for smaller customers (so-called "load profile-settled" customers). The electricity market regulations should therefore specify a new independent settlement group (flex settlement), where revised requirements as regards validation and deadlines can reduce the additional costs of an hourly settlement solution for currently load profile-settled customers.

Implementation: 2013-2014
Responsible: Energinet.dk, grid companies

■ MEASURE 9 – HOURLY SETTLEMENT OF CUSTOMERS

Establishing individual incentives to encourage electricity customers to be price-flexible is a key condition for realising the socio-economic benefits of a Smart Grid in Denmark. More widespread use of an hourly settlement system will encourage customers to engage in flexible electricity consumption and also contribute to strengthening the dynamics in the retail market.

Frameworks and regulation must be adapted to support the establishment of an hourly settlement system. A long-term and robust solution must be established entailing the roll-out of hourly settlement for all customers.

Implementation: 2014-2017
Responsible: Authorities, grid companies

■ MEASURE 10 – VOLUNTARY AGREEMENTS WITH SELECTED CUSTOMERS ON FLEXIBILITY

It must be possible for grid companies and major customers to enter into bilateral agreements on activating flexible electricity consumption to defer grid investments. Agreements may be made on, for example, interruptibility, regulation and using electricity at particular times of the day. In the long term, grid companies will, via their trading in flexibility products, demand specific services for flexible electricity consumption.

Implementation: 2014-2019
Responsible: Grid companies

■ MEASURE 11 – VARIABLE GRID TARIFFS

Variable grid tariffs must be introduced which reflect the benefit of shifting electricity consumption to times of the day or night with available power grid capacity. A new tariff model should be drawn up so that tariffing according to the model will be possible once new legislation about the so-called wholesale model as well as new price regulation for establishing grid tariffs take effect.

Implementation: 2013-2014
Responsible: Grid companies

■ **MEASURE 12 – HANDLING SEVERAL ELECTRICITY METERS AT EACH CUSTOMER**

It must be possible to install several electricity meters at individual customers as, with the new consumption units, there may be a need to measure different types of electricity consumption separately (for example for an electric car or a heat pump). It is necessary to examine whether, in future, aggregators can use their own measurements and assume responsibility for submitting measurement values (i.e. act as metering point administrator). At the same time, it is necessary to look at whether meters can be coupled in series with the household's main electricity meter. This measure involves preparing new connection terms with the grid companies, and adapting the data hub so it is able to handle time values from separate electricity meters for separate types of electricity consumption.

Implementation: 2014-2015
Responsible: Energinet.dk

8.4 // OTHER MEASURES

To convert the power grid to a Smart Grid, it is imperative that a new financial regulation of the grid companies is established that supports the introduction of new technology in the power grid and lays down the framework for activating customers' flexible electricity consumption.

At the same time, it is necessary to focus on data security while strengthening customer involvement in flexible electricity consumption. The so-called wholesale model means that customer contact is transferred to the electricity suppliers in the retail market from autumn 2014. Thus, the possibility of offering flexibility services to customers transfers, in principle, to the electricity suppliers. However, it is the grid companies which primarily stand to benefit from value creation by activating customers' flexible electricity consumption, and therefore they should assume some of the responsibility for involving customers.

OTHER MEASURES SUPPORTING THE DEVELOPMENT OF A SMART GRID

■ MEASURE 13 – NEW REGULATION THAT PROMOTES A SMART GRID

The existing regulation does not support the use of Smart Grid technology in the power grid. Converting to a Smart Grid requires considerable investments in new technology, but the existing regulation of the grid companies assumes that all costs and investments are driven by traditional grid components. Companies that want to implement a Smart Grid are thus financially worse off, which poses a barrier to grid companies being able to convert the distribution grids to a Smart Grid.

Thus, it is necessary to devise a new and modern regulation of the grid companies which prioritises the establishment of balanced and positive investment incentives for rolling out Smart Grid solutions in the distribution system. The regulation must therefore provide a robust incentive and make it possible for grid companies to introduce new technology in order to optimise and utilise grid capacity (for example via improved measurement, monitoring and automation).

The grid companies must also be encouraged to effectively weigh up hardware-based solutions against operating solutions which entail the active involvement of players on commercial terms.

The existing regulation assumes that the grid companies' costs are predominantly driven by the number of physical cables and transformers as well as the ability of the power grid to transport a certain volume of energy over time. It is therefore necessary to look at the new elements which will drive the grid companies' costs in future. They might, for example, include critical peak load situations locally in the power grid as well as the number of local production units.

Implementation: 2013-2014
Responsible: Authorities

■ MEASURE 14 – IT AND DATA SECURITY

The grid companies' communication needs will increase and change in nature. IT systems which have previously been run as closed networks will now have a much larger interface to the world at large, increasing the risk of malevolent attacks on the systems. The threats and consequences must be assessed before drawing up security policies which can prevent attacks or mitigate their impact. Moreover, security requirements in other countries, for example Germany, and a forthcoming EU regulation on personal data protection focus on protecting the private lives of customers. The task is to ensure protection without limiting the possibility of using, for example, electricity consumption data to control the grid more effectively.

Implementation: 2013-2017
Responsible: Grid companies

■ MEASURE 15 – STRENGTHENING CUSTOMER INVOLVEMENT

In a future Smart Grid, customers will play the role of both flexible electricity consumers and local electricity producers. Customer involvement is therefore an important aspect when establishing Smart Grid initiatives. Customer involvement must be driven by financial incentives, but also by non-financial values, for example a "green" approach or a desire to move first on new technology. It will be possible to connect and intelligently and automatically control new components such as electric cars, solar cells, heat pumps etc. without compromising customer comfort. Standards and communication protocols must ensure interoperability and independence of a single supplier.

Implementation: 2015-2017
Responsible: Commercial players (electricity traders, aggregators, electric vehicle operators etc.)

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