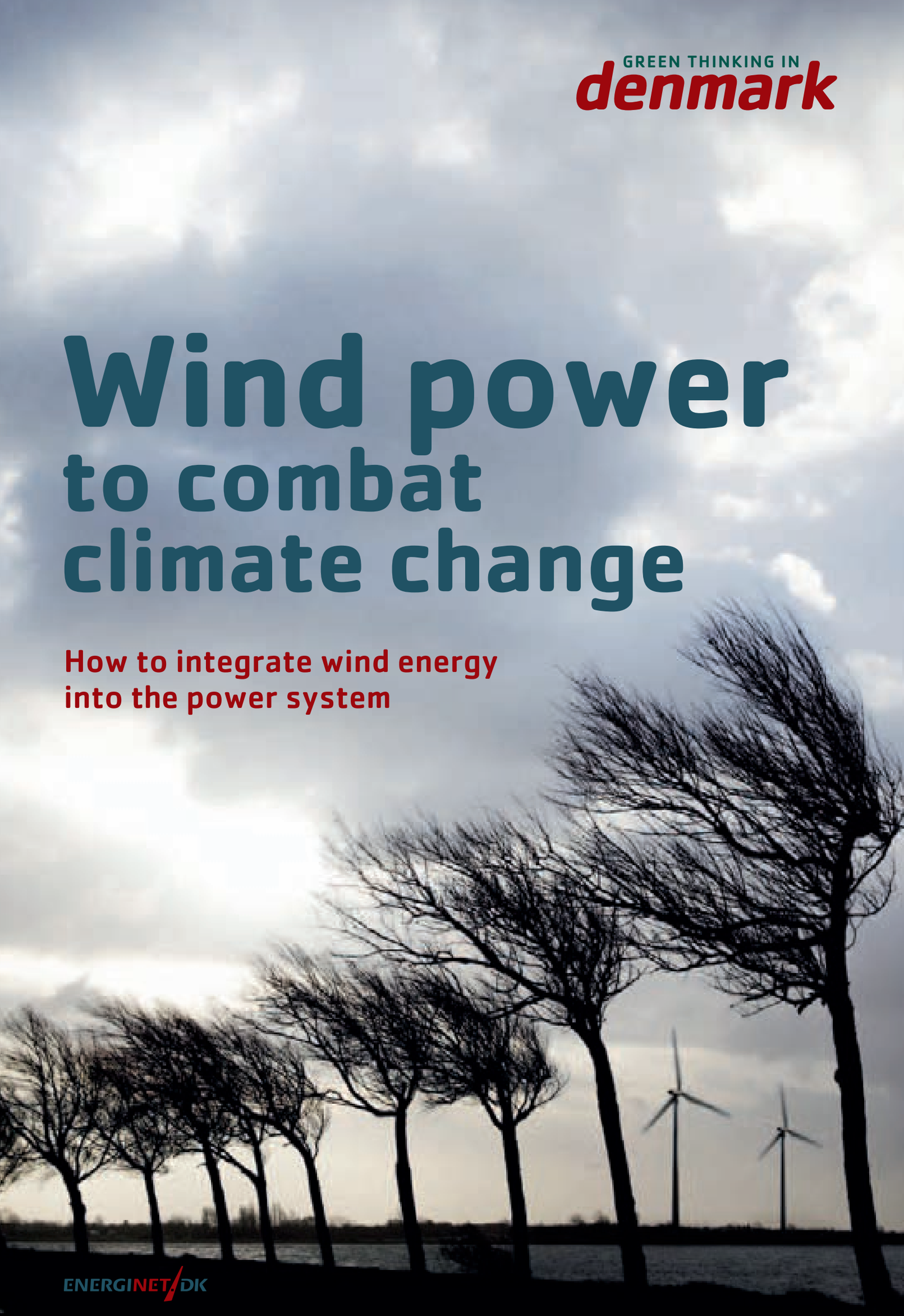
GREEN THINKING IN denmark

Wind power to combat climate change

How to integrate wind energy into the power system



ENERGINET.DK

WIND FARM

You need an active imagination to comprehend a world without electricity and heat. This is where Energinet.dk comes in – the independent public enterprise that owns the main electricity and natural gas systems in Denmark.

We maintain security of supply and ensure efficient electricity and gas markets with fair competition to the benefit of the consumers.

We also integrate renewable energy into the power system. We support research and development in environmentally friendly power generation and administer the public subsidies for renewable energy.

Do you want to contribute to tomorrow's energy solutions?

Environmentally-friendly alternatives to traditional energy sources should be strong enough to take some blows. This is why we welcome unsolicited applications from skilled candidates who are interested in using their professional expertise in the hot spot of public interest, energy policy and international cooperation.

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GREEN THINKING IN denmark

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Tonne Kjærsvej 65
DK-7000 Fredericia
Tel. +45 70 10 22 44
kommunikation@energinet.dk
www.energinet.dk

Revised edition

Editor
Sanne Safarkhanlou
Tel. +45 76 22 48 12
ssa@energinet.dk

Journalist
Torben Bülow (DJ)
Tel. +45 76 22 48 04
tob@energinet.dk

Vice President,
Corporate Communications
Hans Mogensen (resp.)
Tel. +45 76 22 48 00
hmo@energinet.dk

Translators
Ad Hoc Translatørservice A/S

Front-cover photo
Niels Hougaard

Montage
Anders Finderup

Distribution
Claudia Pring
Tel. +45 76 22 48 10
clp@energinet.dk

Layout and print
Datagraf

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All countries may learn from the Danish Wind Case

INDEPENDENT: The Government's long-term vision for Denmark is to be 100 per cent independent of fossil fuels. An independent climate commission is now producing recommendations as to how and when that vision may be achieved. Their report is expected on 28 September 2010. The Government will then present its strategy as to how and when the long-term vision may be achieved.

The world is faced with the twin challenges of addressing global warming and ensuring security of supply. In Denmark, one answer lies in how we produce and consume energy. To reach our long-term vision we have set a series of interim targets within Danish energy policy up to the year 2020. Today, about 20 per cent of the electricity is generated by some 5,100 Danish wind turbines. In the near future, we will see a strong development of wind power - both onshore and offshore.

Integrating 20 per cent wind-generated electricity into the power system is a challenge for our utilities and dispatch centres, but we have already eliminated several obstacles. In this magazine Danish wind and grid specialists highlight some of the lessons learned.

At EU level, great prospects lie in creating super grids that move inevitable power generation from renewable sources to high-demand regions. Nationally, the roll-out of Smart Grids can lead to better monitoring of wind power and improve the matching of supply and demand.

Wind power deployment is rising globally. Within the EU, the boom in offshore wind power is benefiting Danish wind turbine manufacturers and enabling governments to meet their EU targets. Cross-country dialogue is necessary, as offshore wind power can make our future more sustainable.

Our way of integrating wind energy is what we call 'the Danish Wind Case'. To support the Danish case, we have recently decided to develop a test site for wind turbines of up to 250 metres in height. I hope the world will profit from the Danish experience.

Lykke Friis
Minister for Climate and Energy

Illustration: Franck Wagnersen

Wind power tools

TO THE READER: Not a single day goes by without mention of the environmental and climate challenges facing the world.

The ice caps are melting right before our eyes and the oceans are rising as we quest for answers and durable solutions to the world's growing energy needs.

Wind is one of Denmark's most abundant natural energy sources, today accounting for one-fifth of the electricity supplied through Danish outlets.

As the illustration shows, a number of tools provide the recipe for integrating considerable amounts of wind energy into the power system, thus ensuring that wind energy is always used where most needed.

The list of tools available today is long and will be growing longer. Because there is more to come. The goal is 50 per cent wind power in 2025. But how?

This is precisely what this magazine wants to clarify.

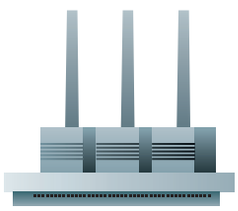
Pages 6-10 contain articles on the historical background for Danish wind power.

Pages 11-30 describe the tools that allow us to manage 20 per cent wind power in the power system today.

Pages 31-39 offer articles on how electric vehicles and a range of other tools will enable us to reach our goal: 50 per cent wind power!

And if you are interested in the more technical and financial aspects, you can read more about them in the back of the magazine on pages 43-55.

Enjoy your reading!



OIL CRISIS

Climate front-runner

In the mid-1970s, Danes had to adjust to car-free Sundays and cold radiators. The energy crises spurred societal changes that have brought Denmark to the forefront of today's climate challenge.

In the past 25 years, Denmark's economy has grown by 75 per cent, while energy consumption has remained largely constant.

A targeted strategy, an unrelenting, active political effort and a unique innovation culture have created this Danish success story. We call it the Danish example.

Oil boycott

October 1973. The energy crisis came as a shock – precipitated by the war between Israel and Egypt/Syria and the Arab oil boycott of the USA and Western Europe.

The oil price skyrocketed, generating major uncertainty about the future energy supply.

At the time, oil covered 90 per cent of Denmark's energy requirements, and motorists had to learn to live with car-free Sundays, while shop owners were asked to turn off lights outside opening hours. It was just the beginning.

In 1979, a new oil crisis followed the Islamic Revolution of Iran and the fall of the Shah.

The shock of two oil crises galvanised innovation and change in Danish society.

Mr and Mrs Denmark turned down the heat and insulated their houses.

Popular movements worked to meet the global challenges engendered by the energy crises and thus advanced development.

Companies began taking an interest in energy savings and energy efficiency, and politicians made energy policy a priority.

The first Ministry of Energy

In 1976, the first complete energy plan came into being, focusing on decreasing energy consumption and dependence on oil.

In 1979, the Danish Parliament passed acts on the supply of heat and natural gas, Denmark created its first Ministry of Energy, and in the following years, acts govering renewable energy subsidies and energy savings in buildings were passed.

ALTERNATIVES: When the uncertainty about the country's oil supply peaked in 1973/74, car-free Sundays were introduced, offering new possibilities – like here on the motorway to Copenhagen. Photo: Polfoto

In the 1980s, district heating and co-production of electricity and heat were dramatically expanded, and in the 1990s, the Danish Ministry of Environment and Energy grew very strong.

Green taxes

New energy plans set continually higher goals for reducing energy consumption and CO_2 emissions. These objectives were met with the help of stricter legislation, green taxes, incentives and energy-saving campaigns.

Since the turn of the millennium, the basis of energy policy has changed once again. Large oil price increases and a new, strong climate awareness in Denmark and globally have given rise to new energy agreements with even higher targets.

By Hans Mogensen | hmo@energinet.dk

Read more about the milestones in the promotion of Danish wind power on pp. 44-45.

FACTS:

Efficient energy use

COMBINING HEAT AND POWER

Among the many initiatives to boost energy efficiency, co-production of electricity and heat has played a vital role in the Danish energy fairytale.

Combined heat and power production ensures far more efficient use of fuels for production. The most efficient CHP plants have an efficiency exceeding 90 per cent.

High political demands have helped to develop the collective heat supply and the world's most efficient power stations.

Today, more than 80 per cent of Danish district heating is co-produced with electricity. Similarly, approx. 50 per cent of electricity is co-produced with heat.

ENERGY STANDARDS

Denmark has launched a series of consumer- and company-aimed measures to increase efficiency in end-energy consumption. High energy standards have been set for buildings, energy labelling schemes for electrical appliances, public campaigns for household energy saving, energy-saving agreements with industry, and last but not least, taxes have been imposed on energy consumption.

Danish environmental and energy taxes help to bring the price of energy consumption in line with the environmental costs of production at power stations and their scrapping.

LEGISLATION, TAXES AND INCENTIVES

The interplay between innovative companies and increasingly stricter energy legislation has prevented Denmark's energy consumption from increasing alongside economic growth.

Denmark is among the countries where green taxes constitute the greatest share of the gross domestic product – taxes that affect company and consumer behaviour.

This has given Denmark immense experience in designing green taxes and incentives promoting renewable energy.

RESEARCH AND DEVELOPMENT

Denmark has gained its strong position in the energy field through research and development and the demonstration of technologies and systems.

Because of its long-term broad cooperation on energy research and development, Denmark has good experience with and can present examples of efficient cooperation projects and networks between companies and research and knowledge institutions.

The Danish Government supports research through a variety of research and innovation programmes and through basic research at research institutions.

WIND TURBINES FOR THE WORLD

The constant political and corporate focus on energy efficiency and new technologies has made Denmark a leading exporter of energy technology solutions.

The export of clean technologies has overtaken many other Danish exports. Today, for instance, Denmark accounts for approx. one-third of the global wind turbine market.

SYMBOL: The Tvind wind turbine, erected by laymen in the 1970s, became a symbol of the result of ordinary people's campaign against nuclear power and centralised energy supply. Here it is in its new 'garb' designed by the architect Jan Utzon.
Photo: Dagbladet Holstebro

BACKGOUND

When grass roots and wind outdid nuclear power

In the wake of the 1973 oil crisis, popular movements launched the virtually untested wind energy as a viable alternative to nuclear power.

The great saviour. This was how the majority of Danes perceived nuclear power in the wake of the 1973 oil crisis, when heating went off and electricity became expensive. Popular sentiment, however, shifted over the next decade, fuelled by strong opposition from a number of grass-root movements.

Instead, the anti-nuclear movements launched wind power as a viable alternative energy source. In 1985, nevertheless, Elsam, the predominant regional Danish power producer, had advanced far in its plans to build Denmark's first nuclear power plant, when the Danish Parliament responded to the shift in public opinion and struck nuclear power from its energy plans.

This decision actually breathed new life into wind energy, which now 25 years later covers one-fifth of Danish electricity consumption.

A rocky and winding road

The road has been rocky and winding. As early as in the 1890s, the physicist Poul la Cour succeeded in supplying the Askov Folk High School in Jutland with direct current from his own windmill. Oil and coal soon took the wind out of wind power, which, however, experienced a brief boom during the two world wars. Not until 1957, when the power company SEAS introduced the asynchronous motor as a generator in an experimental turbine near the town of Gedser, was the way paved for wind power in the public power grid.

But after five years, the power companies concluded that wind-powered electricity production was no match for coal and oil. In 1967, the Gedser turbine produced its last kWh for the grid. So, when the first oil crisis hit Denmark in 1973, wind power remained for only its staunch supporters.

In the following years, numerous craftsmen, teachers and folk high schools experimented with wind power, but only a few of the pioneers managed the transition from home builder to industrial company. Still, the 1980s and the early days of the green climate and energy movement saw the production of limited-series wind turbines ultimately get underway.

Mass production

In the early 1980s, a number of small machine manufacturers joined forces and started mass-producing the first wind turbines. Concurrently, the Danish Government and the large energy companies erected a number of experimental turbines.

The major private manufacturers used this experience to construct turbines for the wind farms that successive energy ministers had ordered the large energy companies to build. This includes the first offshore wind farms at Horns Reef off the west coast of Jutland and Rødsand south of the island of Lolland, which were supplied by Vestas and Bonus (today Siemens), respectively.

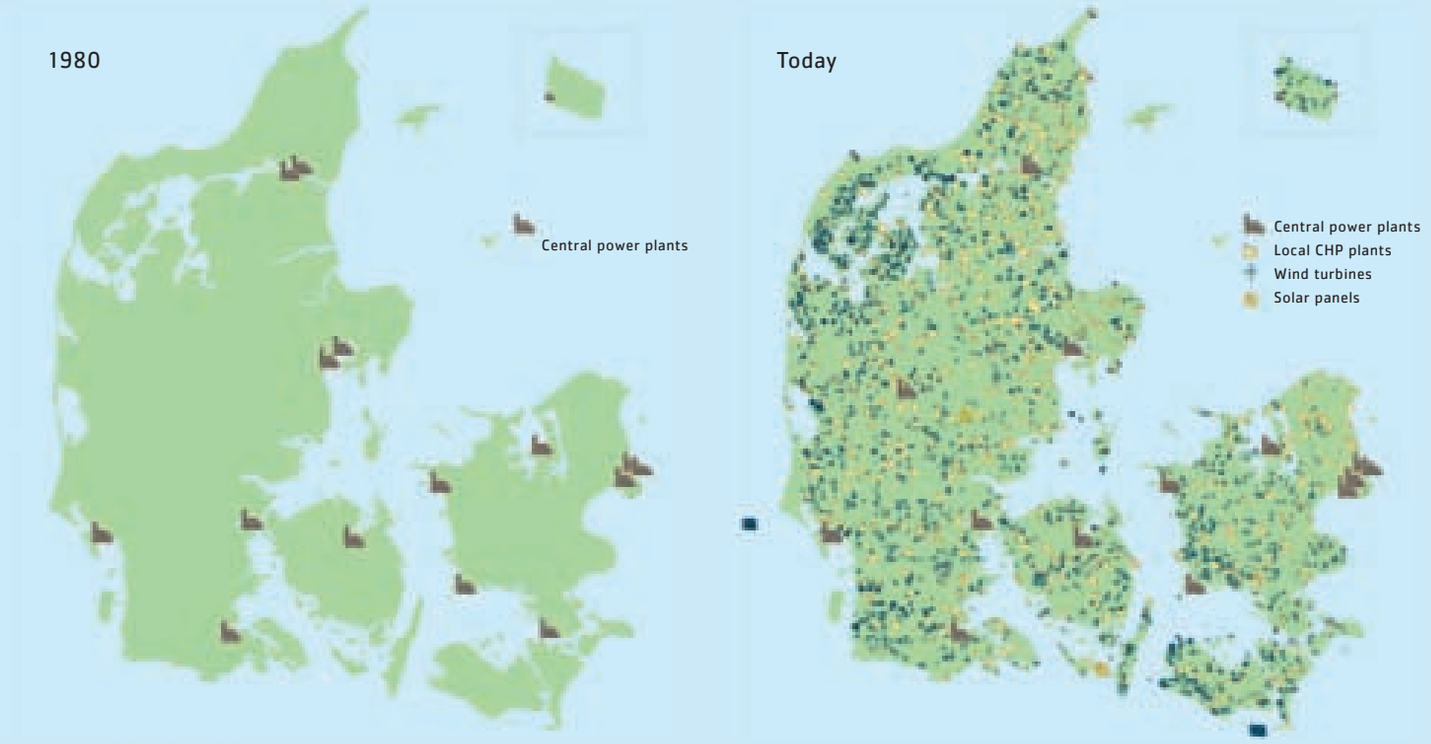
In the 1990s, favourable payment terms encouraged thousands of private individuals to make joint investments in wind turbines, which gradually moved off shore as opposition to onshore turbines grew louder. The first wind turbine went up at Middelgrunden near Copenhagen in 2000, where a cooperative owns half of the turbines, and more were subsequently erected south of the island of Samsø.

Today, cooperatives provide 15 per cent of the Danish wind capacity.

By Torben Bülow / tob@energinet.dk

Read more about Danish cooperatives on pp. 46-47.

SYMBOL: Wind power pioneer Christian Riisager with a blade model of his ground-breaking 22 kW wind turbine from the mid-1970s. In the background a huge wind turbine from Bonus (now Siemens) in Brande in Central Jutland that further developed the ideas of the visionary carpenter. Photo: Elmuseet



UNDERGROWTH: Since 1980, a fertile undergrowth of wind turbines and local CHP plants has emerged around the central power stations that formerly supplied Denmark with electricity. Illustration: Energinet.dk

GRID CONNECTION

From anarchistic grid connection to role model

In 1976, a private wind turbine constructor was the first to make his electricity meter run backwards – without permission. Today, wind power covers one-fifth of Danish electricity consumption.

It is one thing to build a wind turbine, but quite another to produce electricity for the public power grid. Today, it is so common that wind turbines covers close to one-fifth of Danish electricity consumption. The integration of wind energy makes Denmark a global role model, but in the 1970s this was completely uncharted territory.

In 1976, out of dire necessity – and without asking permission – wind power pioneer Christian Riisager discovered that his home-built turbine in his back garden could make his electricity meter run backwards. Inspired by the innovative Gedser wind turbine, he had used an asynchronous motor as a generator, which requires grid connection.

The somewhat anarchistic grid connection prompted common regulations for the entire electricity supply, ushering in an all-new era for renewable energy sources. Denmark soon gained a head start in wind technology – a head start that has been growing longer ever since.

Security of supply

The Danish head start is much in evidence when it comes to the all-important ability to integrate large amounts of often highly unpredictable wind energy into the power system without compromising security of supply, a feat that only a few central and typically coal-fired power stations have so far been able to accomplish. For as long as electricity cannot be stored, the power system must balance supply and demand hour by hour. This requirement takes planning and a well-equipped toolbox.

In the 1980s, however, the challenges posed by wind energy in the power system could still be met, but during the next decade environmental policy took another direction that fostered highly favourable payment terms. As a result, the number of even larger wind turbines owned by private individuals as well as by cooperatives and power stations increased dramatically.

First claim to the grid

When the climate-neutral wind energy obtained a first claim to the grid, the many wind turbines put tremendous pressure on the power system during the 1990s – not least because, during the same period, the power system had to manage an increasing number of local CHP plants, which also had a first claim.

Brussels, however, came to the rescue, adopting an EU directive on electricity market liberalisation that required the unbundling of production from transmission. In 1998, the Danish Government subsequently assigned the responsibility for the power system and renewable energy resources to the transmission systems operators – Eltra in Western Denmark and Elkraft in Eastern Denmark. In 2004, the two TSOs merged to become Energinet.dk, which now manages the entire Danish power system from its control centre in Fredericia in Jutland.

By Torben Bülow / tob@energinet.dk

Read more about unbundling on p. 48.

Photo: Jan Djenner, BAM

STATUS 2009

Wind power champion

In just under 30 years, Denmark has become world champ when it comes to harnessing the otherwise tough-to-control wind energy in the power system. The key to success is a well-equipped toolbox.

A hundred years ago, hardly anyone would have imagined that nature's bountiful storehouse would come to play such an important role in a small country far to the north, where variations in the otherwise flat countryside come only with the undulating hills and small valleys.

Today, however, wind turbines are generously scattered throughout the country, the majority of them on the west coast of Jutland.

In the past couple of decades, wind turbines have grown in popularity generating anything between 0 and approx. 3,100 megawatts (MW) for the power grid daily.

Over the past 25 years, the invisible wind has become one of Denmark's most valuable natural resources.

A wide range of tools

Today, wind supplies 20 per cent of the electricity used in Denmark. In future, this percentage will have to increase if our ambitious climate goals are to be achieved.

The following pages describe the many tools available today and those that must be developed in the future to ensure that Denmark will continue to be 'wind power champion'.

Wind power is an unstable element requiring various tools to control it.

– The secret is, however, that this entails not a single but several tools. To integrate wind power and ensure a high degree of interaction, we need a wide range of tools, says Dorthe Vinther, Head of Strategic Planning at Energinet.dk.

The range of tools includes everything from the planning of the power grid and robust interconnections through accurate wind forecasts and adequate reserve capacity for calm periods to a well-functioning electricity market in which players trade themselves into balance, and consumer behaviour comes to reflect the strength of the wind.

The power grid is the backbone

Transmitting wind force from the turbine blades to consumers' wall sockets poses a huge challenge to the electricity transmission grid.

“Wind power is only of value if the power lines between the wind turbines and the end-users are up to standard, says Lene Sonne, Vice President of Electricity Market, Energinet.dk.

– Wind power is only of value if the power lines between the wind turbines and the end-users are up to standard. This involves more than just Danish consumers. To make optimum use of wind energy, we have to be able to transmit it to the location in Europe where it is most needed, explains Lene Sonne, Vice President of Electricity Market, Energinet.dk, which is responsible for integrating renewable energy into the electricity transmission grid.

Consequently, Energinet.dk spends an annual amount in the nine-digit range on expanding and reinforcing the Danish grid and the interconnections.

A task that puts strong demands on planning as well as analysing the estimated need for new power lines and the siting of wind farms.

Reserve capacity for calm periods

Consumers demand electricity whether the turbines rotate or not. Therefore, substantial amounts of wind power require considerable reserves of other types of power generation.

In changing weather conditions, the output of Danish wind turbines may go from 0 to close to 3,100 MW in only a few hours – and vice versa.

Steady and adequate supply of electricity depends to a considerable extent on access to other production facilities capable of taking over should the wind calm down. One option is coal-fired power stations, but Norwegian hydropower in particular is an excellent supplement to wind power.

– Denmark is fortunate enough to be located between the hydropower-based Nordic system and the thermal power-based system to the south. Therefore, we are often able to import environmentally friendly electricity from Norwegian hydropower stations, when the wind is not strong enough. This is often the case during the summer months when Danish CHP plants supply less electricity and heat than in the winter months, explains Peter Jørgensen, Vice President of Electricity System Development, Energinet.dk.

First priority to green electricity

To provide Danish consumers with as much renewable energy as possible, green electricity from renewable energy sources is given first priority in the power grid. In this way, wind energy provides a ‘bottom’ under the market, but as the amount of wind energy in the grid literally fluctuates with the weather, the price charged by other producers for electricity is subject to similar fluctuations.

– Our market model forces other electricity suppliers to produce only when it is profitable. Danish consumers, therefore, benefit from electricity generated with the least possible environmental impact, explains Anders Plejdrup Houmøller, Director of Business Development with the power exchange Nord Pool Spot, which organises the trade in electricity between the Nordic countries.

Wind energy for a multitude of purposes

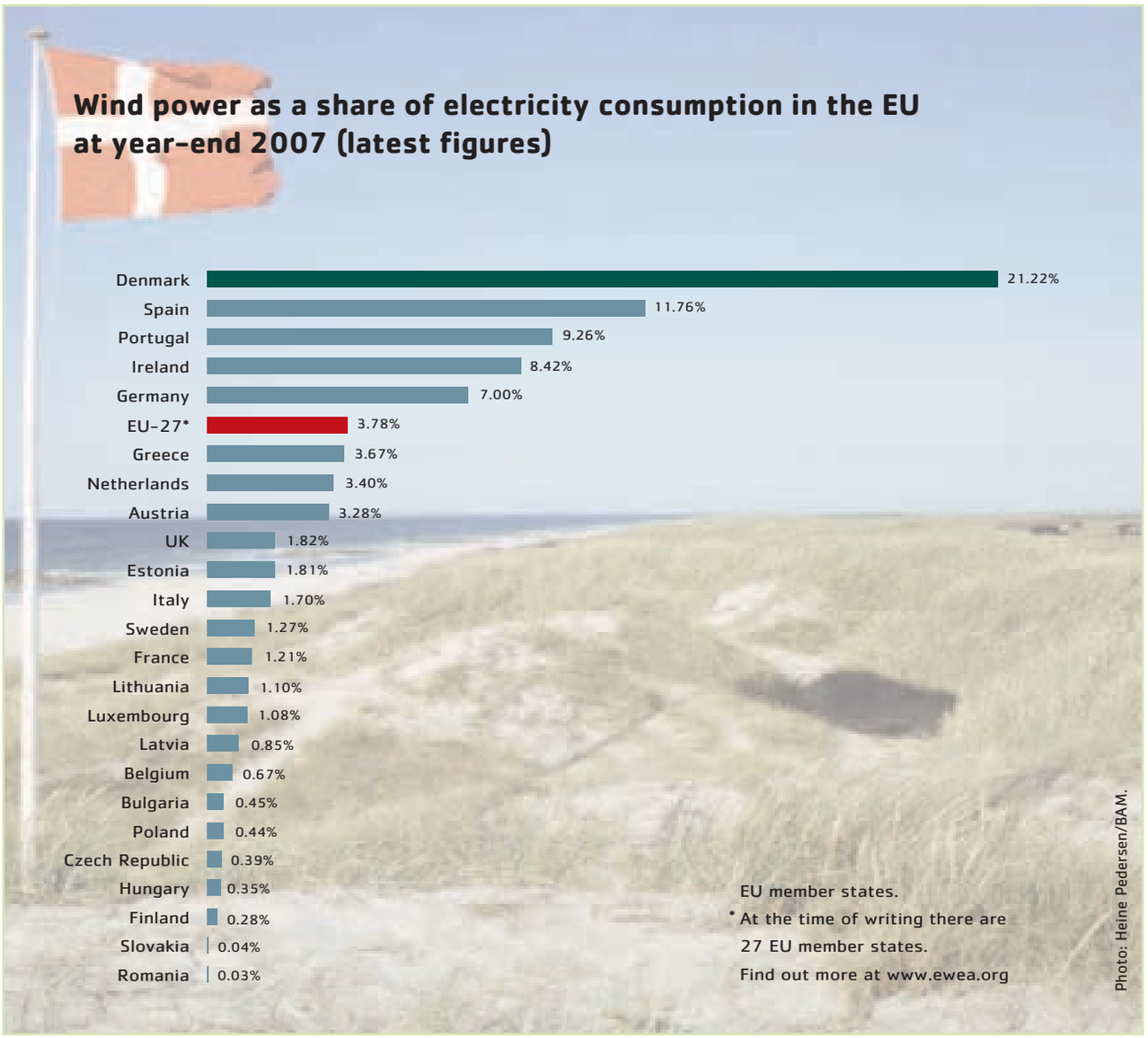
When it comes to renewable energy, Danish and European politicians are very ambitious, so in 2025, 50 per cent of

IN SHORT:

In 2025, close to 50 per cent of Danish electricity will come from renewable energy sources.

This means many more wind turbines than today, and the plan is to increase capacity by almost 40 per cent until 2013, with the vast majority of turbines being placed offshore.

Consequently, the number of tools has to be increased.



Danish electricity will come from renewable energy sources. This means many more wind turbines than today, for which reason the number of tools must also be increased.

– Managing the amount of wind energy available in the future will present quite a challenge, but we have already come a long way in developing tomorrow's tools.

We need to put wind energy to even better use. To use it for transport, electric vehicles and heating in our houses. We need to integrate all energy systems and use wind energy for an increasing number of purposes. This will allow us to handle even larger amounts of wind, says Dorthe Vinther.

By Mary-Anne Karas | freelance journalist
Photo: Palle Peter Skov

FACTS:

In Denmark, there are close to 5,200 wind turbines with a capacity of almost 3,100 megawatts. On a day with wind speeds of up to 10 metres per second, they can meet the electricity requirements of all Danish households during peak periods, ie between 5 and 7 pm when parents are preparing dinner and kids are watching TV.

MARKET FORCES:

'Wind energy causes the price of electricity to fluctuate and forces other suppliers to produce only when it is profitable,' says Anders Plejdrup Houmøller, Nord Pool Spot.

Photo: Private

OVERVIEW: The control centre is equipped with no less than 34 screens and one big screen measuring 9 x 2 metres. All screens are in use, so it requires skill to maintain an overview – a skill that Lars Fogt Andersen as balance supervisor with Energinet.dk possesses. Photo: Palle Peter Skov

Balancing the power system

BALANCE

A well-equipped toolbox and quick intervention are a must when the supervisors at Energinet.dk's control centre balance the power system. Production and consumption must balance minute by minute, 24-7. Otherwise, the power grid may break down.

The average Dane's electricity consumption is amazingly predictable. Fortunately. Because statistics on total daily consumption hour by hour and day by day truly help the employees in Energinet.dk's control centre, who are responsible for maintaining a constant frequency and voltage in the Danish part of the European power system. No more, no less. The slightest imbalance requires action.

Wind forecasts – a challenge

A key task of the control centre is to find out whether the wind is actually blowing at the exact speed predicted. It rarely is.

– It is not uncommon for forecasts to be off by 30-40 per cent, says Lars Fogt Andersen, balance supervisor at Energinet.dk.

At wind speeds between 5 and 15 metres per second, a single, unpredicted m/s increase or decrease will cause the Danish wind turbines to feed approx. 350 MW more or less into the power system.

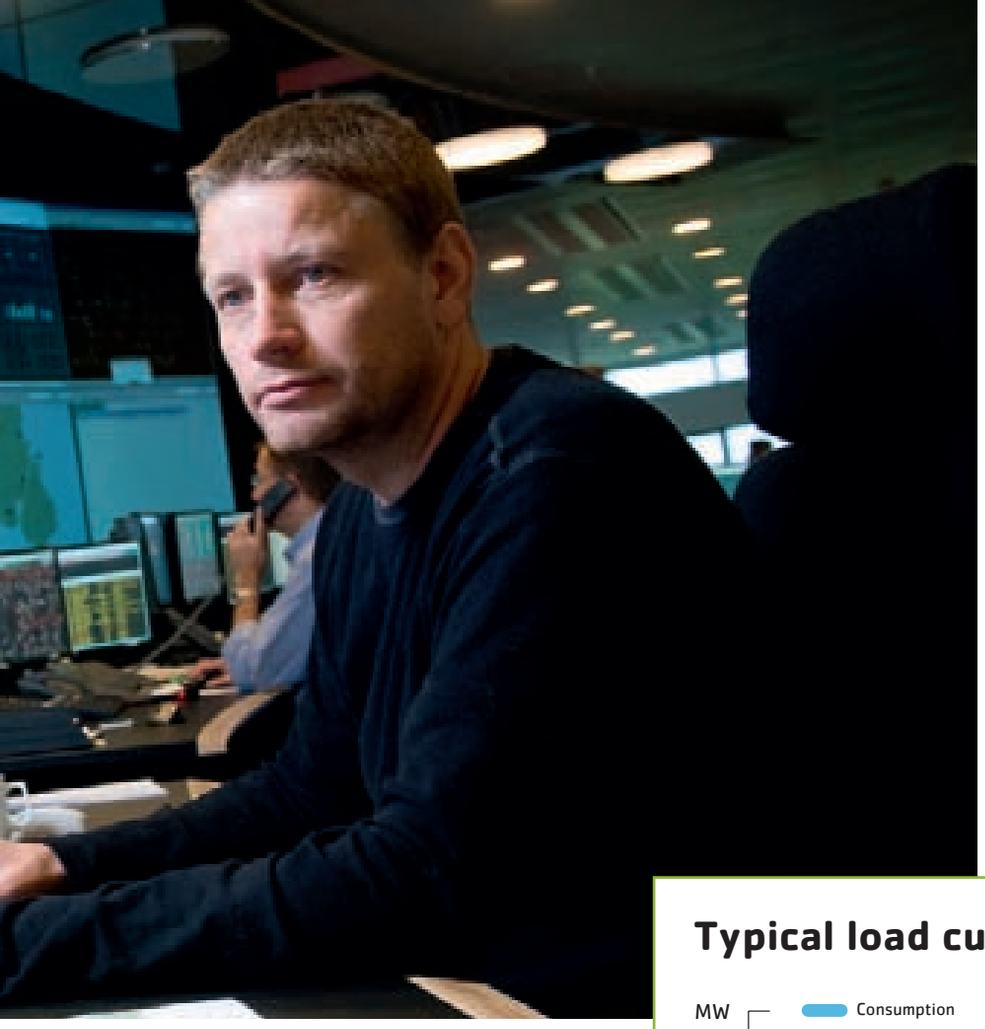
Thus, control centre employees keep a watchful eye on wind power production. If it deviates from the forecasts, they have to take action.

Several advanced systems support the balance supervisors in their daily work. By combining online readings from the wind farms with statistical calculations, forecasts can often be adjusted to make deviations manageable. Inaccurate wind forecasts cost Energinet.dk millions of Danish kroner – because finding another power producer or buyer becomes a race against time.

Accelerator and brakes

The two principal levers used by the employees in this situation are called upward and downward regulation.

– The principle resembles that of a car: If you want to increase the speed, you step on the accelerator. If you are going too fast, you hit the brakes. In our system, the accelerator equals the power stations that can increase their power production precisely when needed. They fire their boilers harder. The brakes are the power stations that can quickly halt some of their power generation, explains Lars Fogt Andersen.



IN SHORT:

The vast amount of wind power is a daily challenge for Energinet.dk, which – as system operator – is responsible for ensuring balance between consumption and production around the clock. All imbalances must be balanced through trading.

On an ordinary day, the levers are pulled approx. 50 times. Therefore, the job as balance supervisor requires paying close attention to the movements of the many curves and graphs on the screens.

Market mechanisms apply

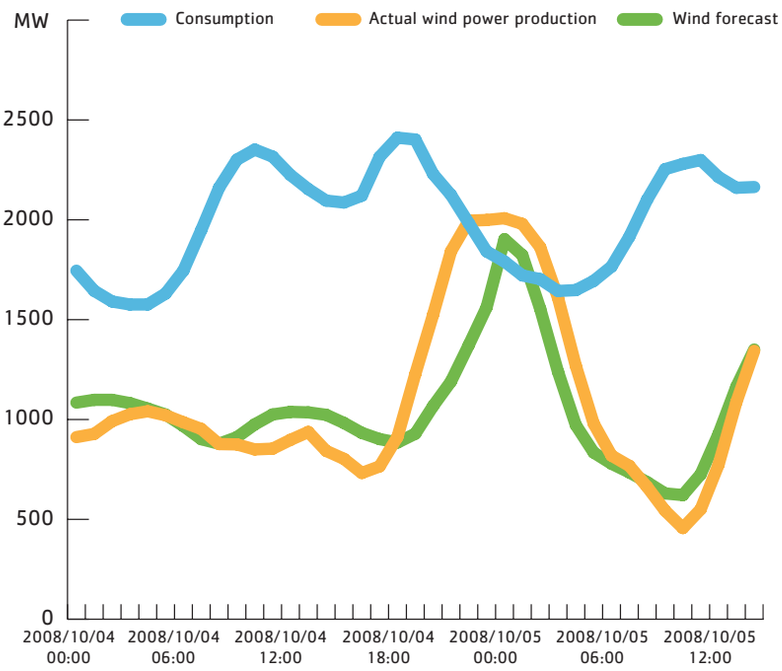
The figures on the 34 screens tell the balance supervisors where in Denmark, Germany, Norway and Sweden they can buy upward or downward regulating power etc., as all power stations with available capacity participate in the Nordic electricity market on a continuous basis. They state how much extra power they can produce at a given time and at what price – and, when there is a power surplus, they state how much of their planned production they can stop at short notice.

Thus, the telephone is an important tool in the control centre. The balance supervisor uses it every time he deals with his Nordic cooperation partners. Danish producers are activated via an electronic message.

– In principle, all imbalances in the system must be balanced through trading. And the market mechanisms apply: We buy extra power at the lowest price possible and sell surplus power at the highest price possible, explains Lars Fogt Andersen.

By Mary-Anne Karas | freelance journalist

Typical load curve, winter weekend



CONSUMPTION: Only rarely does the wind blow exactly as forecast, as Saturday night, 4 October 2008, clearly demonstrated. The wind hit Western Denmark approx. three hours earlier than forecast, and it was so strong that the wind power production from 10 pm until 3 am exceeded consumption by up to 250 MW/hour. As the wind turbines produced up to approx. 650 MW more than calculated, the balance supervisor had to perform downward regulation by selling the excess power, ie pay some generators not to produce. The graph also shows that household appliances were being used intensively at 10 am on Saturday morning - perhaps for the weekly washing and house cleaning - and that Danes were busy using the stove, oven and cooker hood on Saturday evening at 6 pm. The graph covers Western Denmark, ie Jutland and Funen, where approx. three million of Denmark's 5.5 million inhabitants live.
Source: Energinet.dk

Photo: Jens Morten

When wind topples electricity prices

MARKET

The market price tends to dive when wind turbines feed vast amounts of electricity into the power system. In Denmark, this is especially the case when wind-generated electricity exceeds consumption.

It is almost a given: When the west wind is strong, electricity prices plummet at the Nordic power exchange, Nord Pool Spot, where power from the Nordic countries is traded. Anywhere between 50 and 100 hours a year, the spot price hits rock bottom.

This usually occurs when the some 5,200 Danish wind turbines are working at full throttle, transmitting approx. 3,100 MW into the grid at a time when everybody is off work.

– The Danish electricity price is highly sensitive to the amounts of wind power in the system. So the varying amounts of wind make electricity prices go up and down like a yo-yo. It forces the other power suppliers to keep an eye on their costs at all times – and to produce electricity only when it is profitable, explains Anders Plejdrup Houmøller, Director of Business Development at Nord Pool Spot, and adds:

The market ensures minimal environmental impact

– According to the Danish Electricity Supply Act, electricity from renewable energy sources has prioritised access to the power supply grid. As wind turbines also have very low marginal costs, wind-generated electricity is, in fact, offered at the lowest price on the market. In this way, the market mechanisms keep the environmental impact of Denmark's power supply to a minimum.

Exactly how much wind affects the market price, Anders Plejdrup Houmøller hesitates to guess. But he knows that the environment pays the price when wind turbines stand still:

– If you imagine that the wind stopped blowing for a year, many old coal-fired power stations would have to run at full capacity. That would be expensive for consumers and incredibly bad for the environment. But this is a hypothetical situation. If the wind turbines had not been built, the Danish production facilities would have been quite different, Anders Plejdrup Houmøller adds. Every day, the Nordic power exchange calculates the electricity price hour by hour based on estimated supply and demand in the next 24 hours. When the wind turbines generate more power than we can use in Denmark, market prices drop. And when production exceeds consumption, settlement prices to the producer may drop to zero.

Free electricity – then again, maybe not

In that case, the wind turbine owner in principle supplies free power to the grid, but the consumer will not

IN SHORT:

Fluctuating amounts of wind energy result in equally fluctuating electricity market prices. So wind energy increases competition in the market. For approx. 100 hours a year, production exceeds consumption and the market price drops to zero. However, consumers still have to pay Danish environmental taxes and charges on electricity.

experience it as 'free electricity'. The environmental taxes and charges on electricity consumption, which Danish consumers always have to pay, make up approx. three fourths of the total electricity price.

When the electricity price is zero, which it is for approx. 100 hours a year, the consumer only experiences a 25 per cent decrease. Moreover, this only applies to consumers who have made agreements to buy electricity at spot price. If the consumer has a fixed-price agreement, only the supplier benefits from a zero price. However, Denmark is not giving away free electricity to its neighbours. Bottlenecks, as grid congestion is also called, prevent the low price from rubbing off on the neighbouring price areas in need of electricity. Instead, the transmission system operators of the two countries will split the price differential of the electricity transmitted. When the countries are Denmark and Norway, Energinet.dk splits 50:50 with Statnett.

Surplus production exported

Once or twice a year, the wind turbines generate more power than Denmark can use.

– The wind turbines in Western Denmark have an installed capacity of 2,400 MW. So the wind turbines are capable of producing far more electricity than we can use at night in Western Denmark, explains Gitte Agersbæk, a civil engineer working in Energinet.dk's control centre.

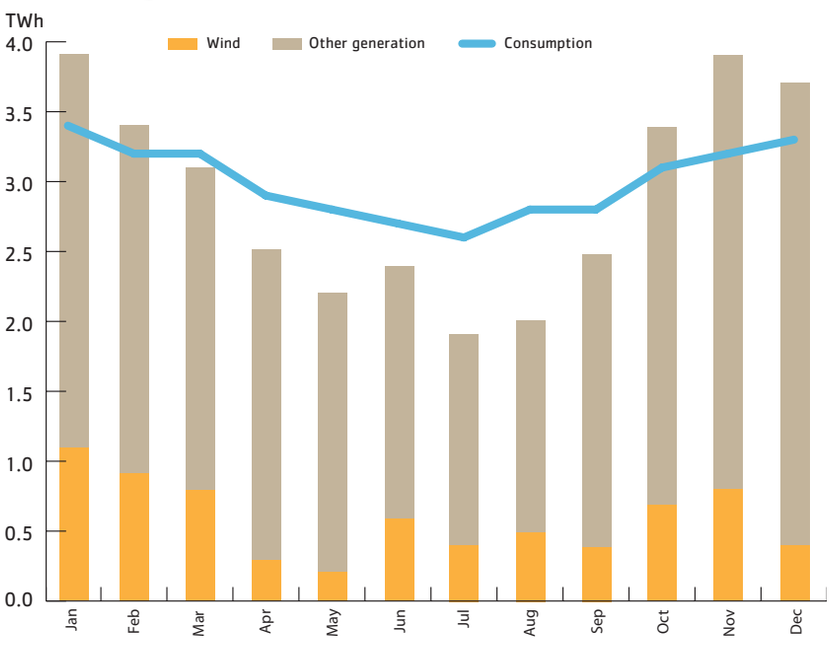
– In those situations, we must quickly find out where in Europe electricity is most expensive, and whether we have available grid capacity to transmit it there, she explains.

In 2009, the power exchange will introduce negative electricity prices, which means that electricity suppliers will actually have to pay to sell their power at times when the market is saturated. The negative prices are an attempt to give suppliers an incentive to halt production, which will make it easier to balance production and consumption.

By Mary-Anne Karas | freelance journalist

Read more about subsidies on p. 49.

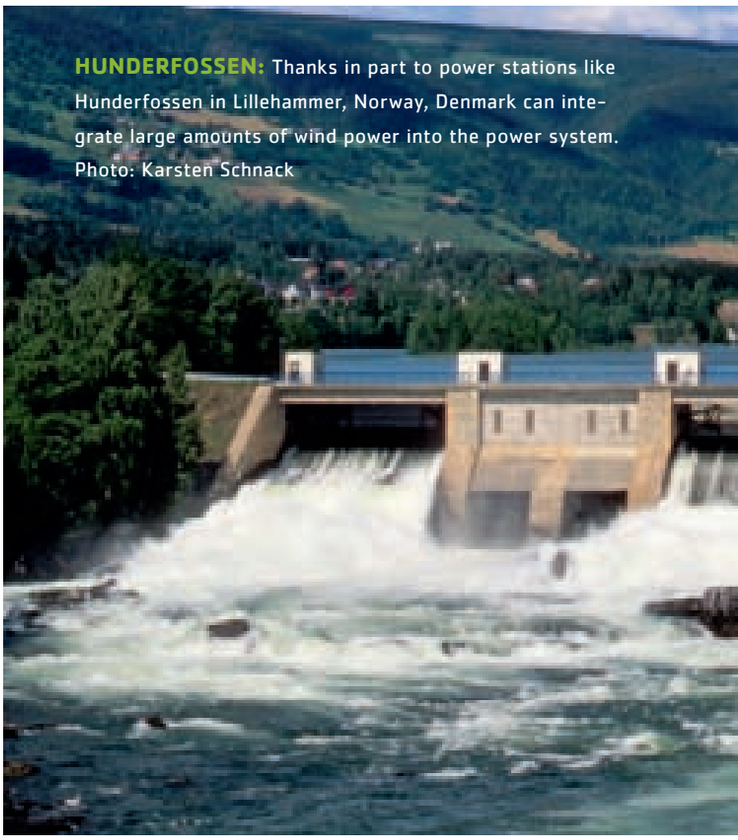
Power generation 2008 broken down by type



WIND POWER: In 2008, total Danish power generation reached 34.6 TWh. The wind turbines generated 7.0 TWh electricity, a drop of some 3 per cent on 2007 as a result of poorer weather conditions. In the period March-September 2008, total Danish power generation was less than consumption, and Denmark saw net imports of hydropower from Norway and Sweden. One of the reasons for the imports was the high levels in the Nordic water reservoirs, which affected the price of electricity.

Source: Energinet.dk

EXPANSION: 'A robust transmission grid is a must for increasing the amount of renewable energy,' says Peter Jørgensen, Vice President of Electricity System Development, Energinet.dk.
Photo: Palle Peter Skov



HUNDERFOSSEN: Thanks in part to power stations like Hunderfossen in Lillehammer, Norway, Denmark can integrate large amounts of wind power into the power system.
Photo: Karsten Schnack

Nordic electricity back and forth

HYDROPOWER

Wind power and hydropower are the yin and yang of the power system. Together, the two forces of nature create the necessary harmony and balance. Thanks to robust Scandinavian interconnections, hydropower serves as a storage facility for wind power.

Wind is much like everything else in life: It comes when we least expect it or need it.

– But that's just a basic condition of the work we do. The unpredictability of the wind is our major challenge, explains Peter Jørgensen, Vice President of Electricity System Development, Energinet.dk, and adds:

– Western Denmark's fortunate geographical position means our interconnections allow us to transmit wind energy to Norway in times of surplus production and to import electricity when the wind calms down. Wind power and hydropower are as close to a perfect match as you can get.

When the wind blows, Norway saves water

In Norway, 99 per cent of electricity is generated from hydropower, which is based on a simple principle of utilising the energy contained in huge amounts of running water.

A hydropower station typically comprises a number of water reservoirs from which water is led through a turbine that powers a generator and thus converts mechanical energy into electrical energy.

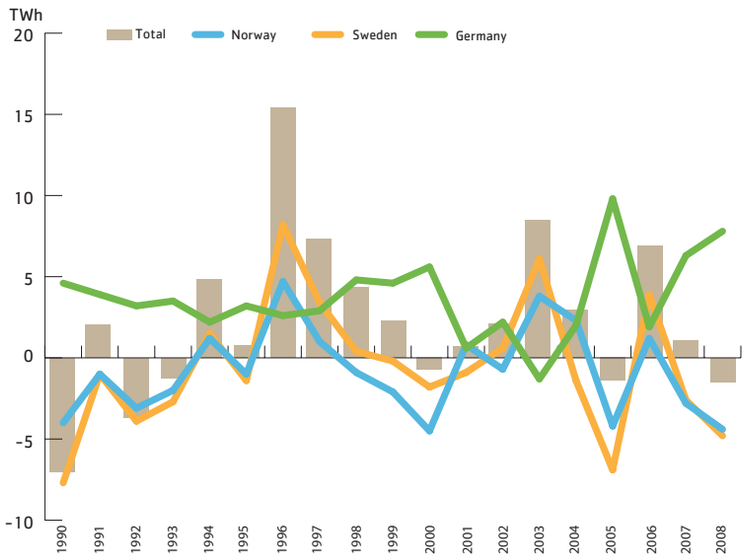
When the Norwegians receive wind-generated electricity through the direct-current submarine cables from Denmark, they close the valves at the hydropower stations and use Danish electricity.

Generating energy from hydropower requires abundant amounts of water and a considerable difference of height between the water stored and the turbine plant. While wind power is a non-storable energy source, hydropower can be stored as needed. Hydropower also allows electricity to be generated whenever it is required.

– In other words, the water reservoirs serve as an energy storage facility. If surplus Danish wind power is utilised to reduce the amount of water used from the reservoirs, wind power is, in fact, stored in hydropower, Peter Jørgensen explains.

This is only possible if the wind power and hydropower interconnections are up to standard, which, fortunately, they are. In 1965, the Danish peninsula of Jut-

Net exports of electricity broken down by country



EXPORTS: Denmark's foreign trade in electricity is strongly affected by the prices on the Nordic power exchange, Nord Pool, which are again affected by the precipitation rate in Norway and Sweden with their predominantly hydropower-generated electricity. In 2008, Denmark had total net electricity imports of 1.5 terawatt hours, TWh, as a result of net exports to Germany of 7.8 TWh and net imports from Norway and Sweden of 4.4 TWh and 4.8 TWh, respectively.

SOURCE: Data for 1990-2007 are based on the Danish Energy Agency's energy statistics. Data for 2008 are based on the data contained in Energinet.dk's Environmental Report 2009.

land was connected to Sweden via the Konti-Skan cable and in the 1970s to Norway via the Skagerrak interconnection.

Robust cables and power lines

Robust cables and power lines on land, at sea and in the air guarantee that electricity is transmitted from the wind turbines off the west coast of Jutland to the regions where it is most needed.

The interconnections are used frequently. In a typical calendar year, Denmark imports and exports close to 10-11 terawatt-hours, TWh, nearly 30 per cent of overall annual consumption.

– The Danish transmission grid is a true link between the Nordic countries and the Continent. A robust European transmission grid is simply a must for integrating large amounts of renewable energy into the system and for making optimum use of the existing grid, Peter Jørgensen points out.

By Mary-Anne Karas | freelance journalist

Read more about market players and the Nordic electricity market on p. 50 and pp. 52-53.

IN SHORT:

Wind power and hydropower go well together. Denmark, Norway and Sweden exchange large amounts of environmentally friendly electricity.

When Danish wind turbines generate more electricity than required, surplus electricity is often transmitted to Norway or Sweden, which reduces the drain on the water reservoirs. When the wind calms down, the hydropower stations step up production, transmitting electricity to Denmark.

Robust interconnections and a traditionally sound working relationship are preconditions for importing and exporting environmentally friendly electricity.

Strong transmission grid ensures good wind energy

INFRASTRUCTURE

Wind power requires a strong transmission grid capable of sending power from the place where it is produced to the place where it is worth the most.

Beaches, sand, dunes and water – the first sight that greets visitors arriving at the lighthouse in Blåvands Huk, Denmark's westernmost point. However, if they let their eyes wander over the waves, 80 offshore wind turbines quickly catch their attention.

About 15 kilometres off shore, wind turbines soar from the sea. Since June 2002, the wind turbines have accounted for approx. 1.5 per cent of Denmark's total electricity consumption.

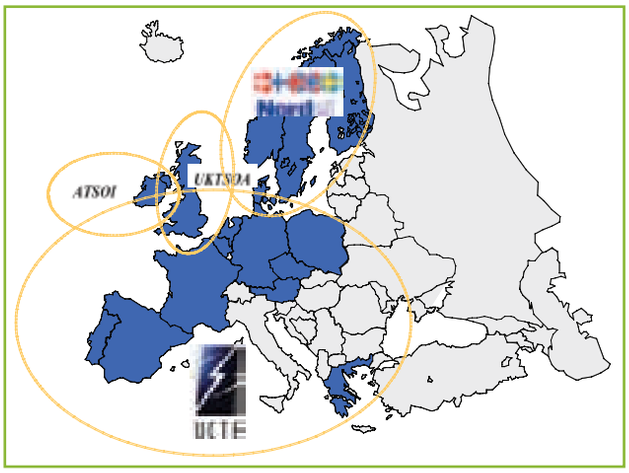
In clear weather, the attentive observer will soon make out the contours of another 91 wind turbines in the horizon, namely Horns Rev 2 offshore wind farm.

The wind turbines will be erected during spring 2009 and are set to be connected to the transmission grid in May 2009. When this happens, the two offshore wind farms at Horns Reef will generate power corresponding to approx 3.5 per cent of total electricity consumption in Denmark. However, a giant effort is required before this can happen.

Dependent on good weather

The Horns Rev 2 offshore wind farm will be the largest in Denmark. The farm is placed 35 kilometres off shore, and Energinet.dk is tasked with bringing power from the wind turbines ashore and transmitting it to the consumers. A task requiring specialist knowledge, money and quite a lot of time, technology and not least loads of cables and good weather.

– Numerous factors impact on this type of construction project, turning it into a jigsaw puzzle. Delivery times on both transformers and cables are long, and the weather may quickly disrupt the time schedule. For instance, the transformer can only be sailed out and mounted on the platform in fairly calm weather, and

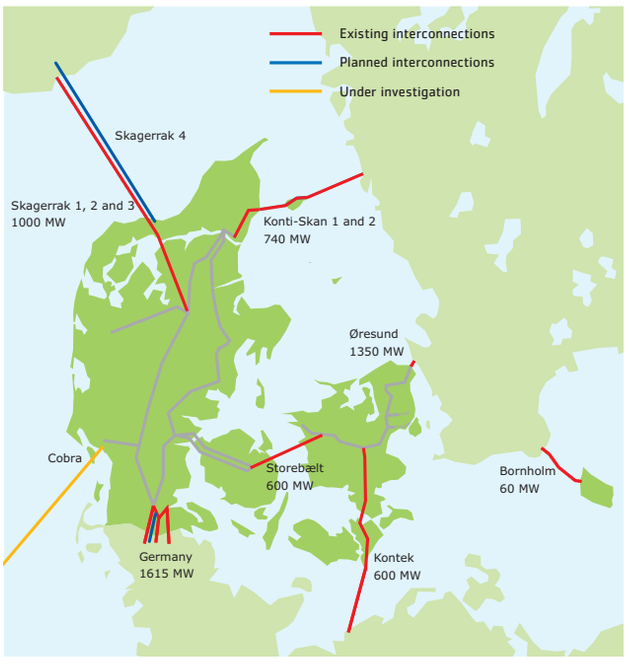


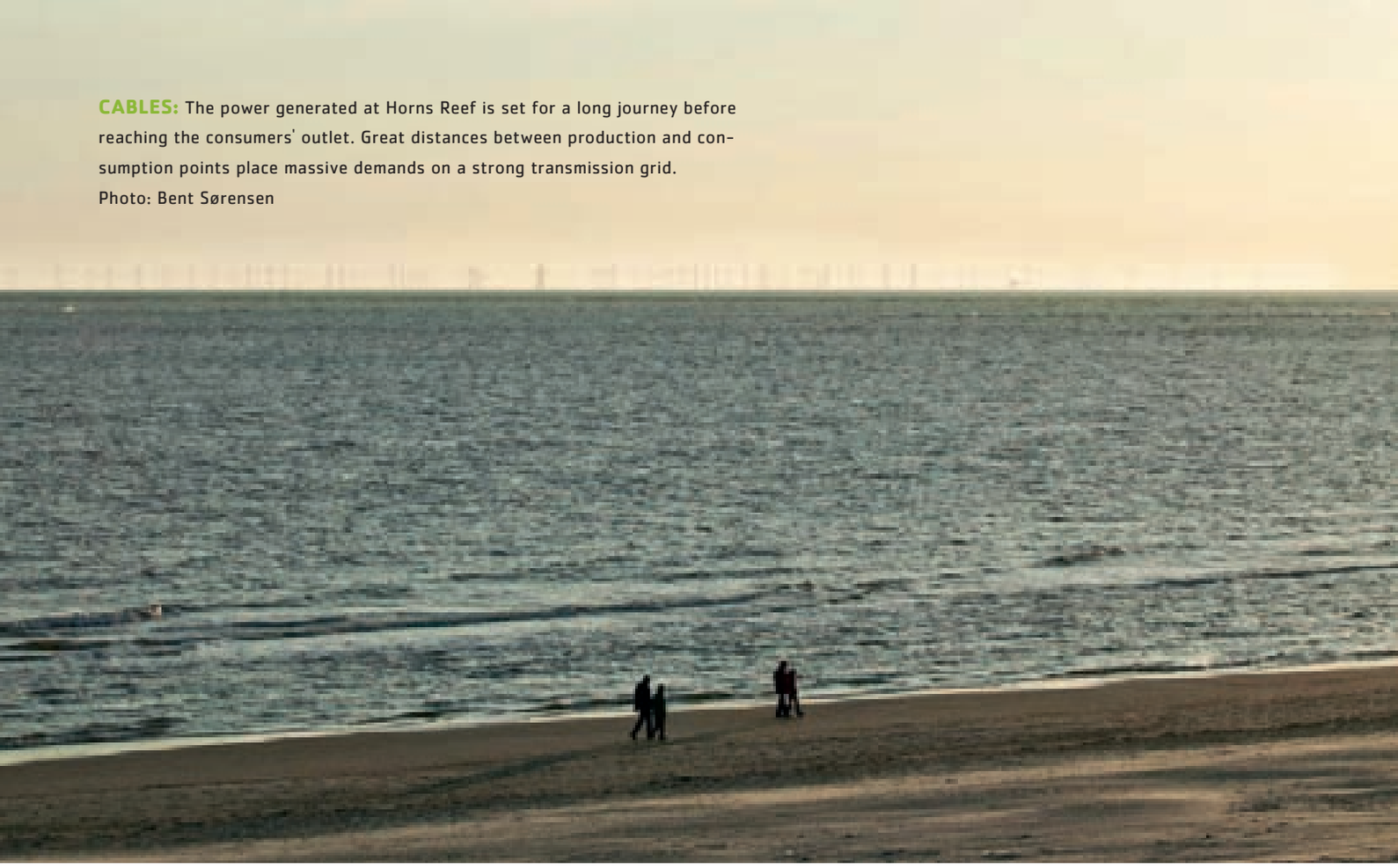
Countries participating in the EWIS collaboration

SYSTEMS: Thirteen European countries participate in the EWIS (European Wind Integration Study) project. This is the first time four European synchronous areas, each with their own frequency, join forces in a collaboration project to plan the future power systems with a high share of wind power. One of the challenges is to find the best possible interplay between technology and markets. The four synchronous areas are now organised in ENTSO-E, which comprises all European TSOs. The cooperative bodies of Nordel and UCTE have been discontinued.

Read more about EWIS on p. 55.

High-voltage interconnections in Denmark





CABLES: The power generated at Horns Reef is set for a long journey before reaching the consumers' outlet. Great distances between production and consumption points place massive demands on a strong transmission grid.
Photo: Bent Sørensen

cables may sustain damage if we work when temperatures fall below 5° C, explains project manager Jens Christian Hygebjerg from Energinet.dk.

And laying the almost 100-kilometre long cable will not do it alone. Offshore wind farms are generally placed far away from the consumers, so electricity often needs to be transmitted several hundred kilometres before reaching the consumers' outlet.

Wind power as a business

– The stronger our transmission grid, the more customers we can reach. We need to expand the international grid and not just the national connections to integrate much more renewable energy into the system, emphasises Peter Jørgensen, Vice President of Electricity System Development, Energinet.dk.

Historically, the infrastructure of national transmission grids throughout Europe accommodates national needs, typically creating bottlenecks when international connections are used for trading large amounts of wind power as imports/exports.

– Electrons do not respect national borders. To ensure optimum exploitation of wind and other renewable energy sources, we need to view it as a business and make sure that energy goes where it is worth the most, explains Peter Jørgensen.

In his opinion, this is why the work of expanding the motorways of electricity should be handled internationally.

New pan-European cooperation

Other European countries have long faced the same problem. This is why some 50 experts from European transmission system operators (TSOs) are discussing the possibilities of working closer together to meet the challenges of integrating vast amounts of wind energy.

– This is the first time work is coordinated on an international scale to address the issues in connection with grid expansion and operation and to share knowledge about the future location of wind turbines. We discuss the necessary framework conditions such as harmonisation of connection rules and managing wind power in electricity markets, etc. Discussions are founded on an awareness that wind power requires dialogue, says system analyst Antje Orths, who is Energinet.dk's representative in the European collaboration project EWIS.

EWIS stands for European Wind Integration Study and boasts participants from 13 European countries.

– The European grid must be used to its full potential to integrate wind energy while maintaining security of supply. Power flows to where it encounters the least resistance. This is the law of physics. We therefore need to work together to establish an optimum grid and good balance possibilities allowing us to manage the massive fluctuations in power generation, which wind power is certain to engender, she explains.

Many scenarios

EWIS works with various scenarios for the interaction between wind power and the rest of the power system. One of the challenges is to uncover how technology and markets best cohere. Discussions are held about grid expansion requirements, reassessment of market regulations as well as exploitation and expansion of grid flexibility based on one interconnected grid.

– We need to know what will happen in Denmark, for

example, in case of a short circuit in Germany and the other way round. Are there any risks we need to foresee and what are the costs? And is anything preventing us from sharing our reserve capacities for the benefit of the environment and the consumers? We have a lot of questions which we can only answer together, stresses Antje Orths.

Although it may at times seem insurmountable to map the interaction of all aspects of the European power system, it is the only way to keep energy efficiency high.

– Lacking knowledge of how to make systems interact in future and of who is in charge of the various expansion plans may quickly result in expensive, wasted investments.

– If Denmark is to reach the goal of 50 per cent renewable energy, all systems must interact, the interconnections being particularly important in this respect, she adds.

Fair share of sun and wind

– If the EU countries are to reach the overall target of 20 per cent renewable energy by 2020, all countries need to accept our interdependence, states Peter Jørgensen and continues:

– Increased European interdependence is basically a precondition for reducing our dependence on fossil fuels.

In other words: Ideally, the transmission grid must be organised so that sun and wind energy can be distributed in Europe where it is needed. In principle, the stormy forces often at play in the North Sea should be able to reach Spain via the wind turbines at Horns Reef. And when the weather turns, Denmark will benefit from environmentally friendly power from Costa del Sol.

By Mary-Anne Karas | freelance journalist

Read more about grid codes and voltage levels on p. 54.

COOPERATION: 'Wind power requires dialogue', says Antje Orths, Energinet.dk, who is participating in the collaboration project EWIS. Photo: Palle Peter Skov

IN SHORT:

A strong transmission grid is a precondition for integrating vast amounts of wind-generated electricity into the power grid. To exploit wind-generated electricity, the European countries are boosting cooperation to expand the transmission grid. The goal is to use all resources to the fullest.

Wind power in Europe

In 2008, European wind power reached 67,000 MW. Approx. 75 per cent of the wind turbines are placed in Germany, Spain, Great Britain, Portugal and Denmark.

WIND FORECASTS

Wind forecasts must be accurate

One metre of wind more or less per second corresponds to the output of a large power station. Forecasts are therefore crucial tools for Energinet.dk.

– When winds heading towards Denmark hit the Scottish or Norwegian mountains, they may change strength and direction, so that we will not get the amount of wind power we had anticipated. We therefore constantly need to adjust forecasts based on the latest weather forecasts and any instant readings we receive from the wind farms, explains Lasse Diness Borup, model developer at Energinet.dk.

One metre of wind more or less per second may not sound overwhelming, but translated into power it corresponds to 350 MW, which is quite noticeable in the system.

Pinpointing the time of impact

– If, for instance, the wind blows two metres more per second than anticipated, wind power will generate a surplus production equalling the output of a large power station. Forecasts are therefore crucial tools for us, emphasises Lasse Diness Borup.

His work involves pinpointing the time when the forecast weather fronts hit the Danish wind turbines and their impact on the power system.

Energinet.dk's control centre needs to stay constantly updated on how much power the wind turbines will generate in the coming 24 hours. This is a key factor for selling power on the Nordic power exchange and maintaining the balance between consumption and production.

Forecast accuracy impacts the spot price in the market and the price of regulating power during the day of operation.

Mountains affect wind direction

Four times each day, Energinet.dk receives forecasts from three different providers of meteorological forecasts.

– When forecasts deviate sharply, we contact the meteorologist on duty at the company whose forecast deviates the most from the rest, explains Lasse Diness Borup.

– We discuss the causes. Often it is a mistake, other times we may need to be aware of greater uncertainties than normally, he adds.

North-westerly winds are particularly hard to predict.

By Mary-Anne Karas | freelance journalist
Photo: Gerth Hansen

METRES PER SECOND:
'Wind forecasts are crucial as they influence the price on the power exchange and the price of regulating power during the day of operation,' explains Lasse Diness Borup, Energinet.dk.
Photo: Palle Peter Skov

IN SHORT:

Wind forecasts are used to calculate how much wind power the wind turbines will generate minute by minute. Energinet.dk bases its expectations for purchase and sale of power in the electricity market on wind forecasts, among other things. So forecasts must be as accurate as possible.

ELECTRIC BOILERS

Turning wind into hot water

In Denmark, gigantic water tanks at CHP plants now function as immersion heaters – to the profit of plant and power system alike.

'A storm from the northwest is expected to hit the country tonight with gusts of up to 25 metres per second.' The Danish Meteorological Institute regularly issues this kind of weather forecast in the winter months.

Strong winds and night make a head-splitting cocktail for the power system, as the combination creates an electricity surplus produced by the imbalance between high production and low consumption. For this reason, CHP plants have now begun giving the power system a helping hand, using the surplus electricity to heat district heating water.

Legislation lowers taxes

Norway and Sweden have long used the immersion heater principle with electricity from hydropower stations, but in Denmark, taxes on electricity used for heating were so steep until recently that it was unprofitable.

However, in 2008, a new act was passed, reducing taxes on electricity used for heat generation at CHP plants to such an extent that the plants can now save money by replacing oil or gas with surplus electricity when the electricity price is low.

So far, this has resulted in four units with water tanks wrapped in 30 cm insulation capable of keeping several million litres of water hot for many hours before it is distributed to the consumers. In other words, right until the storm that made prices plummet has passed, and the electricity price regains its strength. Then, the fuel of choice will once again be oil and gas.

Two birds with one stone

The CHP plant in Skagen at the northernmost tip of Denmark has spotted the trick. When power is cheaper than natural gas and oil, the electric boiler can reduce the plant's operating costs.

This improves the budget of some 2,500 households to which the plant distributes heat, but also produces some positive side effects that Jan Diget, operations manager, greatly appreciates:

– The electric boiler transforms environmentally friendly wind energy into district heat, thus helping to give the plant a green image. The unit has also enabled us to act as a so-called interruptible customer on the natural gas market, since we now have an alternative fuel, he explains.

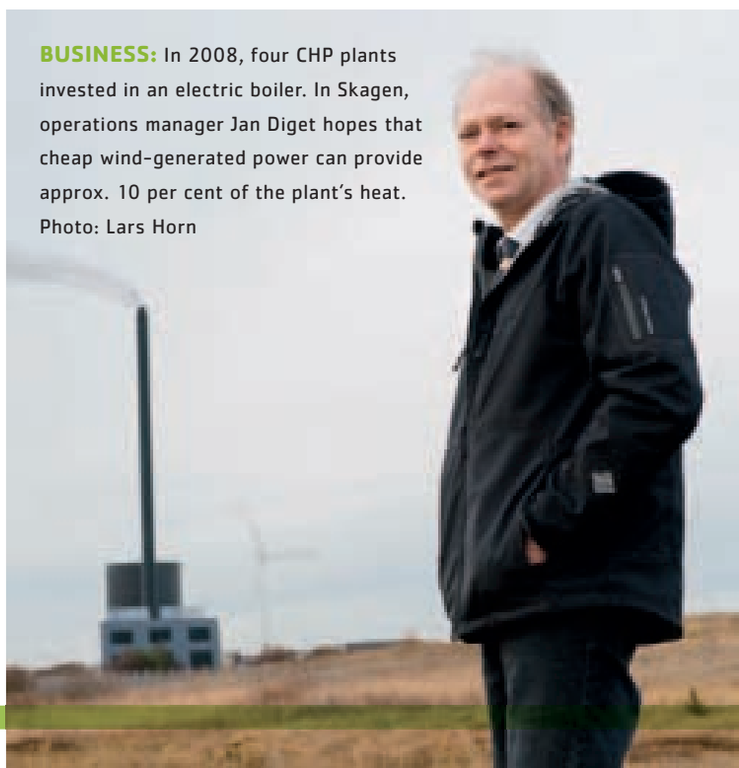
... and highly profitable

According to the plant's own analysis of spot prices in 2007, running the boiler for about 800 hours would have been profitable. That amounts to 10 per cent of the plant's annual heat generation.

– When electricity is free or cheaper than gas and oil, we turn the electric boiler on ourselves. Some days we even make money on power because of surplus production.

Apart from saving money by heating water with inexpensive power, the plant earns money by making the electric boiler's 10 MW capacity available to the power system as a downward regulation unit.

By Mary-Anne Karas | freelance journalist



BUSINESS: In 2008, four CHP plants invested in an electric boiler. In Skagen, operations manager Jan Diget hopes that cheap wind-generated power can provide approx. 10 per cent of the plant's heat. Photo: Lars Horn

IN SHORT:

CHP plants now use electric boilers to produce heat and compete in the regulating power market (downward regulation). An electric boiler works like a battery that Energinet.dk charges when the power system has surplus power. This serves to transform wind energy into heat. Electric boilers are an example of integrated planning of different technologies in the energy system.

MARKET

Negative electricity prices to keep production in check

Wind turbine owners and other power producers will have to respond to market signals if they want to avoid taking a financial risk.

PLAYERS: It would be impractical for Kristian Jacobsen to install a communication device in his more than 10-year-old wind turbines to cut production when electricity prices may be negative. He will have to choose between paying to unload the electricity or bringing the turbines to a complete standstill. Photo: Heidi Lundsgaard

COMMUNICATION:
Today, new wind turbines have a built-in communication device allowing for automatic control, braking or a possible full stop when there is a risk of negative electricity prices. This type of communication device can be installed in most wind turbines.

For more than 10 years, the two wind turbines on Kristian Jacobsen's field on the Danish island of Funen have padded out his pockets with every turn of their blades, but later this year it may even cost him money. Because Nord Pool Spot, the Nordic power exchange, plans to allow the price of electricity to fall below zero whenever supply exceeds demand.

This means that power producers will have to choose between paying to supply electricity, stopping the wind turbines or perhaps just cutting production to meet market demand. Being economically minded, they will probably choose the latter.

– Wind turbines can always profit from responding to market demand, as the last kWh costs us nothing to produce, whereas fossil-fuel based power stations always have manufacturing costs, adds Kristian Jacobsen. He is the chairman of the Danish Wind Turbine Owners' Association, representing 80 per cent of the installed wind power.

Active team players

Anders Houmøller, Director of Business Development at Nord Pool Spot, describes negative electricity prices as just one of many tools designed to cut power production on winter nights when the wind is strong and electricity consumption low.

– More wind power in the power system requires increasingly flexible production as grid overload increases the risk of power failure. Our ambition, therefore, is to turn wind turbine owners and other producers into active team players who respond to market demand, says Anders Houmøller.

At 12 noon, the power exchange determines the electricity prices for the next 24 hours on the basis of the offers made by market players. During the actual day of operation, however, the power stations are always required, against payment, to adjust production to balance the power system. These adjustments come at a high price to electricity consumers, but the need for regulating power will decline once power producers learn to adjust production to market demand.

A signal during critical hours

– Negative electricity prices send producers a signal that, during the critical hours, reflects a possible imbalance between supply and demand. Therefore, negative electricity prices increase the possibility of providing a balanced power system at 12 noon before the day of operation, explains Anders Houmøller.

Consequently, he is convinced that Kristian Jacobsen and other power producers need not be concerned about the new initiative.

– The mere risk of negative prices will provide an incentive to match supply and demand before the price moves below zero, says Anders Houmøller.

By Sanne Safarkhanlou | ssa@energinet.dk

IN SHORT:

Nord Pool Spot, the Nordic power exchange, will introduce negative electricity prices sometime in 2009. Consequently, power producers will be charged for selling their electricity when production exceeds consumption. This way, market forces will help to create the necessary balance in the electricity market.

PLANNING

Everybody must be heard – including the ducks

It takes more than a compass and a chart to find suitable sites for large offshore wind farms. Denmark has good experience with long-term planning in this area.

Drawing: Franck Wagnersen

Some might wonder what scoters, porpoises, channels, ferry routes, military shooting ranges and marine archaeology have to do with wind turbines. But for others, the connection is as clear as day: They are all on the list of parties to be considered when offshore wind turbines are to be constructed.

– It is always a matter of placing wind turbines where they do most good and disturb the least – and, of course, the site must be financially viable, explains Anders Højgaard Kristensen, a civil engineer with the Danish Energy Agency.

'Denmark's gift to the world'

As one of the few European countries, Denmark has a long-term plan for offshore wind turbine sites. The first plan was prepared in 1997, and a few years later resulted in the wind farms Horns Rev 1 off the coast of Esbjerg in the North Sea and Rødsand 1 south of the island of Lolland in the Baltic – each with a capacity of roughly 200 MW.

Svend Auken, the then Minister for Environment and Energy, launched the two wind farms as Denmark's 'gift to the world'.

The wind farm plan was last updated in 2008.

– Back then, we quickly predicted that a conflict of offshore interests would arise, so we chose to bring the parties together and prepare a long-term plan, says Anders Højgaard Kristensen.

Representatives of the parties involved were then tasked with combing the Danish waters for suitable sites. The result was 26 crosses on a map of Denmark.

Before the site search began, a comprehensive research and analysis process had taken place, the results of which gave Denmark an edge when it comes to knowing how offshore wind farms affect the local environment.

Taking wildlife into account

– Assessing sea depths, coast distances, channels and the like is very straightforward. But when questions like how will the wind turbines affect marine mammals such as seals and porpoises arise, another set of supervision programmes is required to find the answer, explains Anders Højgaard Kristensen.

A good example is the scoters by the island of Læsø. The shallow waters southeast of Læsø are among the

Facts:

Four years in the making

As transmission system operator (TSO), Energinet.dk has the overall responsibility for the Danish power system.

The Danish Electricity Supply Act stipulates that Energinet.dk must carry out coherent and holistic planning of the power system. When new high voltage lines and installations are planned, the basis for decision-making includes ensuring security of supply, the environment and sustainability, the functioning of the electricity market and socioeconomics, etc.

Energinet.dk is thus responsible for building offshore transformer platforms and laying cables that land power from the offshore wind farms and lead it to the power grid.

Before the construction of an offshore wind farm can begin, an approval in pursuance of the Danish Spatial Planning Act of the offshore wind farm and the landing facility must be obtained, as well as an approval of the social investment by the energy minister.

Only when all approvals have been granted by the authorities, can the turbines be erected and the power grid expanded.

Despite the comprehensive groundwork required to find 26 areas in Denmark suitable for offshore wind farms, it often takes more than four years from the time the Danish Parliament makes a decision to construct new offshore wind farms and all authority approvals are granted until the farm is completed and commissioned.

Energinet.dk aims to reduce the period to three years.

POTENTIAL SITES: The map shows potential offshore wind farm sites in Danish waters, as well as existing and planned farms at Horns Reef and Rødsand. The 26 potential sites were chosen following careful consideration of a series of interests, including the environment, sea depths and socioeconomics.
Illustration: Energinet.dk

birds' preferred habitats, due to the abundance of mussels and snails, their favourite food. In the past, assumptions that offshore wind turbines would scare away ducks from the area made the Danish Energy Agency halt plans to use the site.

– Ten years on, the environment surveillance programmes have made us wiser. As it turns out, mussels and snails attach to the turbine foundations and the ducks can find food there. That is one reason why we are reconsidering the site off Læsø, says Anders Højgaard Kristensen.

Focus on socioeconomics

Once both the interests of birds and fish are ensured, each potential site has to be considered with regard to the cost of erecting and connecting an offshore wind farm on that particular site.

In addition, the wind farms should preferably be geographically spread to ensure that wind fronts do not hit all turbines at once. A geographic spread helps to ensure that wind energy is effectively integrated into the power system and thus used optimally.

Speeding up expansions

– The mapping we have completed in Denmark makes it far easier for politicians to speed up the expansion of renewable energy at sea. By now, we have conducted so many readings and studies of how turbines affect the environment that politicians more or less have only to deal with the financial aspects. They basically have to determine which site would generate most renewable energy for the money, explains Anders Højgaard Kristensen.

He adds: – In many other countries, politicians lack a proper decision-making basis, which hinders the development of renewable energy at sea.

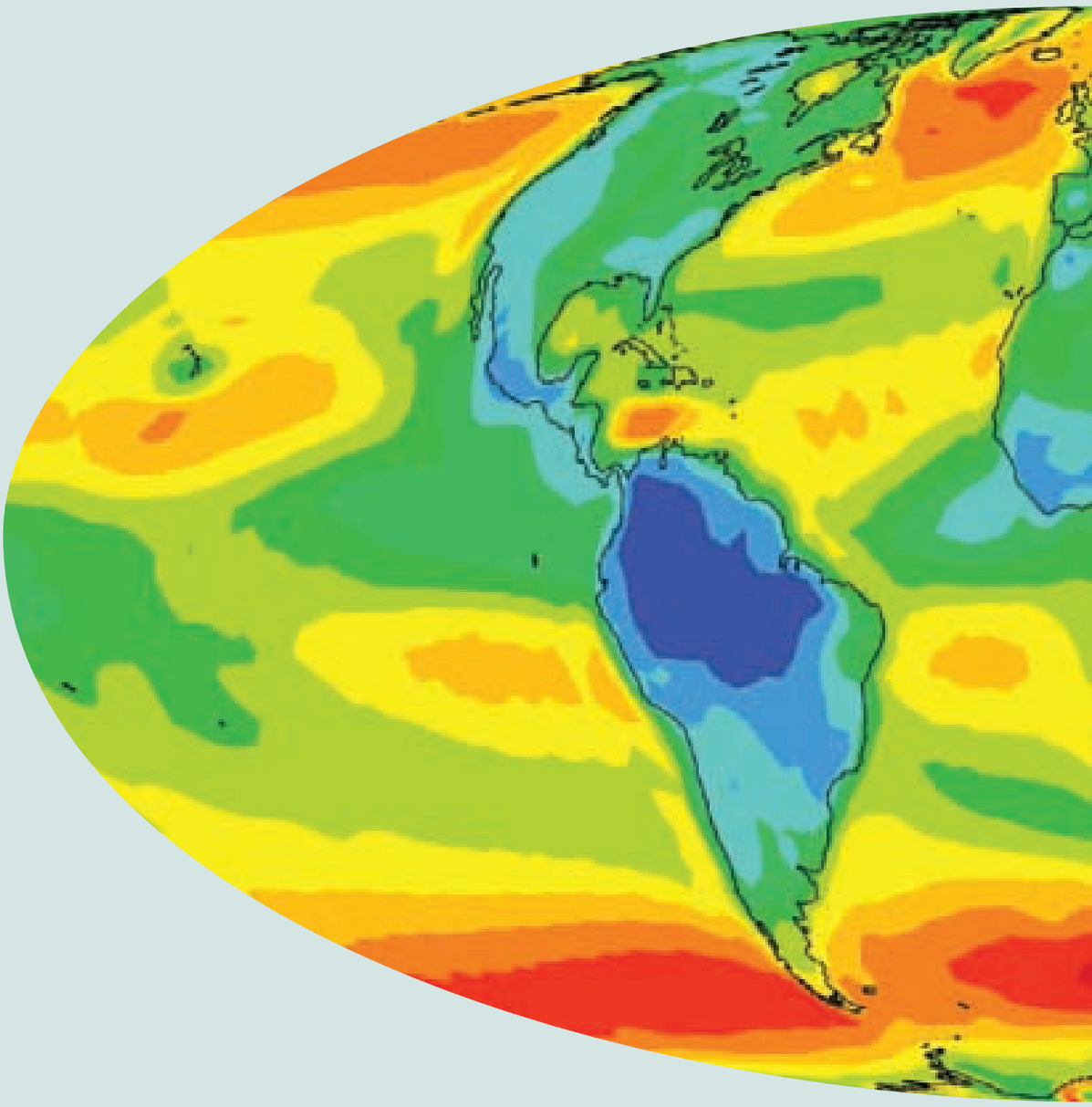
By Mary-Anne Karas | freelance journalist

IN SHORT:

Rapid wind energy expansion requires a long-term action plan. Since 1997, Denmark has had a plan demarcating the best potential offshore wind farm sites. When potential sites are selected, wildlife, sea depths, channels and socioeconomic aspects must be considered.

EXTENSION: Anders Højgaard Kristensen from the Danish Energy Agency is convinced that the thorough groundwork behind the Danish offshore wind farm plan will advance the expansion of offshore wind energy. Photo: Private

Average wind speed



NCEP/NCAR re-analysis averaged winds

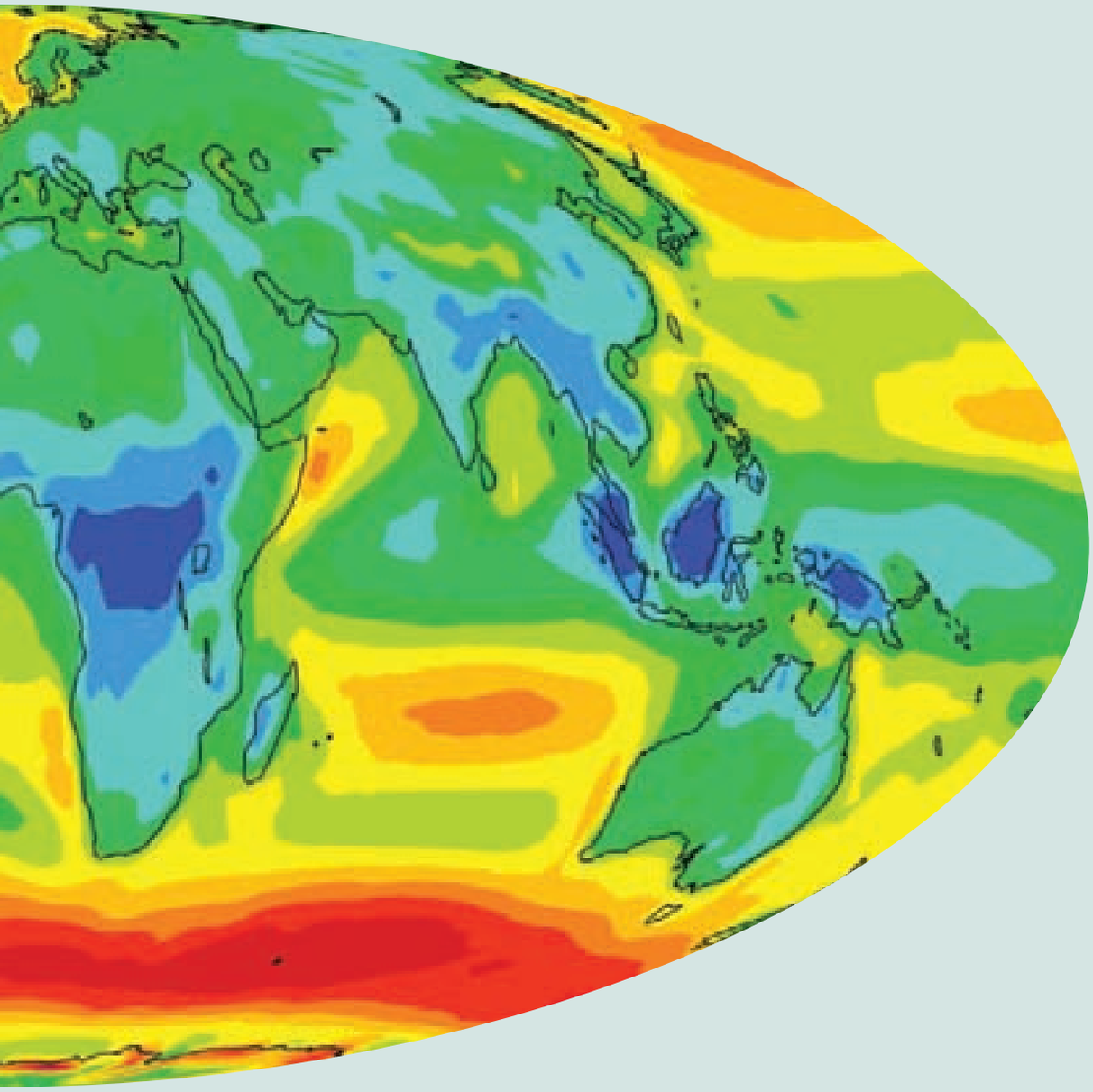
CALCULATIONS: The wind climate in terms of the average wind speed at 10-metres above ground level was calculated from output from a joint re-analysis project undertaken by the USA National Centers for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR).

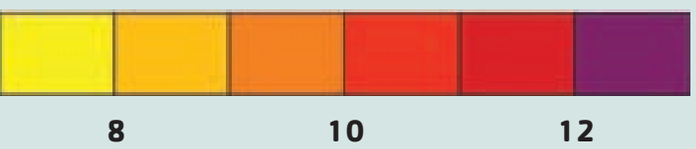
– The re-analysis uses a state-of-the-art numerical weather forecast model and techniques that allow taking into account measurement data from around the globe in a consistent fashion from 1948 to the present day.

This dataset was generated to provide a reference for the state of the atmosphere and to identify any features of climate change. The dataset is also a long-term record of the large-scale wind climate.

Because of the low resolution of the model

throughout the world





10-m AGL wind speed (m/s)

(2.5° latitude × 2.5° longitude), these data serve only as an indicator for the wind resources of a particular region. To estimate the actual wind energy potential, other higher-resolution models, wind observations, and detailed knowledge of the topography and surface characteristics have to be used.

The stronger winds are found between the latitudes of 40 and 50 degrees. In both hemispheres the strongest winds on earth occur over the southern ocean (sometimes called the 'roaring 40s'). Land masses tend to have weak winds, especially along the equator over the rain forest areas.

By Andrea N. Hahmann
Risø National Laboratory for Sustainable Energy
Technical University of Denmark – DTU

INTEGRATED PLANNING OF ENERGY SYSTEMS

Smart homes and smart cars

If everything goes according to plan, Denmark is well on its way to ending its dependence on fossil fuels by 2030. But what will the world be like then – from the point of view of the consumer and of the energy sector? Get a sneak preview below:

Wouldn't it be great to live in a house intent on making you as comfortable as possible?

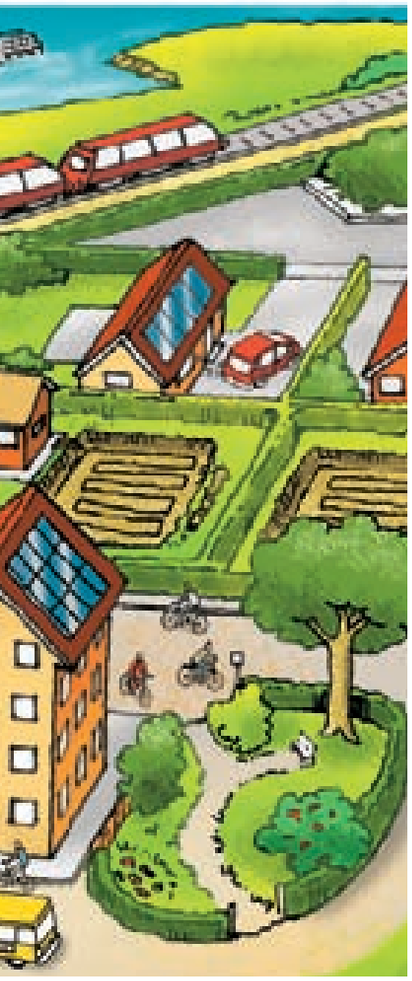
A house that remembers to open and close the windows when you forget to do it or just cannot be bothered. A house that keeps the level of indoor humidity exactly the way you want it. A house that satisfies your desire for a snugly warm living room in the evening and opens the window at night so your bedroom can be cool and airy.

– In 2030, a home will not just be a passive pile of bricks draining your energy budget. In the future, your home will be an intelligent place that, like a butler, ensures your maximum comfort even though you sometimes make mistakes. It is known as a forgiving, smart home, explains Göran Wilke, Head of the Danish Electricity Saving Trust Secretariat.

Smart and forgiving because, for instance, the house knows that you usually shower at 6.30 am before leaving for work, for which reason it makes no sense to use a lot of energy keeping your water-heating system going between 8 am and 4 pm, when you are not at home.

Your house will therefore warn you of the additional energy cost if you suddenly change your habits and, contrary to expectations, take a shower at a later time.

– Of course, you can still take a shower, though it will



THE FUTURE: To test the soundness of long-term investments and solutions, Energinet.dk has endeavoured to create four scenarios illustrating future developments.
One scenario is Greenville 2030 whose internationally oriented citizens take a keen interest in environmental issues.
Drawing: Franck Wagnersen

district heating. These include geothermal heat, fuel cells and PV cells.

As another example, houses could have a micro CHP unit that generates both electricity and heat to replace the gas boiler or a heat pump that produces heating.

– Regardless of the solution required, it can certainly be automated to use electricity when it is cheap and plentiful. For the benefit of your household budget as well as the environment, says Göran Wilke, who is backed by Dorthe Vinther, Head of Strategic Planning at Energinet.dk.

The power system is the backbone

Smart homes are just one example of how we will use energy more intelligently in future.

– Global resources are limited, so we have to use energy wisely. This means we have to integrate tomorrow's energy systems in a brand new way. Today, we refer to gas, heat and transport as different systems.

In the future, they will be integrated into a common, complementary energy system, explains Dorthe Vinther.

– Most of the energy supply will be based on electricity, with the power system forming the backbone that integrates a substantial production of renewable energy into the gas and heating systems and the transport sector.

In other words, different energy sources must be available for different purposes, and all systems must

cost you. Because the house disregards your little blunders and adjusts accordingly, he says.

Wall – move!

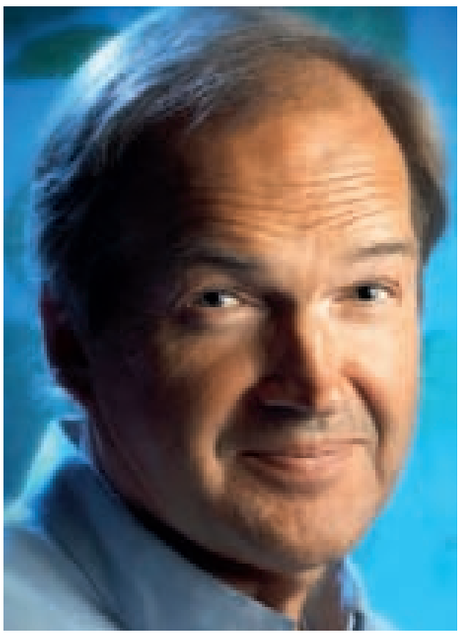
But future homes will offer much more than the omnipresent butler. They will include features like ultra-mobile TVs that let you watch TV wherever you want, and adjustable walls to give your house the optimum layout at any time – depending on where you are in your life. You might, for instance, need a couple of extra children's bedrooms at some point, and presto – wall, move!

And then of course you need not worry about electricity and heating bills if you live in a state-of-the-art house.

– The house of the future is energy neutral on an annual basis. It produces as much energy as it consumes. Thanks to the invisible PV cells in the window panes and on the roof, says Göran Wilke.

If, during the cold, dark winter months, you need more energy than the PV cells generate, it will be bought at the lowest possible price – and you do not have to worry about a thing. Just leave it to the system.

Not all houses, old houses in particular, have adjustable walls or forgiving butlers. Still, energy-efficient solutions can be found, perhaps in combination with



BRICKS: In 2030, your house won't be a passive pile of bricks, says Göran Wilke, Head of the Danish Electricity Saving Trust Secretariat. Photo: The Danish Electricity Saving Trust.

interact intelligently and flexibly offering an array of opportunities for using electricity, for driving vehicles and for heating houses.

From the consumer standpoint, integrated planning of energy systems will be reflected in our cars and homes, which renewable energy will heat in the future:

– Wind power will be in plentiful supply and must be put to optimum use, for instance to heat houses via heat pumps converting electricity to heat. Other houses will be heated by district heating generated from biomass or solar energy, says Dorthe Vinther.

Vehicles must store wind power

It is not just your future home that will become an active participant in the struggle to create a society whose energy requirements are based on renewable energy sources.

– Your car is another good example. It will probably run on biofuels or electricity, says Dorthe Vinther. Electric vehicles in particular will have become increasingly popular in Denmark by 2030.

– Electric vehicles offer the huge advantage that the batteries can be used to store wind power when it is in abundant supply and as battery storage if wind power is in short supply in the power system.

– Of course, it's also a question of making the vehicle and the power system intelligent enough to recharge the batteries when the price is low and to feed electricity into the system when the price per kWh is high, she says. This benefits your household budget as well as the environment.

Sun in the south, wind in the north

So, if you momentarily board the helicopter that gives a bird's eye view of the future, a totally different energy landscape emerges.

A supranet crisscrossing Europe and possibly northern Africa. An 800 kV high-voltage grid allowing green energy to flow unhindered between countries, depending on where demand is strongest and the price therefore the best. Without any national preferences or red tape.

The EU member states have adopted legislation allowing solar energy from sunny regions to be used throughout the system, just as Danish electricity generated from wind power and biomass is distributed to regions where the price is high.

– In 2030, the entire energy sector will be highly international, and the member states will address the environmental challenges in close cooperation. I'm certain that close cooperation in the EU on security of supply and the environment will result in resources being optimally utilised between the member states, says Dorthe Vinther.

And finally: You are in for a treat – if we take all this at face value, the future will be more comfortable and no doubt much more fun. Enjoy the fact that this is all happening right before our eyes.

By Sanne Safarkhanlou | ssa@energinet.dk

ENERGY POLICY: 'In 2030, the EU member states will address environmental challenges in close cooperation,' believes Dorthe Vinther, Energinet.dk. Photo: Palle Peter Skov

CONTROL

No one can stop the wind

All new wind turbines must have emergency brakes; otherwise wind energy will break down the power system.

Wind energy is a gift. However, too much wind energy may become a plague. To avoid this, the transmission system must be able to accommodate the unthinkable.

– Security of supply must always be the top priority. The skill lies in factoring in all critical situations that may cause the power system to break down, explains Jens Møller Birkebæk, Head of Energinet.dk's System Operation Department, Electricity.

In 15-20 years, wind turbines and other renewable energy sources will account for half of Denmark's production capacity. This means that a heavy storm may activate the turbines to such an extent that production rapidly exceeds consumption. We must therefore be able to stop part of the production. Even the wind turbines.

New wind turbines must be remote-controlled

It must be possible to stop all new wind turbines. In practice, this may be done by turning the blades approx. 90 degrees away from normal operating position – a feat to be accomplished in just under one minute.

Today, most wind turbines are remote-controlled by the balance-responsible party for production, so they can easily be turned off. But the intention is for the wind turbines to supply all the power they can.

– This is an emergency situation we are trying to ward off, explains Jens Møller Birkebæk.

– Our task is to organise the power grid and the market so that producers can transmit power to where it is most expensive and thus exploit wind power optimally. However, should market mechanisms fail and we still experience bottlenecks in the grid, we must be able to stop part of the production, adds Mr Birkebæk.

By Mary-Anne Karas | freelance journalist

Read more about the Danish rules of financial compensation on p. 51.

TOP POSITION: If you want to be on top, the wind turbine industry may be just the thing for you. Just ask these fitters working 124 metres above ground to fix a few details in connection with German manufacturer Enercon's erection of an E-112 wind turbine with 50-metre blades. The wind turbine will cover the annual electricity consumption of 3,500 households. Photo: Jan Oelker, Ina Agency Press

INFRASTRUCTURE

Love your car

The Danish power system will reap the benefits of the electric car's rising popularity when in 2025 wind power covers half of our electricity consumption.

ECO-FRIENDLY RACER: It is possible to be green despite having an inclination to fast sports cars. The electric Tesla Roadster's top speed is more than 200 km/h, and it goes more than 350 km per charge. Photo: Sisse Stroyer

Danes have never really taken a fancy to electric cars even though they are tax-free. For this reason, only about 300 electric cars buzz along the Danish roads.

But now the EDISON consortium has its mind set on making the electric vehicle a household product throughout Denmark. The consortium plans to develop a new Danish infrastructure that will allow car owners, the power system and not least the climate to benefit from electric vehicles in the thousands.

– Wind turbines and electric vehicles are a perfect match, says Esben Larsen, associate professor at Centre for Electric Technology at the Technical University of Denmark (DTU), a member of project EDISON.

– Wind turbines supply large amounts of clean energy, and electric vehicles can absorb surplus wind power, significantly reduce transport sector CO_2 emissions and help to balance the power system if the batteries are charged or drained as required, he says.

We are mostly parked

The Vehicle To Grid (V2G) study performed by Siemens and the DTU shows that on average a Danish car

Demonstration on the island of Bornholm

The island of Bornholm in the Baltic has been selected as a test area for the technology being developed by the project.

At the same time, Østkraft, the local power company, and the local authorities have joined forces to bring close to 25 electric cars on to the roads of Bornholm. The ambition is to accelerate development rather than leave it all up to the market.

To find out more about the project, visit www.edison-net.dk. Photo: Think

International cooperation

Project EDISON is a consortium of Danish and international corporations and institutes including DONG Energy, Østkraft, IBM, Risø, Siemens, Rittal and a number of DTU departments. The Danish Energy Association manages the project.

Project EDISON has a budget of EUR 5.7 million and receives funding to the tune of EUR 4.3 million from the PSO pool, from which Energinet.dk annually awards EUR 17.4 million to promote the development of environmentally friendly power generation technologies.

> **“Let’s face it, old habits die hard, and we are used to filling the tank with 50 litres of petrol or diesel now and then...**

is parked for more than 22 hours and travels a distance of less than 40 km a day.

More surprisingly, however, only 12 per cent of cars are on the road when Copenhagen rush hour traffic is at its peak. Incredibly, the other 88 per cent are parked somewhere.

– That’s precisely why the electric vehicle offers such great storage for surplus electricity, Esben Larsen points out.

IN SHORT:

Electric vehicles and wind turbines are a favourable combination that can help to fulfil the Danish Government’s ambition of having wind turbines cover half of Danish electricity consumption by 2025.

Car batteries can help to balance the power system by absorbing surplus wind turbine power when production exceeds demand and supplying electricity to the system when demand exceeds production.

Moreover, electric vehicles will reduce transport sector CO_2 emissions.

– The batteries will help to balance the power system by storing wind-generated electricity when production is high and supplying electricity to the grid when the turbines cannot keep up with demand, he adds.

This is what Denmark needs in order to meet the political ambition of having wind power cover 50 per cent of Danish electricity consumption in 2025.

– This represents a completely new way of energy thinking, offering a wide range of interesting perspectives. Focusing on intelligent and flexible systems will allow us to integrate more wind power into the power grid and reduce overall CO_2 emissions from cars, he says.

New habits

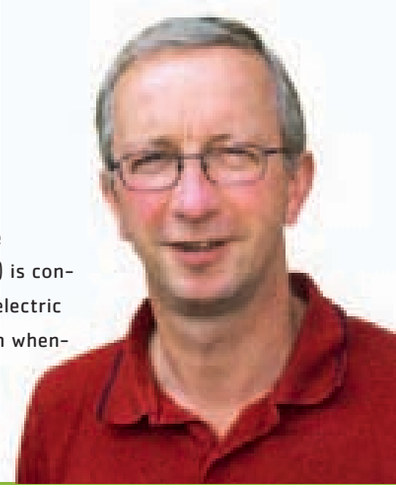
For electric cars truly to capture the Danes’ hearts, however, a technical solution must be found to recharging the car at home, at work and in the cities. Moreover, project EDISON must help to set up ways to control the charging of electric vehicles.

Esben Larsen admits that in the long term the real challenge will be persuading the Danes to invest in electric vehicles – and to remember to plug them in when they are parked. In return, they will be able to travel a distance of 200 km every morning without having to think about the battery.

– Developing the technology is not enough; we also need to change consumer behaviour. Old habits die hard, and we are used to filling up the tank with 50 litres of petrol or diesel now and then, he says.

The tools to speed the process along already exist, and Esben Larsen is convinced that in 2025 one in 10 Danish driveways will have an electric car parked in it.

By Sanne Safarkhanlou | ssa@energinet.dk



BEHAVIOUR: Esben Larsen from the Technical University of Denmark (DTU) is convinced that persuading Danes to buy electric vehicles and remember to plug them in whenever not in use will be an uphill task.
Photo: Private

Soon it will be possible to replace the electric vehicle battery

EASY: Driving an electric vehicle must be easy. This is the motto of the US-based company, Better Place, now establishing itself in Denmark.

Like other electric vehicle owners, owners of Better Place cars will be able to recharge flat batteries at charging stations at home, at work or at traffic hubs.

What is new is that when travelling over long distances, electric vehicle owners may choose to let an industrial robot replace the battery. The plan is to make this possible at a number of service stations throughout the country.

Better Place cooperates with DONG Energy, which sees a great potential in recharging batteries at night when limited consumption and considerable wind power production keep electricity prices low.

ELECTRICITY STORAGE

Moneymaker on wheels?

Your future electric car could be the real deal, believes Jacob Østergaard, professor at the Technical University of Denmark (DTU), who has crunched the numbers.

It has no smell. It makes no noise. It leaks no oil in your driveway, and it can even boost your household budget by as much as EUR 1,300 a year!

– I agree. It sounds almost too good to be true. Nevertheless, Jacob Østergaard, professor at the Department of Electrical Engineering at DTU believes that future electric cars could become quite lucrative for their owners.

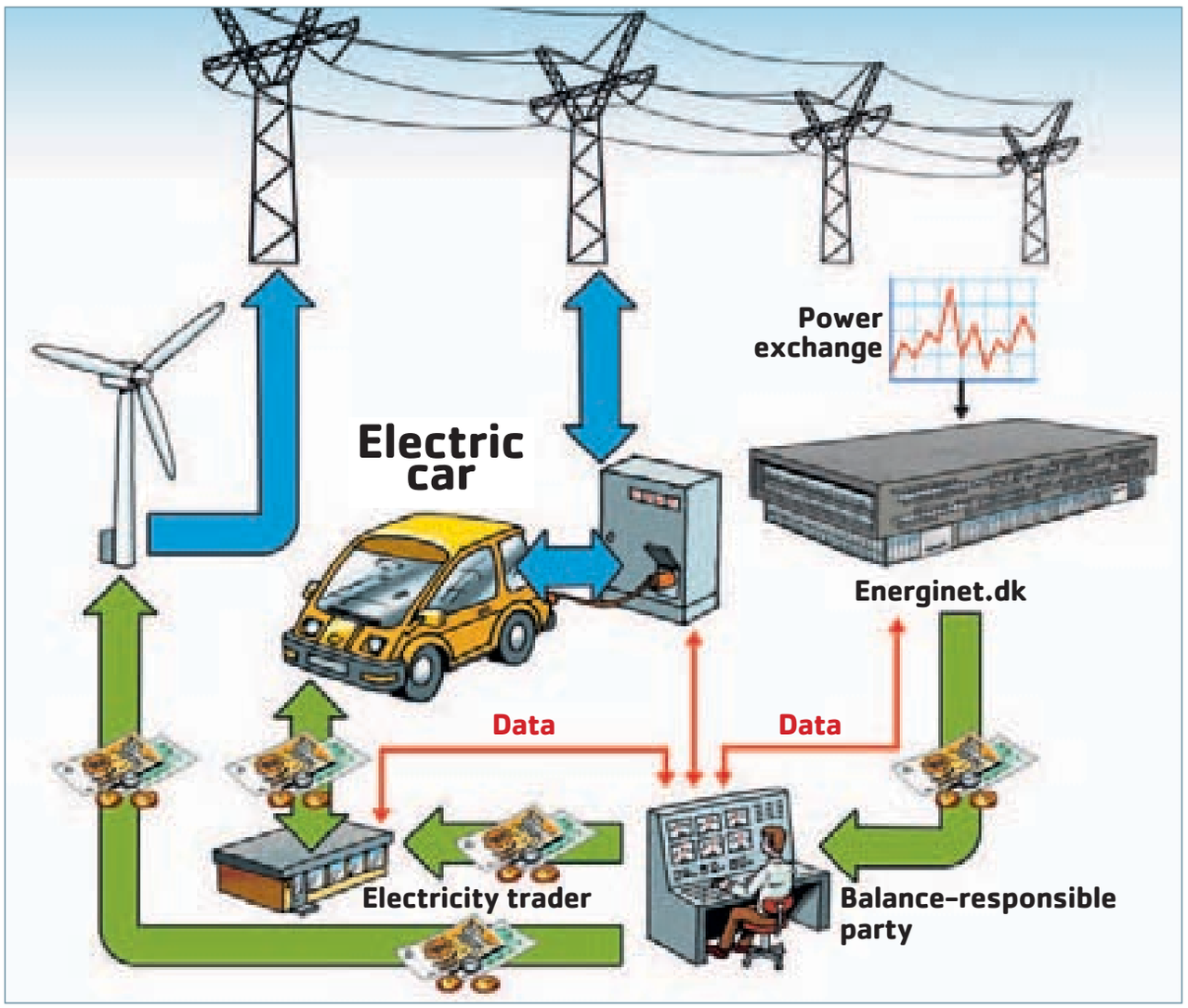
– It costs Energinet.dk – and thus electricity consumers – EUR 67 million a year to have power stations supply regulating power, ie increase and decrease production to balance the power system. In principle, electric car owners might as well earn that money and simultaneously do the environment a favour, says Jacob Østergaard.

Notice the battery

The car battery will make the entire difference as opposed to today when your four-wheeled friend is guaranteed to be synonymous with expenses. Because once parked and plugged in, the electric car can supply a number of services to the power grid.

For instance, the battery will be capable of storing surplus electricity from wind turbines or supplying power to

How to make money on your electric car



CYCLE: In future, you will be able to make as much as EUR 1,300 a year by charging or discharging your electric car battery at the right time, Jacob Østergaard believes. The illustration shows where the money comes from and how the electricity market will settle your electricity account using current electricity prices on the power exchange. Illustration: Franck Wagnersen

TEST DRIVE: Professor Jacob Østergaard from the Department of Electrical Engineering at the DTU did not have to think twice when offered a chance to drive the electric Tesla Roadster.
Photo: Peter Hoffmann, DTU

> **“ It costs Energinet.dk – and thus electricity consumers – EUR 67 million a year to have power stations supply regulating power. In principle, electric car owners might as well earn that money and simultaneously do the environment a favour.**

the power grid when extra kilowatts are needed. All without any risk that you will be left stranded with a dead car battery, unable to get home and pick up the kids on a Friday afternoon.

Developers will naturally create a system that ensures you can always drive the kilometres you set as a condition for making your car battery available to the power system.

Supply and demand

According to Jacob Østergaard and his team at the DTU, the service provided by your electric car will be worth EUR 1,300 annually for the first 100,000 electric car owners. Provided, of course, that the owner remembers to plug in when parking.

– Obviously, market forces also apply here, and supply and demand will determine the value of the service. The more batteries available, the lower the price. On the other hand, a future with more electricity from wind power will raise demand, he adds.

However, before scrapping your petrol-guzzling car for one that is noiseless, odourless and leaks no oil, remember that theory differs from practice. Moreover, the technical systems that will make using the electric car as surplus storage for wind energy possible are not ready yet.

– Car manufacturers – and not limitations in the power system – will undoubtedly determine when electric cars become a reality. To make a conservative estimate, I guess it will take three to four years before we see the first electric car capable of interacting intelligently with the power system, says the professor.

By Sanne Safarkhanlou | ssa@energinet.dk

DEMAND RESPONSE

Green – and cheap – electricity

Conscientious consumers have the possibility to buy the most inexpensive and least polluting electricity. In future, they may even help to balance the power system.

Billund Airport does it. Rømø Holiday Centre does it – and in 10 years' time you will probably be doing it too: Using more electricity when it is cheap and less when it is expensive. This is a great idea that benefits both the environment and the consumers.

In Denmark, the price of electricity is often linked to the available amount of environmentally friendly electricity. Typically, wind power from Denmark or hydropower from the Nordic countries equals less expensive electricity. Conversely, high electricity prices are often linked to electricity generated from fossil fuels, such as coal.

Moving energy consumption

– Therefore, the economy as well as the environment would benefit from our using all the Danish wind power ourselves. Since wind power requires windy weather, however, we must consume energy more flexibly, moving our consumption to times of considerable wind power. Close links between production and consumption will improve security of supply, explains Kim Behnke, Head of Research and Development at Energinet.dk.

For this reason, Energinet.dk supports research that will make Danish electricity consumption more flexible so that electricity customers can take advantage of the cheap hourly rates in the electricity spot market. Moving electricity consumption may seem complicated, but it is possible.

Electricity, shifting with the wind

Many companies already take advantage of the option. The close to 100 electric vehicles used to transport luggage to and from the planes at Billund Airport are recharged at night. This is because electricity is often cheap at night when demand is low – and if it is windy, a good deal of it may even be green electricity.

The many electric radiators heating the flats at the Rømø Holiday Centre are often turned off during the day, but turned on at night. The same goes for the pump heating the Holiday Centre's swimming pool.

Neither Billund Airport nor the Rømø Holiday Centre pays particular attention to whether the electricity is green or not, but the prospect of potential savings suffices to make them move some of their energy consumption.

– And this is precisely the reaction we want from even more electricity customers in future, Kim Behnke points out.

With 50 per cent wind power in the system in a few years, we need to consider all available resources – including demand response – when balance is required on a minute-by-minute basis. The wind may suddenly change, and then we need to take the appropriate measures, Kim Behnke explains.

Consumers as team players

This is why numerous tests are being done to identify the share of consumption that can be moved, how to go about it in practice and what that will cost.

– In the future, individual household consumption may be grouped into large pools via computers communicating with stakeholders in the electricity market. In this way, the limited consumption of thousands of individual households becomes large flexible pools to be activated as needed.

– There's no need for each of us to turn consumption on or off, it should be automated, and active electricity

FLEXIBILITY: 'We could save fossil fuels and thus reduce CO_2 emissions by moving some of our consumption away from peak-load periods to times of considerable wind and low consumption,' says Henriette Hindrichsen, Energinet.dk. Photo: Palle Peter Skov.

RESOURCES: Management at Billund Airport has focused on saving resources for years. Therefore, the many electric vehicles used to transport luggage and supplies to the planes are always recharged at night when the electricity price is usually low. Photo: Billund Lufthavn A/S.

customers should receive a cash bonus for participating, he explains.

– This requires the installation of remotely-read hourly electricity meters and remote control. Without smart electricity meters, we'll get nowhere.

Smart electricity meters

A smart electricity meter, today capable of measuring hourly consumption – and in the future consumption per second – and of communicating household consumption data to the electricity market, may be an integral part of all houses in a few years.

Studies show that close to 10 per cent of an ordinary household's electricity consumption can easily be moved to periods during the day when the price is low. This is particularly relevant when it comes to washing machines, electric water heaters, electric floor heating and electric heating.

Smart meters allow customers to monitor consumption closely and to be charged the hourly market rate. Customers save money by moving some of their electricity consumption to periods during the day when the price is low.

Elegant solution

– If introducing smart meters enables us to inspire the business sector and consumers in general to help out during periods of significant imbalance, it's definitely an elegant solution, Kim Behnke points out.

– We'll undoubtedly save fossil fuels and thus reduce CO_2 emissions by moving some of our consumption away from peak-load periods to times of considerable wind and low consumption, says Henriette Hindrichsen, senior consultant at Energinet.dk. However, she also mentions an array of other appreciable advantages of demand response.

Flexibility stimulates competition

– Wind turbines generate electricity at limited marginal costs, ie once erected wind turbines produce energy at a very low price. Therefore, other things being equal, more wind power will force down spot market prices when it's windy, explains Henriette Hindrichsen.

– Today, most of the electricity is sold to small-scale consumers under fixed-price contracts. This means that their electricity bills will not directly reflect whether they use electricity at peak times or not. But if consumption were measured on the basis of the electricity market's hourly rates, more end-users would become more price conscious, she says.

By Mary-Anne Karas | freelance journalist

IN SHORT:

In the future, small-scale consumers will save money by using more electricity when it is cheap and less when it is expensive. If they change their habits they help to integrate huge amounts of wind energy into the power system. This requires a smart electricity meter and being charged by the actual hourly rate. Prices must fluctuate so much that customers are encouraged to change their habits.

Europe aiming at 20-20-20

ENERGY POLICY/ ECONOMY

The EU member states have agreed on a joint climate and energy policy. The targets are ambitious: By 2020, 20 per cent of the EU's energy consumption must be green.

TARGET: Nobody knows the exact cost of reaching the target of 30 per cent renewable energy in 2020. But one thing is for certain: More offshore wind farms – like this one at Horns Reef in Denmark – must be built. Photo: Energinet.dk

In December 2008, a number of European politicians adopted an ambitious, long-term plan to combat climate change. This climate and energy package has set the bar for the countries' energy policies in the years to come, the objectives of which include having renewable energy constitute 20 per cent of energy consumption.

To this end, Denmark has to produce approx. 10 percentage points more green energy by 2020, at which time renewable energy must make up 30 per cent of total Danish energy consumption. Today, that figure is 20 per cent.

Rich countries to carry the heaviest burden

– The EU is raising a high bar for Denmark because of its economic standing. The economic burden has been distributed between the countries so as to place the heaviest burden on the rich countries, says Stina Willumsen, MSc in political science, from Energinet.dk.

Each country decides how to achieve the set targets – but when the figures are calculated in 2020, the EU's bottom line has to read 20 per cent renewable energy.

Save energy

In addition to increasingly using renewable energy, the EU countries must save energy. The Danish action plan includes a range of energy-saving initiatives, the aim being to improve the national energy accounts towards 2011.

The goal is to reduce Denmark's gross energy consumption by 2 per cent from 2006 to 2011 and still further by 2020. To this end, Denmark will primarily decrease the energy consumption of buildings. Energy consumption requirements for new buildings will be 75 per cent higher by 2020.

Automobile energy consumption is also targeted. One aim of the EU's climate and energy package is for 10

COMPETITION: Stina Willumsen of Energinet.dk believes that higher electricity market prices will spur greater investment in renewable energy. Photo: Palle Peter Skov

per cent of fuel used for cars to stem from renewable energy – for instance, electric vehicles running on electricity from wind turbines.

End of free CO_2 emission allowances

Another familiar means of achieving energy savings is increasing energy prices. In that connection, the CO_2 emission allowance system works as a lever.

Since the system was introduced in 2005, industry and electricity producers have been awarded allowances according to their emissions, free of charge. Extra allowances have been traded at market prices. However, 2013 will bring the end of free allowances for most EU power stations. From then on, they will have to buy allowances at market prices.

The emission allowance system will increase electricity market prices by approx. 20 per cent. Higher electricity prices will help us reach the goal of 30 per cent renewable energy in Denmark faster, believes Stina Willumsen:

– Electricity producers will add the allowance price to the electricity price. This will raise electricity market prices, thus making electricity from renewable energy sources, which can be produced without allowances, more competitive. Higher market prices will spur greater investment in renewable energy, explains Stina Willumsen.

Long-term investment

Nobody knows exactly how much it will cost Denmark to reach the target of 30 per cent renewable energy in 2020. However, the Danish Energy Agency has attempted to put a price tag on the target, and costs are estimated at EUR 0.7-0.9 billion so far.

In addition, the climate and energy package will impose a range of other costs on the entire EU, for instance in the form of higher electricity prices. However, implementing the EU's climate and energy package will also generate cash benefits.

The package will reduce the climate impact and simultaneously promote the development of environmentally friendly technologies, as well as allow the Danish business community to strengthen its position on the market for renewable energy and energy efficiency improvement. Today, Danish exports of energy technology and equipment already totals EUR 6.7 billion annually.

– It is a misconception that environmental efforts cost nothing. They do. But the investment is extremely long term, reaching far into the future. One thing is certain: If we do not act, it will cost far more, emphasises Peter Jørgensen, Vice President of Electricity System Development, Energinet.dk.

By Mary-Anne Karas | freelance journalist

Facts about the EU's climate package and the Danish targets

The EU has committed itself to the so-called '20-20-20 plan'.

According to the plan, by 2020 the EU must:

- reduce its greenhouse gas emissions by 20 per cent compared to 1990 levels
- have 20 per cent renewables in the energy mix (compared to 8.5 per cent today), and 10 per cent renewables in the transport sector
- improve energy efficiency by 20 per cent.

The energy efficiency target is a non-binding, recommended target.

The target of 20 per cent renewables is distributed between the individual countries according to economic capability. However, all countries must meet the target of 10 per cent renewables in the transport sector.

For Denmark this means that by 2020 we must have 30 per cent renewables in our energy mix compared to 17 per cent in 2005.

Read more on www.ec.europa.eu under environment, climate.

SELF-SUFFICIENT: Preben Heberg Krogh has invested EUR 67,000 in an 11 kW household wind turbine, an investment that has made him practically self-sufficient in electricity and heating. He expects to make almost EUR 0.1 million on the turbine in the next 20 years.
Photo: Lars Horn

ECONOMY

Green energy must make good economic sense

The new Danish Renewable Energy Act is based on incentives, as the Danes will have to unite in achieving the EU target of 30 per cent green energy by 2020.

Preben Heberg Krogh conceived his wind turbine idea on one of his habitual trips to purchase wood pellets for his pellet burner. It takes time to heat up a 250 m² house when the pellets must first be retrieved and then fed into the burner, which must also occasionally be emptied of ashes.

– I wanted to find a solution that was both easier and less expensive, and I succeeded, says Preben Heberg Krogh. On 1 January 2008, he became nearly self-sufficient in heating and electricity. On that date, his 11 kW household wind turbine was connected to the grid and his pellet burner replaced by a heat pump, for which reason his annual heating and electricity bill dropped from some EUR 4,000 to approx. EUR 940.

Preben Heberg Krogh has no doubt that the turbine in his back garden produces green energy and is economical.

– If energy prices increase by 5 per cent annually, the turbine investment will generate a profit of almost EUR 0.1 million over the next 20 years, explains Preben Heberg Krogh. This is precisely the thinking that will pave the way for more Danish wind energy.

New act paves the way

The number of Danish onshore wind turbines has declined since 2001, but new regulations and subsidy schemes have been put into place to make more people – like Preben – realise that investing in green energy is much more than mere fancy.

The new Renewable Energy Act, passed by the Danish Parliament in December 2008, was intended to motivate local enterprisers, who played a crucial role in making Denmark the world's leading wind turbine nation in the 1990s.

The schemes under the new act make it more profitable to scrap old turbines and replace them with new, more effective ones.

With the new act, the Danish Government has also made an agreement with Local Government Denmark to find sites for new turbines capable of generating 150 MW in total. Depending on the size of the turbines, this corresponds to 50-80 new onshore wind turbines.

Cooperative wind turbines make a comeback

Another new initiative is local co-ownership, which is to help reopen the possibility of erecting new onshore wind turbines.

– The act simply entitles neighbours to buy shares in the wind turbines, thus ensuring that the investment benefits the local community, explains Stina Willumsen, MSc in political science from Energinet.dk.

She is convinced that neighbours' option to buy shares is key to finding new wind turbine sites.

From 20 to 30 per cent

In many ways, the Danish recipe for increasing the amount of renewable energy seems familiar. More subsidy schemes and new regulations must pave the way for more onshore and offshore wind turbines, and greater attention must be paid to the energy consumption of buildings, households and cars.

The goal is to reduce Denmark's gross energy consumption by 2 per cent from 2006 to 2011. Moreover, if Denmark is to achieve the EU target that 30 per cent of Denmark's total energy consumption must stem from renewable energy sources by 2020, consumption must fall still further. Today, the figure is about 20 per cent.

By Mary-Anne Karas | freelance journalist

Photo: Brian Bergmann

If you want to know more

FACT PAGES

Did you know that 15 per cent of the Danish wind turbines are owned by wind turbine cooperatives? Did you know that the Nordic electricity market it the world's most transparent market as a result of the effective unbundling of the energy sector? And that 70 per cent of the electricity used in the four Nordic countries in 2008 was traded on the Nordic power exchange, Nord Pool Spot?

This is some of the questions that will be answered on the following fact pages. Here we focus on political, cultural, financial and technical factors that also play a major role in wind power integration in Denmark.

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Visit our website www.thedanishwindcase.com

Milestones in the promotion of Danish wind power

1973/74: Oil crisis
The Middle East oil countries (OPEC) increase the oil price by about a factor of three and threaten the industrial countries with an embargo. This strengthens the official Danish interest in nuclear power.

1974/75: NGOs for renewable energy
A number of Danish NGOs are opposed to nuclear power and support the creation of a special NGO (called OVE) for the promotion of renewables (RES).

1975/76: The Danish Academy of Technical Sciences promotes wind power
The Danish Academy of Technical Sciences (ATV) publishes reports in 1975 and 1976 proposing research and development programmes for Danish wind power.

1976: First official Danish energy plan
The first official Danish energy plan focuses on a shift from oil-based electricity production to coal, natural gas and nuclear power. Modest attention is given to RES.

1976: First alternative Danish energy plan
An alternative energy plan prepared by researchers at Danish universities includes significant contributions from RES, especially wind, but excludes nuclear power.

1976: Private pioneers of modern wind turbines
Two modern wind turbines of about 22 kW capacity are installed on private initiative. Their reliable production promotes additional private investments in Danish wind power.

1978: The world's largest wind turbine in operation
Young people with no previous experience with wind power technology build the world's largest wind turbine (2 MW) at the Danish Tvind School.

1978: Test station for wind turbines at Risø National Laboratory
A test and certification station for wind turbines is established at Risø National Laboratory. Researchers at the station pioneer the construction of wind atlases.

1979: Investment grant for private wind power investors
By virtue of new legislation private investors in turbines tested and certified by Risø are eligible for an investment grant corresponding to 30 per cent of the turbine purchase price.

1979: First Danish Ministry of Energy
The new Danish Ministry of Energy focuses on the introduction of nuclear power and natural gas in the Danish energy supply system. Modest support for RES.

1981: Second official Danish energy plan
A second official Danish energy plan prepared by the new Danish Ministry of Energy focuses on low-cost


Photo: Jo Selsing

energy and security of supply, giving modest attention to renewables.

1982: Committee for Renewable Energy
A new committee for the promotion of RES becomes a central promoter of research, development and demonstration of new RES systems from 1982 to 1991.

1983: Second alternative Danish energy plan
A second alternative Danish energy plan prepared by university researchers focuses on energy conservation, RES and the use of cogeneration. It excludes nuclear power.

1985: The Danish Parliament excludes nuclear power in Denmark
The Danish Parliament decides that nuclear power will not be an element in the Danish supply system. This opens up for a more general political support for RES.

1990: Third official Danish energy plan
Ambitious goals for RES are set up, including 1,300 MW installed wind power capacity by 2000. This is subsequently promoted by a favourable feed-in tariff.

1991: The world's first offshore wind farm is erected in Danish waters
The first offshore wind farm consists of eleven 450 kW turbines positioned about 1.6 km from the shore in the Baltic northwest of the island of Lolland.

1993: New Ministry of Environment and Energy
Energy and environment policies are combined in a ministry for energy and environment promoting a rapid increase in installed wind power capacity during the 1990s.

1996: Fourth official Danish energy plan
The goal for installed wind power capacity is increased to 1,500 MW land-based capacity by 2005 and additional 4,000 MW offshore wind capacity by 2030.

1999: Official shift in Danish support scheme for RES
Following the liberalisation of the EU energy market in 1996, new Danish energy legislation supports the shift from the feed-in scheme to green certificates trading. This shift was never implemented.

2002: New Danish RES policy
A new government changes the energy policy for RES to rely more on market forces. Feed-in tariffs are reduced and end up as the lowest ones in the EU, resulting in a net increase of installed wind power capacity in Denmark from 2003 to 2008 of close to zero.

2008: New Danish RES act
Rules for RES are integrated in one single act, and the production subsidy for wind power is increased to DKK 0.25/kWh (3.3 eurocents/kWh) on top of the market price.

By Niels I. Meyer,
Emeritus Professor of Physics,
Technical University of Denmark

FACT PAGES

Cooperatives – local and democratic ownership of wind turbines

GUILDS: One of the characteristics of the Danish wind energy sector is the cooperatives or guilds. Many of the wind turbines erected in the 1980s and early 1990s were and still are owned by local cooperatives/guilds. At that time, the wind turbine 'guilds' from all over the country were often the grass-roots activists, working hard to get permission to have their turbines erected and also participating in public debate.

Since then, single-person ownership has superseded the importance of the cooperatives, and now utilities and large energy companies play an increasing role in the establishment and ownership of wind turbines in Denmark, especially when it comes to large-scale wind farms. However, cooperative ownership is still an important factor, and new legislation from January 2009 is aimed at stimulating the local engagement in and ownership of new wind energy projects. The new Danish Renewable Energy Act imposes an obligation on all new wind energy projects to offer minimum 20 per cent ownership to local people, eg cooperatives.

The background for cooperatives

The overall concept of cooperatives can briefly be described as an autonomous association of persons united voluntarily to meet their common financial or social needs through a jointly-owned and democratically-controlled enterprise. A cooperative may also be defined as a business owned and controlled equally by the people who use its services or who work at it. In 1844, local weavers and other artisans in Rochdale, England, set up a society to open their own store selling food items they could not otherwise afford. This is often referred to as the first successful cooperative enterprise, used as a model for modern co-ops.

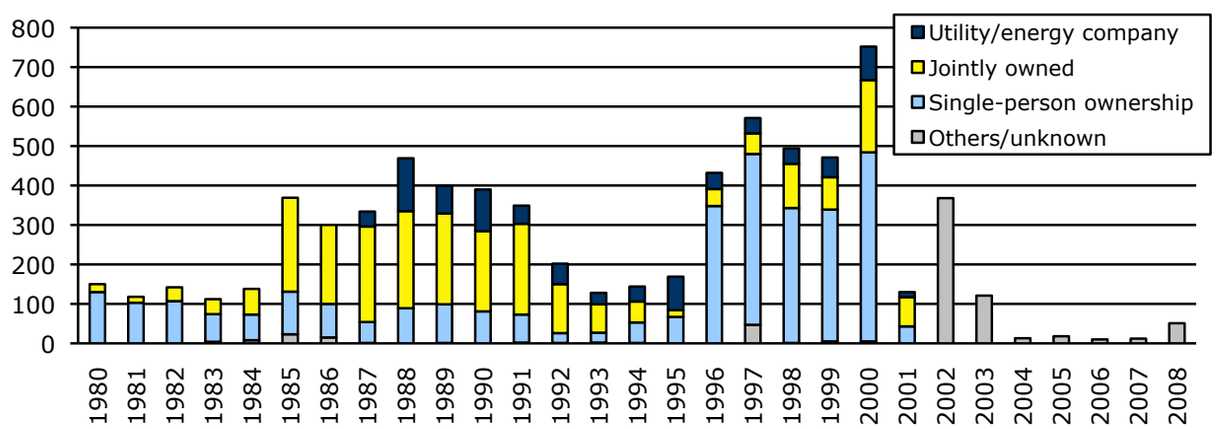
The first co-op store in Denmark was opened in 1866, and the first cooperative dairy was started in 1882 in Western Jutland. Later followed cooperative abattoirs and feedstuff wholesale societies. The foundation of a large number of cooperatives can be considered as one of the most important commercial developments in the history of Denmark.

In the 1970s, many cooperative undertakings disappeared from the villages of Denmark. Some of these are still formally organised as cooperative undertakings, but they have been merged into large units or companies often operating both nationally and internationally. Although the number of cooperative undertakings have fallen, the idea of joining hands, establishing local associations or working groups, is still a widespread phenomenon in Denmark in order to start new businesses or local associations in relation to cultural or social activities. On that basis the wind turbine cooperatives or guilds were formed.

Cooperatives in practice

Wind turbine cooperatives in Denmark are normally partnerships, which in daily practice function as cooperatives. For legal reasons they are forced to establish formal partnerships due to the fact that in Denmark interest on wind turbine loans is tax deductible from the

Ownership of Danish wind turbines



As the number of small turbines (< 600 kW) will decrease over time, the number of cooperatives may also decrease. On the other hand, the new Danish Renewable Energy Act, which imposes an obligation to offer shares for possible local ownership, could revive the cooperatives.

Photo: Jacob Dall, BAM

private income of the individuals in a partnership, not in a cooperative.

Jointly owned wind turbines in Denmark are organised as partnerships with joint and several liability. In practice, the risk of joint and several liability is minimised in that the partnership is unable to contract debt. This is ensured in the bylaws, which maintain that the partnership cannot contract debt, and that the turbines must be adequately insured.

As a partner you own a part of the wind turbine corresponding to the number of shares you buy. Often one share is calculated corresponding to the yearly production of 1,000 kWh from that particular wind turbine.

Private individuals and cooperatives have played an important role in the development of the Danish wind energy sector. On a rough estimate, approx. 15 per cent of the Danish wind turbines today are owned by cooperatives.

Advantages of cooperatives

Local acceptance of a wind turbine project is necessary. Public resistance against wind turbines in the landscape has been and still is one of the largest barriers to the development of wind power.

Opinion polls show wide support in the population in favour of wind power in general. However, uncertainties and lack of information in the planning phase of future wind power projects often give rise to local skepticism.

Experience from a number of wind energy projects in Denmark shows that public involvement in the planning phase and co-ownership increases the acceptance. In addition, two private offshore projects show that cooperative development and ownership is an option also in large-scale projects. The Middelgrunden Offshore Wind Farm (40 MW) close to Copenhagen was developed through cooperation between the municipality, an energy company and not least a number of private individuals. Middelgrunden is the world's largest cooperatively owned wind farm with more than 8,000 members of the cooperative. The Samsø project off the east coast of Jutland (23 MW) was developed by a cooperative with local people on the island of Samsø and the municipality as members.

Strengths of a cooperative

- Active and committed members
- Dialogue and political contacts with many stakeholders through a widespread network
- Large public support
- Direct contact to local authorities

A possible drawback of a cooperative may be the financially weak starting point, but this can be overcome through cooperation with municipalities, utilities or other investors.

Local ownership creates local dialogue and acceptance. Through dialogue with different interest groups widespread understanding of the chosen location and layout of the farm can be generated. Potential conflicts can be avoided by taking direct contact to local stakeholders at an early stage in the development of the project, eg contact and dialogue with local farmers, fishermen, enterprises or inhabitants in villages close to the site.

With local investment in power generation, it is the local people who – at least to some point – take the decision on the planning and implementation of power supply, bringing more responsibility to the local level. Experience from many wind energy projects in Denmark shows that often there are more complaints when unknown investors install the wind power than when the local population does.

Local production of and engagement in wind energy projects make sustainable development understandable. Cooperatives engaged in the development and building of local wind turbines is a concrete example of how private people can contribute to the development of environmentally friendly and sustainable energy production.

By Henrik Skotte
The Danish Wind Turbine Owners' Association

DANMARKS VINDMØLLEFORENING

Liberalisation of the energy sector

UNBUNDLING: Since the introduction of the free electricity market in Denmark on 1 January 2003, all electricity consumers have been free to choose their electricity supplier. The aim of introducing a free electricity market was to create a competitive market.

The Danish electricity market is an integral part of the free Nordic electricity market. The authorities in Denmark and in the EU have promoted liberalisation to further free competition in power generation and trading. Trading in the wholesale electricity market is conducted on the power exchange, Nord Pool Spot, which facilitates trade between generators and traders.

The full opening of the electricity market on 1 January 2003 saw all the players in the Danish electricity business collaborating on setting up rules and specifying the requirements for the systems handling the mutual relations between electricity traders, grid companies, transmission system operators, etc., and the settlement between market players.

New market players

The liberalisation has brought about many new market players. The most important step towards a free electricity market was taken in 1999 when an EU directive dictated full liberalisation of the electricity markets.

This led to the unbundling of the transmission grid from power generation. The grid is now independent, and all market players have equal access to it.

Independent of commercial interests

The state-owned enterprise Energinet.dk was formed to ensure that the main electricity and natural gas infrastructure remains independent of commercial interests.

The Danish Act on Energinet.dk came into effect on 1 January 2005, and as the owner of the main high-voltage grid and the natural gas system Energinet.dk must:

- Ensure efficient operation and expansion of the energy transmission system
- Undertake system operation, ie ensure balance between supply and demand on market terms
- Ensure open access and equal terms for all grid/network users
- Undertake coherent and holistic planning (infrastructure expansion, integration of different types of energy into the power system, etc.).

Energinet.dk also purchases and operates regional electricity transmission grids and natural gas distribution networks, which, due to the state's purchase obligation, must be sold to the state in case of realisation.

By Sanne Safarkhanlou, Energinet.dk

Photo: Jan Djenner, BAM

Subsidies before and now

TARIFFS: Special subsidies are granted to wind-based power generation. Some are granted as a permanent subsidy whereas others are adjusted in relation to the market price so that the total of the market price and the subsidy ensures wind-turbine owners a fixed settlement.

Generally, the trend has been from fixed settlement to more market-based tariffs. That is why the subsidies primarily depend on when the wind turbine was commissioned. In 2008, subsidies for Danish wind turbines totalled EUR 69.5 million.

Wind turbines bought before the end of 1999
receive a subsidy which, together with the market price, ensures a settlement of DKK 0.60/kWh until the full-load-hour share has been used up, and after that DKK 0.43/kWh until they are 10 years old.

The wind turbines will subsequently be settled on market terms, and the subsidy drops to DKK 0.10/kWh until they are 20 years old. The reduced subsidy is adjusted in relation to the market price as the total of the subsidy and the market price must not exceed DKK 0.36/kWh. To this must be added a balancing subsidy of DKK 0.02/kWh.

Wind turbines connected to the grid (2000–2002)
receive a subsidy which, together with the market price, ensures a settlement of DKK 0.43/kWh for 22,000 full-load hours.

The wind turbines will subsequently be settled on market terms, and a subsidy of DKK 0.10/kWh will be granted until they are 20 years old. The total of the subsidy and the market price must not exceed DKK 0.36/kWh. To this must be added a balancing subsidy of DKK 0.02/kWh.

Wind turbines connected to the grid (2003–2004)
receive a subsidy of DKK 0.10/kWh until they are 20 years old. The rule that the total of the subsidy and the market price must not exceed DKK 0.36/kWh also applies here. To this must be added a balancing subsidy of DKK 0.02/kWh.

Wind turbines connected to the grid from 1 January 2005
receive a fixed subsidy of DKK 0.10/kWh in addition to the market price until they are 20 years old. To this must be added a balancing subsidy of DKK 0.02/kWh.

Wind turbines connected to the grid from 19 February 2009
receive the market price plus a fixed subsidy of DKK 0.25/kWh for 22,000 full-load hours. To this must be added a balancing subsidy of DKK 0.02/kWh.

Offshore wind farms
financed by power stations or constructed after a tender procedure are settled according to special rules. The grid-connection costs are socialised and paid for by all electricity consumers. For instance, the 160 MW Horns Rev 1 offshore wind farm receives a subsidy which, together with the market price, gives DKK 0.43/kWh for the first 50,000 full-load hours. Then the market price will apply.

Decommissioning scheme
Wind turbines connected to the grid after 1 April 2001 can receive up to DKK 0.17/kWh in addition to the other subsidies if the new wind turbines replace dismantled ones (decommissioning subsidy).

Costs of balance responsibility
Until the liberalisation of the electricity market in 1999, wind turbines generated power to the grid and received the statutory payment from the grid companies.

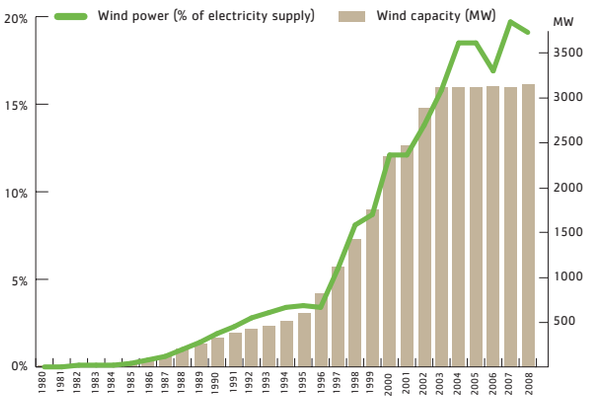
With the introduction of market terms, it was decided that the transmission system operator would be responsible for the sale of power from wind turbines, and that the payment to wind-turbine owners would be collected from the electricity consumers in the form of a PSO tariff; so all costs of balance responsibility would be paid for by the consumers.

From 2003, it became possible for wind turbines not included in any subsidy schemes to undertake balance responsibility and cover the costs of balance responsibility against a subsidy of DKK 0.02/kWh paid by the electricity consumers.

EUR 1.00 = DKK 7.45

Sources: Danish Wind Turbine Owners' Association, www.danmarks-vindmoelleforening.dk, Danish Energy Agency, www.ens.dk, Energinet.dk, www.energinet.dk

Wind capacity and share of wind power in national electricity supply



Even though the wind capacity rose by almost 39 MW in 2008, wind power production was 0.6 percentage points lower than in 2007 as a result of poorer weather conditions. The share of wind power in electricity consumption has been calculated according to the guidelines in the Danish Energy Agency's energy statistics. Note that a different method of calculation is used in connection with the EU RE Directive.

Photo: Polfoto

FACT PAGES

Market players – activities and responsibilities

EFFICIENT: Energinet.dk is transmission system operator in the Danish energy markets and as such responsible for developing the market regulations necessary to ensure an efficient market. Purchase, production and trade in the electricity market are decentralised activities performed by various market players.

The scope of activities for players in the electricity market is based partly on the provisions of the Danish Electricity Supply Act (regulation of grid access, 'unbundling' requirements) and partly on the framework provisions laid down by Energinet.dk (electricity suppliers and balance responsible parties).

Balance-responsible parties

Among the balance-responsible parties (BRPs) are production, consumption and trading companies including purchase organisations and traders. The BRPs have agreed with Energinet.dk to assume responsibility for a specific activity (production, consumption and/or trade).

Electricity suppliers and trading companies

In general, electricity suppliers are responsible for servicing end users and enter into agreements on electricity supply. An electricity supplier must be approved by or have made an agreement with a BRP in order to operate on the market.

Most of the electricity trading companies were established when the distribution companies were transformed into companies with a supply obligation and grid companies.

Grid companies

Grid companies are authorised to operate a distribution network. All grid companies operate as monopolies with an obligation to ensure that registration equipment is installed and metered data supplied to all legitimate recipients. Grid companies must also keep track of which BRP the end user has chosen.

Companies with a supply obligation

Authorised companies supplying end users not having exercised their right to choose their own electricity supplier. The companies have the same rights and obligations with regard to balance responsibility as other market players with grid access.

End users with grid access

As a result of the liberalisation, all end users have access to the grid and are therefore free to choose their own electricity supplier.

Nord Pool Spot

Nord Pool Spot is a power exchange with two market places for electricity trading: Elspot and Elbas. Trade on Elspot is based on the auction principle. Players trade on Elbas to obtain balance when Elspot is closed. Nord Pool Spot also operates an exchange for financial trading/hedging where trading is conducted in the same way as on a traditional stock market and players can hedge against price fluctuations by trading options.

By Lisbeth Rasmussen, Energinet.dk

Rules of compensation when the TSO stops the wind turbines

COMPENSATION: The strongly increased use of wind power in the Danish power system may, in extreme cases, force the transmission system operator to stop wind turbines to avoid the risk of overloading the grid. Energinet.dk will, however, compensate plant owners for loss of earnings.

Currently, Energinet.dk can only order wind turbines owned by power stations to perform downward regulation of the power system as these turbines can be controlled centrally.

Few orders for downward regulation

In recent years, downward regulation has only been used in those rare instances when there has been a combination of storm, cold weather and low consumption. In those cases, Energinet.dk compensated the plant owners for production loss. The new Danish Renewable Energy Act has, however, taken account of the fact that a massive increase in wind power may far more frequently push the power system to the point where the grid needs rescuing at any cost.

The new compensation rules apply to offshore wind farms that have been subject to calls for tenders. The first farm to be subject to the Act is Horns Rev 2, followed by Rødsand 2, located south of the island of Lolland, and the planned 400 MW offshore wind farm near Anholt in the Kattegat.

Very specific rules

The new Act states that Energinet.dk may order the wind turbines to reduce or suspend their production if the landing facilities or the remaining transmission grid malfunction or require maintenance or when there is limited grid capacity.

Downward regulation is only allowed if it is necessary to ensure security of supply or the socially optimal use of the power system. In that connection, the Act points to competition in the electricity market.

The payment of compensation depends on whether Energinet.dk has informed the plant owner of the downward regulation before the planned production has been reported to Nord Pool – ie on the day before the day of operation – or whether the order to perform downward regulation is given as a result of sudden malfunctions and breakdowns.

By Torben Bülow, Energinet.dk

Photo: Per Morten Abrahamsen/BAM

The Nordic electricity market

– focusing on congestion management and transparency

Cross-border electricity trading

It is important that cross-border trading works according to simple rules promoting competition. Cross-border electricity trading is important because some regions in Europe have few local electricity producers. To secure a well-functioning electricity market, it is therefore essential that producers from other regions are able to expose the local producers to competition.

In order to expose local producers to competition, the electricity from outside competitors must flow across bottlenecks in the grid.

Consequently, a key factor for the competition in the European regional markets is congestion management – the allocation of capacity on the grid bottlenecks.

In this article, we will only discuss day-ahead congestion management. There are two market oriented day-ahead congestion management methods: Explicit auctions and implicit auctions.

However, explicit auctions have proved to be a poor day-ahead congestion management system. Consequently, only implicit auctions will be discussed.

Implicit auction – market splitting

Implicit auction ensures that all the capacity on a bottleneck is utilised during all hours with energy flowing towards the high-price area.

There are two kinds of implicit auctions: Market splitting and market coupling.

In case of market splitting one power exchange creates the day-ahead plans for the cross-border flow in its own area.

To explain market splitting, let us consider a bottleneck with a 600 MW capacity. We will consider one given hour of the following day. Assuming, during the calculation of the day-ahead prices, the power exchange discovers that there will be different prices on either side of the bottleneck during this hour: One side of the bottleneck will be a low-price area, whereas the other side will be a high-price area.

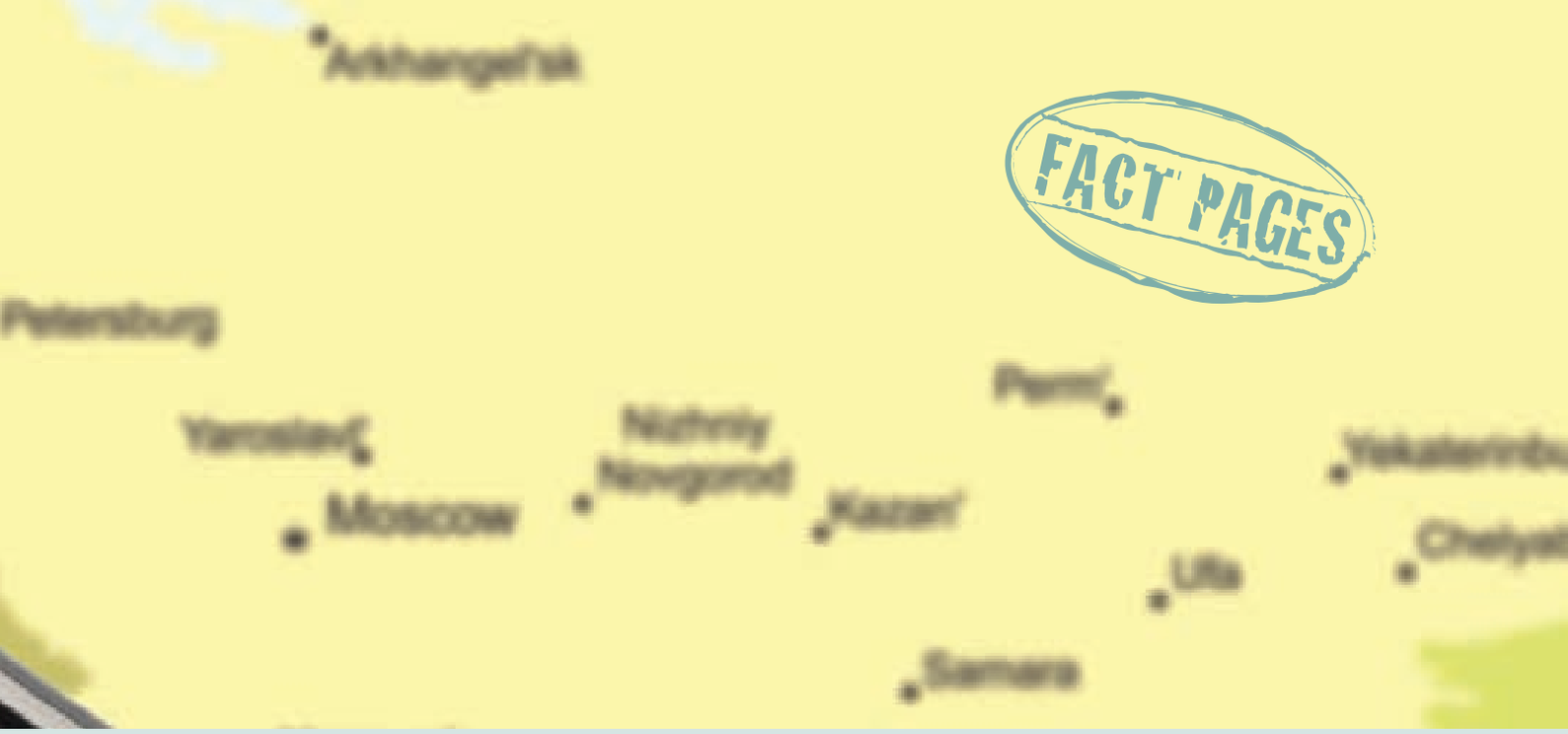
In this case the power exchange will purchase an additional 600 MWh in the low-price area and sell an additional 600 MWh in the high-price area.

The extra sale and the extra purchase are made on the day before the day of operation. The next day, when we reach the given hour, the extra purchase in the low-price area will cause a production surplus of 600 MWh in this area. In the low-price area, there are producers who will produce the extra 600 MWh. However, in the low-price area, there is no corresponding local consumption. Due to the production surplus, electricity must flow out of the low-price area.

Likewise, the extra sale in the high-price area will lead to a production deficit of 600 MWh in this area. In the high-price area, there are end users who will consume the 600 MWh. However, in the high-price area there is no corresponding local production. Due to the production deficit, electricity must flow towards the high-price area.

Hence, once the exchange has made the extra purchase, the low-price area, the extra sale in the high-price area and the laws of nature will do the rest. The next day, cheap electricity will flow from the low-price area into the high-price area.

Naturally, the extra purchase will increase the price in the low-price area. Likewise, the extra sale will decrease the price in the high-price area. Thus, market splitting



also implies that the bottleneck capacity is used to level out price differences as much as possible.

By means of market splitting, the Nordic power exchange, Nord Pool Spot, carries out the day-ahead congestion management on the interconnections between Denmark, Norway, Sweden and Finland.

Furthermore, Nord Pool Spot carries out the day-ahead congestion management on the domestic bottlenecks in Norway by means of market splitting.

Implicit auction – market coupling

Consider a border where two power exchanges meet. The two power exchanges can carry out the day-ahead congestion management on the border using the principle described above. When the power exchanges, during the calculation of the day-ahead prices, realise there is a price difference on the border, the power exchange in the low-price area buys extra electricity, and the exchange in the high-price area sells extra electricity. This day-ahead congestion management is called market coupling.

In the second quarter of 2009, we will have market coupling between the Nordic area and Germany. The two power exchanges involved are the Nordic exchange Nord Pool Spot and the German-French exchange EPEX Spot.

Transparency

In order for market economy to work, there must be transparency. This means all players must have the same access to all price-relevant information.

This level playing field is a precondition for the free market to create the socioeconomic benefits, which have established the wealth in Western societies.

As for transparency in the electricity market, the Nordic countries have become a role model in that there are very strict transparency rules for all the participants in Nord Pool Spot.

These exchange rules apply to all relevant Nordic players, as all the large and medium-sized Nordic players participate in Nord Pool Spot.

For example, unplanned outages must be reported to Nord Pool Spot not later than 60 minutes after the accident causing the outage.

Also, for example, where power stations larger than 400 MW are concerned, maintenance plans and other planned outages must be announced three years ahead of the planned outage: the information must be sent to Nord Pool Spot not later than 60 minutes after the plan has been approved by the relevant company body.

For smaller power stations, planned outages must be announced 6 weeks ahead in time.

Further, all exchange participants must send any other information likely to have a significant effect on the electricity prices to Nord Pool Spot.

Nord Pool Spot distributes the information to the market. Hence, for the Nordic area, the Nord Pool Spot is the distributor of all market information.

The Nordic power exchange

Nord Pool Spot is the Nordic power exchange where electrical energy is traded day-ahead and intra-day. Nord Pool Spot is owned by the transmission system operators in Denmark, Norway, Sweden and Finland.

In 2008, the turnover at Nord Pool Spot's day-ahead auction market Elspot was 298 TWh. The turnover at Nord Pool Spot's intra-day market Elbas was 1.8 TWh.

In 2008, about 70 per cent of the electricity consumed in the four Nordic countries was traded on Nord Pool Spot.

By Anders Plejdrup Houmøller,
Director of Business Development
Nord Pool Spot AS

NORD POOL
NORD POOL SPOT AS

Outline on grid codes and voltage levels

FACT PAGES

PENETRATION: The development of grid codes aimed at wind turbines in Denmark is driven by the penetration of wind power into the Danish power system. The first grid code was published more than 20 years ago when wind power was considered a marginal and unimportant part of the power system. The wind turbines were small and built as single turbines or a few turbines connected to the same point in the grid.

First grid code in 1999

The first grid code dealt with safe operation of the distribution network only, and it therefore focused primarily on relay settings and inrush current limitation when starting the wind turbines. At that time, the grid codes did not place any requirements on wind turbines' ability to perform any kind of control functions apart from being able to disconnect from the power system whenever needed and staying disconnected until the normal voltage and frequency were restored.

This changed dramatically in 1997 when the Danish Government published a plan for offshore wind turbines. According to this plan, starting from 1999, a 150 MW offshore wind farm was to be built and connected to the transmission system in the following 20 years or so.

The TSOs (Elkraft and Eltra, now merged into Energinet.dk) realised the need for better control of the production from wind turbines and set up a task force to develop a grid code.

The first grid code to require control functions in wind turbines was published in 1999 and applied to all wind turbines connected to the transmission grid (above 100 kV). It was the first grid code for wind turbines in the world that required:

- Control of active power production from wind turbines
- Control of reactive power production from wind turbines
- Fault ride through capability of the wind turbines
- Power quality
- Remote monitoring and control capability.

The wind turbine industry succeeded in meeting the requirements for the first two offshore wind farms (Horns Rev 1 and Nysted). The wind turbines had undergone a transformation from being pure energy generators into being power stations with capabilities allowing for much higher wind-power penetration than previously.

Since then, the development of onshore wind turbines has led to the development of a grid code for wind turbines connected to lower-voltage networks featuring almost the same turbine requirements. The reason is the installed wind turbine capacity in the distribution network.

Production often larger than consumption

The importance of the wind turbines connected to low-voltage networks featuring control capabilities is stressed by the fact that in many areas the production from wind turbines in the distribution network is much larger than the electricity consumption.

In 2003, the grid codes were revised to take account of the recent developments in wind-turbine technology, offering even better control functionality. The revision of the grid codes will continue, forcing the industry to develop the wind turbines to become even better power stations. This development is one of the most important preconditions for pushing the limit of wind penetration into the power system upwards.

By Jan Havsager, Energinet.dk

Voltage	Number of turbines	Installed capacity (MW electricity)	Remarks
132-150 kV	152	325.6	Meshed transmission only used on offshore wind farms
30-60 kV	62	97.3	Meshed and radial distribution
10-20 kV	2795	2010.9	Radial distribution
0.4 kV	2163	719.4	Radial distribution
Total	5172	3149.6	

CONNECTION: Almost all small wind turbines are connected to the distribution network, ie from 20 kV and lower, whereas the large land-based wind turbines use the 30-60 kV network. Only the large offshore wind turbines generate power direct to the transmission grid (132 and 150 kV).

European Wind Integration Study

PROJECT: In response to the challenge of meeting the European 2020 renewable energy targets European transmission system operators (TSOs) have launched a pan-European grid study on wind power integration.

The European Wind Integration Study (EWIS) is financed by the European Commission and covers all four European power systems – the Continent (UCTE), Great Britain and Ireland (UKTSOA, ATSOI) and Scandinavia (Nordel).

The study is conducted by a consortium of 15 TSOs from 13 countries. External stakeholders, who sit on the project consultation board (eg the European Commission, EURELECTRIC, EWEA, etc.), give advice and comments to ensure that all aspects are considered within the study.

The final results were presented in the autumn of 2009.

Objective

The study's objective is to obtain the necessary information about technical and operational measures for risk mitigation and safe operation of the European power grids. This is done by steady-state and dynamic analyses using power grid models established within the study.

Market and regulatory aspects are taken into consideration as well. The study examines potential reinforcements of the transmission grid, improved operating procedures and linkage with market arrangements as well as technical and connection requirements for wind power generators.

The EWIS project covers all relevant technical, operational and market aspects relating to the integration of large-scale wind power in Europe. For each of these aspects, the project is subdivided into work packages such as the present situation and market aspects, scenarios and exchange schedules, power system analyses, operational aspects, cost calculation and communication.

The objective for reference year 2008 is to find solutions to actual load-flow problems due to wind power. The longer-term target (2015) is to develop common pan-European recommendations and grid reinforcement measures in order to prepare for future challenges.

Final results

The final results will comprise not only the necessary requirements relating to the further increase in wind power production capacities within a national/regional generation mix in terms of system reliability but also measures to counteract identified limitations. An assessment of the costs and expected TSO investments in such measures, and the consequences of existing, medium- and long-term issues relating to wind power integration will be considered as well.

Furthermore, the results will cover stability assessments and impacts and recommend harmonised grid code requirements for wind turbines to ensure the successful integration of wind power into European power grids while maintaining system security and stability for the 2015 time frame.

By Antje Orths, Energinet.dk

Visit the EWIS website for further information: www.wind-integration.eu

ewis
european wind integration study

Focus on Danish energy solutions

WWW: Denmark invites you to share our climate and energy solutions. We would like to show you our energy plants and our energy systems, all based on experience gathered and optimised over the last 25 years.

You can visit Denmark or read about our energy solutions on a number of interesting websites. Let me introduce a few:

www.energymap.dk is a website providing information on renewable and conventional energy installations in Denmark. The participating companies and institutions are ready to inform you about their installations or products.

www.kemin.dk is the website of the Danish Ministry of Climate and Energy. Here you will find information on the Danish efforts to replace fossil fuels with renewable energy.

www.thedanishwindcase.com is the website for the Danish efforts to integrate wind energy into the power system.

www.energinet.dk is the website of the Danish Transmission System Operator. Here you will find information on the current production of all Danish wind turbines and information on the Danish energy system.

Photo: Bent Sørensen