# System Plan 2006

ENERGINET.DK

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Energinet.dk

**System Plan 2006**
Published by Energinet.dk

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# Contents

# 1. Introduction

Energinet.dk was established in the summer of 2005 with reference to a broadly based political agreement concluded in 2004. Subsequently, the Danish State assumed responsibility for the operation of the main electricity and gas transmission systems in Denmark.

The tasks of Energinet.dk relate to the social responsibility of ensuring market development and security of supply, while at the same time safeguarding the environment within the framework of an efficiently managed and rationally developed main infrastructure for electricity and gas transmission.

This is not possible without planning. The transmission systems must optimise all these interests at once – and in an optimum way from a socio-economic point of view. This requires comprehensive and ongoing development of analyses and methods.

Whereas there used to be three transmission system operators (TSOs) in Denmark, Energinet.dk is now the one national TSO for electricity and gas. Coordinating electricity and gas systems and harmonising the electricity systems in Eastern and Western Denmark pose a substantial challenge. System Plan 2006 is the first system plan to cover all of Denmark and represents the first step towards meeting this challenge.

System Plan 2006 provides a status for a number of fundamental preconditions for electricity and gas planning. These are described in chapters 5-12. Chapter 2 (Conclusions and focus areas) is a review of the forward-looking parts of the System Plan, focusing on the most important challenges to planning in the coming years and at the initiatives which Energinet.dk will be introducing to meet these challenges.

Enjoy your read.

Peder Ø. Andreasen
President and CEO

# 2. Conclusions and focus areas

Energinet.dk's vision for the development of the Danish electricity and gas infrastructure is clear. Coherent planning must ensure that the electricity and gas infrastructure is robust and fully optimised in view of developments in the Danish energy sector – in both the short and the long term.

Planning must support the objectives of Danish and European energy policies, including the Danish government's Energy Strategy 2025. Furthermore, the development of the electricity and gas systems must strike a balance and take account of the wish for a high level of security of supply, emergency management, the functioning of the market, the environment and socio-economics.

**Cooperation is a priority**

For the purpose of these planning activities, Energinet.dk relies on its cooperation with a number of external parties. Cooperation within the area of planning is broadly based and extends in several directions. For example, Energinet.dk engages in cooperation with TSOs in the neighbouring areas, the regional companies in the electricity and gas sectors, generators, the authorities and a number of research institutions. High priority is given to this cooperation, which will intensify in future.

A number of new national committees for the electricity sector have been set up in the form of a Transmission Committee, a Grid Committee and a Market Committee.

Energinet.dk is responsible for the long-term planning of the main electricity transmission grid in Denmark. The transmission grid consists of both the 132/150 kV and the 400 kV grids and must therefore be planned and operated as a whole in this context. The regional transmission companies own the 150 kV grid in Jutland and on Funen and the 132 kV grid in Eastern Denmark. The companies make the grids available to Energinet.dk. Under the agreement on Energinet.dk, the company (the Danish State) is granted a pre-emptive right and obligation to buy the transmission grids. This naturally requires close cooperation on the most expedient development of the main electricity system.

Furthermore, high priority continues to be given to ongoing contact with the grid companies. The optimum development of the whole electricity infrastructure and the efficient handling of a very local production system require close cooperation with the local grid companies.

As regards natural gas, cooperation primarily takes place nationally via the Gas Market 2004 project with the distribution companies, and bilaterally with the gas transmission companies in the neighbouring areas.

**Challenges**
As regards the electricity system, the handling of system operation, securing sufficient production capacity and integrating large volumes of local production remain keywords and focal points for Energinet.dk's planning. The electricity infrastructure must support the increasing use of renewable energy. In this context, the construction of new offshore wind farms and the expansion of existing wind farms will place new demands on the system and entail a need for developing the transmission grid.

As regards the gas system, the market is characterised by a small number of commercial players, limited competition and an ever more pressing call for clarifying the need for establishing new infrastructure to ensure the availability of gas for the Danish market from new sources of supply. In 5-10 years, gas from fields in the North Sea can no longer meet demand in Denmark.

Finally, planning of the electricity and gas infrastructure must to a larger extent be coordinated, where this is expedient.

Energinet.dk addresses these tasks and challenges through constantly prioritising, focusing and increasing the efficiency of its planning activities. New initiatives and tools are required in order to continuously develop the planning tools and methods already available. There is a need to give higher priority to the work involved in redesigning the electricity infrastructure with a view to being able to handle a large share of local production. The high priority given to such development work and the integration of electricity and gas have been decisive objectives for the organisation of Energinet.dk's planning activities.

A number of measures have resulted from the planning of the now merged companies, while a number of new activities have been launched by Energinet.dk. Moreover, we have identified several focus areas within which we intend to launch a number of new and forward-looking initiatives.

## 2.1 Focus areas

### *2.1.1 Electricity system*
The **power balance** in Scandinavia and in Northern Europe is becoming ever more strained. In Denmark, the situation in Eastern Denmark is becoming particularly critical, especially in the run-up to the commissioning of the power link across the Great Belt, but also after this time. Up to 1,000 MW of production capacity may be scrapped, mainly because some of the existing plants do not comply with $SO_2$ and $NO_x$ emission thresholds contained in the EU directive on large combustion plants. At the same time, half of the primary power stations in Eastern Denmark are 30 years old or more, which may also affect security of supply. Establishing a new large power station will in many cases take about 10 years from start of planning to commissioning.

Energinet.dk's focus areas:

- In autumn 2003 and up until June 2005, Elkraft System and Eltra cooperated with the Danish Energy Authority on security of supply. The work involved

discussing operational definitions of security of supply. Based on this work, among other things, Energinet.dk will further develop criteria, methods and tools for quantifying and monitoring developments in security of supply. Energinet.dk has launched a strategy process, which includes the objective of determining a desired level of security of supply. The further development of models and methods and the future quantification of security of supply will be based on the results of this strategy process.

- An important tool for assessing system sufficiency is power balances. At a Nordic level, the work going into developing methods for assessing power balances and establishing adequacy criteria is coordinated by a Nordel working group headed by Energinet.dk.

- Energinet.dk will continue to work for the introduction of the best possible market incentives for the establishment of new power station capacity. It is also important to create the physical framework for it to enable new generators to establish new power station capacity on commercial terms – optimised in view of the operational reliability of the power system and the available infrastructure.

- Moreover, Energinet.dk gives priority to its continued efforts to promote demand response as a means to strike a balance between supply and demand in both the short term and the long term. Via our PSO R&D 2005 and 2006 programmes, Energinet.dk has subsidised eight research, development and demonstration projects on the control of electricity supply systems and electricity consumption. All the projects include the potential for demand response as an important element. A better basis for assessing the potential in Denmark is therefore expected to be available within a period of 3 years.

An increasing volume of wind power production and increasing focus by our neighbours on imbalances on the interconnections are expected to increase the **need for ancillary services**. It is therefore important to reassess and optimise the use and purchasing of ancillary services at regular intervals.

Energinet.dk's focus areas:

- With a view to ensuring efficient competition, ancillary services have since January 2004 been procured via open call procedures. All production units must, in so far as is possible, be activated for the delivery of ancillary services. However, these services continue to be offered primarily by the large generators.

  Energinet.dk is therefore working to develop the models for the purchasing of ancillary services so as to make it worthwhile for electricity consumers and minor generators, including owners of local electricity and CHP units, to offer these services. In this way, they can help to strengthen competition, while at the same time increase the security of electricity supply in the short term.

  In 2006, Energinet.dk will work to procure the necessary manual regulating power reserves on a daily basis and on market terms in Eastern Denmark.

The experience gained here will contribute to and form the basis of a nationwide scheme.

- Emergency power units were previously an overlooked resource for the main electricity system. In future, Energinet.dk would like more emergency power units to be activated for the supply of ancillary services. These units, which are located as part of consumer installations, can typically be started up at very short notice. In this way, the demand for electricity from the public grid by such installations may be reduced in situations of power deficit for the benefit of the balance of the system. Energinet.dk is currently engaged in two pilot projects within this field. Both projects are testing ways in which such units may be of use in the electricity system.

- Concurrently with these projects, Energinet.dk has initiated activities aimed at reassessing and optimising the total volume of ancillary services. The construction of the power link across the Great Belt will pave the way for the sharing of ancillary services between Eastern and Western Denmark. The Great Belt power link alone is expected to reduce purchases of reserve capacity by 300 MW.

For **successful competition** in the electricity market in Denmark, the market must be efficiently connected with the markets in our neighbouring countries. It is therefore of decisive importance that sufficient exchange capacity will be available and that it will be handled in the most efficient way from the point of view of the market.

Energinet.dk's focus areas:

- In the period between fourth quarter of 2005 and first quarter of 2006, spot prices were regularly very high in Eastern Denmark. The high prices are mainly attributable to the handling of internal congestion in Sweden. Energinet.dk and Svenska Kraftnät are currently discussing how to avoid the problem of soaring spot prices in Eastern Denmark. Svenska Kraftnät has suggested a solution whereby Eastern Denmark and Sweden are combined into one price area. In the opinion of Energinet.dk the right solution from the point of view of the market is to handle congestion where it arises and not to force congestion onto the interconnections in order to maintain any one country as one national price area. Energinet.dk has raised the issue in Nordel and with the EU Commission and will continue to work actively to resolve the issue in a correct way from the point of view of the market.

- Trading across the border between Jutland and Germany improved in 2005, but capacity remains restricted on the border. Energinet.dk has raised the issues of improving trade and expanding transmission capacity between Germany and Jutland with E.ON Netz.

- Energinet.dk is working with the Norwegian TSO Statnett to prepare the necessary documentation for a decision to be made concerning a new Skagerrak 4 connection, which is one of Nordel's five priority cross-sections. The documentation is expected to be presented to the supervisory boards of the companies in the third quarter of 2006.

The **planning of the Danish electricity transmission system** is challenged by the uncertainty surrounding the fundamental preconditions for the expansion of the transmission grid: The expansion of offshore wind farms and the expansion of the interconnections. At the same time, the documentation and the solutions must meet ever stricter requirements with regard to robustness and socio-economic optimisation. The technical solutions recommended often have a useful life of 30-40 years.

There is therefore a need for long-term transmission plans to be updated and for tools to be developed for the quantification and pricing of, eg, the security of supply in connection with grid planning. A well-founded set of developments must also be developed which can be used to test the robustness of the long-term transmission plans in the face of potential developments in the energy sector.

Energinet.dk's focus areas:

- Based on updated assumptions concerning future offshore wind farms and interconnectors, Energinet.dk wishes to reassess the long-term 400 kV grid structure and to outline national development for the uniform and long-term development of the transmission grids in Eastern and Western Denmark. These activities are expected to be launched at the end of 2006.

- The expansion of wind power has a bearing on electricity system requirements. The long-term planning and socio-economic optimisation of investments in electricity infrastructure are currently hampered by the lack of a long-term plan for the expansion of offshore wind farms in Denmark. Energinet.dk will therefore work to ensure that a long-term and coordinated plan is made as soon as possible for the expansion of offshore wind power and the related expansion of the transmission grid.

  In 2006 Energinet.dk is represented on the Danish Energy Authority's committee on the future expansion of wind power (*Fremtidens Havvindmølleudbygning*). The Danish Energy Authority is heading the committee. Energinet.dk wants considerable attention to be given to the question of the derived heavy investments in the transmission grid necessitated by the establishment of offshore wind farms.

- Moreover, the formation of Energinet.dk has enhanced the possibility of harmonising and reassessing the principles for grid planning between Eastern and Western Denmark, including the possibility of harmonising the grid design rules to make national rules. Energinet.dk has launched activities aimed at harmonising the grid design rules with such harmonisation taking account of the geographical and organisational affiliation of the areas to Nordel and the UCTE, respectively.

- Work is also going into incorporating the dimensioning of the so-called reactive power into the rules. The aim is to harmonise requirements as regards the voltage-regulating properties of the production units and the dimensioning of the reactive resources of the grid. The work will be undertaken jointly

by Energinet.dk and the grid and transmission companies and is expected to be completed mid-2007.

- The current experience-based documentation for grid expansion with technical/economic comparisons of alternatives is supplemented with a purely socio-economic approach, which will form the basis of any decisions made concerning specific investment projects. Decisions concerning expansion are no longer determined by the grid design rules alone. This means that better methods must be developed for making socio-economic assessments of factors which have a bearing on grid expansion, such as the security of supply, the market and the environment. Energinet.dk has initiated this work, and methods and tools will be subject to continuous development and improvement.

As regards the **environment**, Energinet.dk is responsible for the annual collection of production and environmental data from Danish electricity and CHP production units. These data are used to prepare a number of annual environmental impact statements for electricity. The statements are used by companies drawing up environmental reports, but also by end-customers wishing to gain insight into the environmental impacts of using 1 kWh of electricity. Furthermore, 10-year projections are prepared to illustrate the expected environmental impacts of the electricity and CHP sector.

Energinet.dk's focus areas:

- Electricity customers are increasingly buying electricity with special environmental properties. Certificates and guarantees of origin are used to some extent today, but no common accredited system is available. If growth in environmental electricity production is to be ensured, there is a need for increased focus on the credibility of the various systems. The fact that electricity is also traded across borders is a further complication.

  Energinet.dk takes part in the joint European E-Track project which is aimed at developing a joint system of certificates and guarantees of origin for trading in electricity with special environmental properties. The work is being closely coordinated with the Danish Energy Authority and will run until the end of 2007.

  In parallel with this work, Energinet.dk is responsible for the establishment in Denmark of a reliable system for the issuing of declarations by electricity traders for electricity with special environmental characteristics. This work is being carried out in cooperation with the Danish Association for Electricity Trade (*Dansk Elhandelsforum*) and the Danish Energy Authority.
- In the 1998-2000 period, the Danish electricity sector prepared for a life cycle analysis (LCA) as such of the entire process from the procurement of fuel to the generation and transmission of electricity. The intervening period has seen many changes to the production facilities of the electricity sector, and thereby also to the environmental aspects of the electricity production. Today, renewable energy contributes approx. 30% of electricity production with wind power alone accounting for approx. 20%.

The LCA study from 1998 must be updated to reflect these changes. Energinet.dk has initiated the identification of relevant parties from the electricity industry which will contribute to updating the study. Initial cooperation involves the Danish Energy Authority, Dansk Energi and some generators. The work will be completed in 2008.

### *2.1.2 Gas system*

Energinet.dk is responsible for the **security of supply of natural gas** and must also assess the need for long-term expansion of the infrastructure.

Denmark is currently supplied with natural gas from the Danish gas fields in the North Sea only. Expectations are that within the next 5-10 years Danish natural gas reserves will no longer be sufficient to meet demand, and there is thus a need to focus on the **security of gas supply** with a view to ensuring the long-term availability of gas for the Danish market. The possibility of establishing **(a) new transmission pipeline(s)** between Denmark and the European gas system with a view to importing gas from Norway and/or Russia must be analysed. A decisive issue in this context is the allocation of roles, including the question of who will be responsible for the necessary long-term investments in the gas infrastructure.

Energinet.dk's focus areas:

- The existing emergency supply concept is being reviewed, to some extent due to the liberalisation of the gas market, which means that the review must take account of the new and flexible products being offered. Moreover, a number of problems with regard to the level of interruptibility and the scope for procuring gas in emergencies have been identified. It is also thought that shippers in their capacity orders state a far higher share of interruptible emergency supplies than what could actually be interrupted in an emergency situation.

  In 2004 a decision was made to prepare a new emergency supply concept, especially as regards the possibility of interrupting delivery to consumers in an emergency situation. Energinet.dk has, in cooperation with the other licensees/distribution companies on the steering committee of Gas Market 2004, prepared a new emergency supply concept which suggests a new distribution of roles, new categories of interruptibility and new procedures to govern relations between the companies. The plan for the new emergency supply concept is to come into force on 1 October 2007.

- In connection with the implementation of the EU's directive on security of supply, Energinet.dk would like the distribution of roles and responsibilities in the Danish gas market to be assessed and clarified in further detail in view of the long-term security of supply. It is, among other things, necessary to decide how to ensure the availability of natural gas for the Danish market in 5-10 years' time.

- There is a need to establish new gas infrastructure after 2010 to ensure the availability of gas and security of supply. Potential transmission pipelines be-

tween Denmark and the European gas system must be analysed with a view to procuring supplies from Norway and/or Russia. The possibility of deliveries of LNG to the Danish market must also be considered. Energinet.dk has launched an internal review concerning the possibility of establishing new infrastructure after 2010. The review will include an assessment of Energinet.dk's role as operator and owner of new infrastructure.

Two years after the opening of the market, the situation in the **Danish market for trade in natural gas** remains characterised by a small number of commercial players and limited competition, especially in the wholesale market. Liquid and competitive wholesale markets are a precondition for consumers benefiting from the advantages of competition.

Energinet.dk's focus areas:

- Energinet.dk is working for a market-based reference price of gas in Denmark. This requires increased liquidity – both in the form of larger volumes of gas and in the form of more buyers and sellers in the gas market. For the purpose of increasing liquidity and improving the scope for establishing a market-based reference price, Energinet.dk will intensify work going into harmonising terms with neighbouring systems in Northern Germany and Sweden (balance rules, tariff models, interoperability). This will take place in closer dialogue with the neighbouring TSOs. A closer coupling of the markets will then be achieved, resulting in increasing competition.

  Furthermore, Energinet.dk will work for the appointment of a large commercial player as market maker. This will take place in close dialogue with the authorities.

### *2.1.3 Long-term development of the electricity and gas systems*

One of Energinet.dk's tasks as the TSO in Denmark is to develop the electricity and gas systems so as to ensure that they live up to short-term as well as long-term objectives concerning security of supply, the environment and the functioning of the market.

This raises a number of challenges in connection with decisions concerning both the operation of the electricity system and the design of the transmission grids. Decisions made today concerning the design of the transmission grids will affect the scope for living up to these objectives in both the short and the long term. Some of the tools suitable for shedding light on and handling these challenges are research and development, scenario analyses and ways of incorporating wind power.

Energinet.dk's focus areas:

- Develop the electricity infrastructure for the efficient handling of many small production units, including prioritisation of development projects on optimum integration of local units into the electricity grid (new system architecture).

- Use long-term scenario analyses as an important tool for shedding light on the robustness of decisions in relation to various future scenarios.

- Continue to assess the interplay between gas and electricity consumption and its importance for the capacity and security of supply of the transmission systems.

- Be the driving force in the cooperation with the other Danish energy research programmes on the development and consolidation of strategies, issuing programme calls and providing information about energy research.

- Establish and cooperate on an R&D environment for research into natural gas and other hydrogenous energy carriers.

# 3. Energy sector

## 3.1 Structural changes in the energy sector

The structure and ownership of both the electricity and the natural gas sector in Denmark is changing, and this will affect the future functioning of the electricity and natural gas markets in Denmark.

### *3.1.1 Electricity sector*

Since the liberalisation of the electricity market, the electricity production sector in Denmark has been characterised by two dominant producers – Elsam in Western Denmark and Energi E2 in Eastern Denmark. This situation changed markedly in March 2006 with the EU Commission's approval of the merger of DONG, Energi E2, Elsam, Nesa, Frederiksberg Forsyning and the electricity activities of Københavns Energi. The new company is called DONG Energy.

The merger was preceded by an agreement made in 2005 between DONG and Vattenfall. Under this agreement, Vattenfall's ownership stakes of approx. 35% in Elsam and 40% in Avedøre 2 were transferred to DONG in return for Vattenfall taking over ownership of a number of CHP and renewable energy units in Denmark and abroad. DONG will own electricity production assets of approx. 7,300 MW, including 6,200 MW of thermal production capacity in Denmark, while Vattenfall will own approx. 2,200 MW electricity production capacity in Denmark, including approx. 1,900 MW of CHP capacity. DONG Energy will also own parts of the electricity distribution and the natural gas distribution on Zealand and in Southern Jutland.

This means that DONG Energy will have access to a considerable share of both the production and the trade in and distribution of electricity and natural gas in Denmark.

The EU Commission has approved Vattenfall's takeover of assets from Energi E2 and Elsam in the form of CHP and renewable energy plants. The Commission believes that Vattenfall's access to the electricity markets in Eastern and Western Denmark will contribute to improving competition.

The construction of a power link across the Great Belt is also expected to improve the market situation and competition in the Danish market.

### *3.1.2 Gas sector*

Energinet.dk owns the gas transmission grid in Denmark, whereas DONG Energy owns the upstream pipelines (marine pipelines) in the North Sea between the offshore installations and the shore, the gas pipeline between the Tyra Øst and Harald gas fields and the gas treatment plant in Nybro, the gas pipeline between Syd Arne and Nybro and the gas storage facilities Stenlille and Ll. Torup (negotiations are currently underway conducted for the sale of one of these storage facilities to Energinet.dk) and 49% of DEUDAN, which owns the transmission pipeline from/to Denmark in Northern Germany. **Figure 8.1** illustrates the location of fields and gas pipelines.

Moreover, DONG Energy is the co-owner of the natural gas pipeline from the Tyra field to the Dutch shelf area (F3/Nogat). With the establishment of the pipeline to the Dutch shelf – and thereby a connection to the grid of gas pipelines connecting the gas fields in Norway, the UK, the Netherlands, Belgium and Germany, DONG Energy is able to choose between selling gas in the Danish market and selling it to the rest of the European market.

Finally, DONG Energy owns two out of five gas distribution companies and the majority of the most flexible gas customers (electricity utilities). To this come agreements concerning purchases of North Sea gas and gas deliveries to the regional natural gas companies HNG/Midt-Nord along with Swedish and German customers. All in all, this strengthens the company's position and reduces the gas volumes traded in the Danish wholesale market.

The EU Commission's approval of the DONG-Elsam merger was granted on a number of conditions which must ensure that the merger does not hamper competition in the gas markets, among other things because the acquired electricity companies could have acted as gas wholesalers. Firstly, DONG Energy must divest one of its gas storage facilities to enable potential competitors to rent storage space. Secondly, DONG Energy is obliged to auction gas corresponding to 10% of the annual Danish consumption at six annual auctions in the 2006-2013 period.

According to a cross-party political agreement from 2004 concerning the sale of shares in DONG, the natural gas infrastructure (grid and storage facilities) must remain public property. If the state's major shareholding in DONG Energy is sold, the state will thus buy back the natural gas grid and storage facilities from DONG Energy.

## 3.2 EU initiatives

At the Lisbon European Council meeting in March 2000 the strategic goal was set for Europe to become "the most competitive and dynamic knowledge-based economy in the world", and the liberalisation of the energy markets for electricity and natural gas is seen as an important step to ensure this.

Since 2000, the EU has worked more intensely on the security of electricity and gas supply in Europe. The background is, among other things, the EU's increasing reliance on energy imports. Approx. 50% of the energy used in the EU is imported, and the EU is expecting the share covered by imports to increase to 70% within the next 20-30 years, if current trends continue. Such reliance involves both financial and social risks for the EU, especially as a considerable share of energy imports comes from unstable countries and regions.

### *3.2.1 Competition, security of supply and the environment*

The market directives for electricity and natural gas prescribe full market opening from mid-2007, and in the directives the need to safeguard security of supply and consumer protection is reflected in a number of specific measures. For example, the electricity directive has introduced a tender procedure for new electricity production capacity and energy efficiency in the form of demand control. Furthermore, the directives lay down a large number of obligations con-

cerning the safety and operation of the transmission systems which must be met by the TSOs, and well as a number of requirements aimed at ensuring that the TSOs are independent and non-discriminatory. Energinet.dk is obliged to meet these requirements and submits an annual report to the Danish Energy Regulatory Authority concerning compliance.

A precondition for the internal market in energy in the EU is improvements in cross-border trading. The EU has tried to promote this through its regulation on grid access in connection with cross-border exchange of electricity. Among other things, the regulation regulates what costs may be included in the tariffs from cross-border exchange and what the revenue may be used for. Furthermore, a regulation concerning access to the gas transmission grid was adopted in 2005 with the aim of laying down non-discriminatory, objective and transparent rules concerning conditions of access to the gas transmission grid.

The EU continues its work to expand the trans-European grids – the so-called TEN projects – with a view to strengthening trade in both electricity and gas.

Security of electricity supply was back on the agenda in 2004 after a series of blackouts in the power systems in both Europe and the USA in 2003. In 2004, the EU presented its infrastructure package which included a proposal for a directive on the security of electricity supply and infrastructural investments aimed at promoting the necessary grid investments. It is proposed that the TSOs lay down long-term investment plans for the transmission grid. The directive on security of electricity supply was adopted in January 2006 with a two-year deadline for its implementation in national legislation.

The directive on security of gas supply was adopted in 2004 and is currently being implemented in Danish law. The directive emphasises the EU's growing dependence on imported gas. With a view to ensuring the security of gas supply and the functionality of the internal market it is, according to the directive, essential that the tasks and responsibilities of the various market players in relation to security of gas supply be determined.

In the environmental area, the most important EU initiatives of significance for the energy sector have been the directive on large combustion plants and the directive on trade in greenhouse gases. The directive on large combustion plants stipulates threshold values for $SO_2$ and $NO_x$ emissions for large electricity and CHP units. As from 2008, a number of existing Danish units will not be able to comply with these threshold values. The Emissions Trading Directive has introduced $CO_2$ emission allowances to be allocated to businesses and the energy sector according to national allocation plans with the possibility of trading in an emissions allowance market.

In February 2006, the European Commission published the conclusions from the Commission's study of competition in the EU's energy sector. The report confirms the five areas pinpointed by a preliminary study from November 2005 as being problematic: High market concentration, lack of liquidity and limited access to infrastructure and lack of cross-border competition. Moreover, a lack of transparency makes life difficult for new players while energy prices are often not determined on the basis of efficient competition.

The European Commission has subsequently put renewed pressure on the member states which have not yet implemented the market directive in a satisfactory manner. The Competition Commissioner has indicated that the Commission will take a closer look at the conduct of European energy companies in the markets when violation of the rules governing competition is suspected.

### *3.2.2 European Commission Green Paper*

The European Commission's Green Paper on a joint European energy policy was published in March 2006. The Green Paper is the European Commission's contribution to the discussion by the heads of state on how to handle the very considerable challenges facing the EU's energy sector in the coming decades:

- A pressing need for investments. It is estimated that investments of EUR 1,000 billion will be required in the energy sector in the coming 20 years in order to meet the demand for energy and replace outdated infrastructure.

- Growing reliance on imports. Approx. 50% of the energy consumed in the EU is imported, and this share is expected to increase to 70% in the next 20-30 years.

- Concentration of gas reserves in a few countries. Today, approx. half of the EU's gas consumption is covered by Norway, Algeria and Russia. If current trends continue, this share will increase to 80% in 25 years' time.

- Oil and gas prices have almost doubled in the past 2 years.

- Global energy consumption – and $CO_2$ emissions – are expected to increase by approx. 60% in the period up until 2030.

- The UN's climate panel believes that emissions of greenhouse gases have already made the earth 0.6 degrees warmer, and that this increase in temperatures will continue if nothing is done. The economic and ecological consequences may be dramatic.

- The EU's internal energy markets are not fully liberalised, and before this happens, consumers will not enjoy benefits in the form of security of supply and lower prices to the full extent.

The Commission's suggestions on how to tackle these challenges can be divided into three main categories: Sustainability, competitiveness and security of supply. The aim is to reduce the EU's economic and ecological vulnerability.

Efforts will generally concentrate on:

- Implementing the internal energy market in full.

- Ensuring security of supply/preparedness and a diversified energy mix.

- Ensuring sustainable development in the energy sector through increasing energy efficiency and increased use of renewable energy sources and strategic focus on new energy technology as well as the development of a common external energy policy.

Measures of direct relevance to Energinet.dk include a proposal to promote the development of common European rules/regulations concerning grid access (Grid Code) for the purpose of ensuring grid access on equal terms in connection with cross-border trading in electricity and gas. According to the Green Paper, such rules may be reinforced by a joint Council of European Energy Regulators. The Green Paper proposes the creation of a formal body of cooperation between the European TSOs (European Centre for Energy Networks), which could work with the European Energy Inspection Council on preparing the rules. This cooperative body is also to play a central role in connection with the work on common European standards for security and reliability of the transmission grid.

### 3.3 Energy Policy 2006

The Danish government's Energy Policy report from April 2006 also emphasises the long-term and global energy-political challenges presented by unstable or uncontrollable framework conditions. Important elements of any long-term energy policy are therefore the energy sector's ability to flexibly adapt to changing international conditions and for cost-efficiency to be fully optimised.

According to the report, this is best ensured through smoothly operating markets and market-oriented means and through research and development of new efficient energy technologies. Efforts aimed at achieving energy savings will be strengthened markedly, while the coming decades are expected to see a significant increase in the use of renewable energy sources.

# 4. Price development

The System Plan 2006 and the Environmental Report 2006 are based on simulations of the electricity and CHP system for the 2006-2015 period in the form of so-called reference calculations. Based on assumptions concerning developments in electricity consumption, fuel prices, prices of emission allowances and electricity prices, the calculations show developments in electricity production and electricity imports/exports as well as emissions.

## 4.1 Planning basis for electricity

As a basis for the reference calculations, Energinet.dk has forecast electricity consumption and developments in the production facilities, fuel prices, $CO_2$ emission allowance prices and electricity prices.

Calculations are made for two scenarios leading up to 2015: A low-price development for electricity and a high-price development for electricity. The two scenarios describe a possible development of electricity production, exports and imports and total annual emissions of $CO_2$, $SO_2$ and $NO_x$ with normal climatic conditions and precipitation.

The low-price development reflects limited economic growth in Norway and Sweden, initial expansion of gas power in Norway and expansion of renewable energy in Norway and Sweden. Actual developments may result in major or minor price fluctuations, among other things due to wet years and dry years. The prices are annual average prices which vary over any 24-hour period and over the year. The electricity price in the low-price development is DKK 0.27 per kWh (fixed 2005 prices for the whole period) based on the short-term marginal costs of a coal-fired power station. The $CO_2$ contributions are based on the cost of average marginal $CO_2$ emissions.

The electricity price in the high-price development is DKK 0.40 per kWh (fixed 2005 prices for the whole period) based on the long-term marginal costs of a natural gas-fired combined cycle unit. An investment contribution is included. Data concerning the natural gas unit used (investments, fixed and variable costs) are based on the technology catalogue "Technology Data for Electricity and Heat Generating Plants" published by the Danish Energy Authority, Elkraft System and Eltra, March 2005.

For a more detailed description of the most important assumptions, please see the document *Analyseforudsætninger 2006-2015* [Ref. 1].

### *4.1.1 Electricity and heat consumption*

Energinet.dk's electricity consumption forecast was made at the beginning of 2006. The projection of industrial electricity consumption was prepared by Risø National Laboratory on the basis of the EMMA model. Residential electricity consumption was projected on the basis of ELMODEL Bolig that in turn is based on assumptions concerning developments in the number of electrical appliances owned by households and their use.

According to the projection, electricity consumption in Eastern Denmark is 14,588 GWh in 2006, while the maximum power consumption is 2,778 MW. In

2015, the projection for electricity consumption is 16,621 GWh and a 3,152 MW for maximum power consumption (mean winter).

According to the projection, electricity consumption in Western Denmark is 21,888 GWh in 2006, while the maximum power consumption is 3,909 MW. The forecast for 2015 is for electricity consumption of 25,174 GWh and a maximum power consumption of 4,496 MW (mean winter).

Heating production by the Danish CHP units is 137 PJ per year in the 2006-2015 period.

### *4.1.2 Production capacity*

It is assumed that the total production capacity in combination with demand-side resources towards the end of the period will ensure that the security of supply can be maintained, even during the coldest hour.

The volume of biomass covered by the biomass action plan is expected to be used from January 2009 when a biomass-fired CHP unit is commissioned at the Fynsværket power station. Production units which currently do not comply with the directive on large combustion plants are expected to be scrapped, registered for reduced operation (a total of 20,000 hours in 2008-2016) or to have desulphurisation or de$NO_x$ systems installed.

The production units are divided (see **Table 4.1**) into units connected to the transmission grid, units connected to the distribution grid (primarily local CHP units) and wind turbines. The data reflect the situation on 1 January 2006.

| | **Eastern Denmark** | **Western Denmark** |
|---|---|---|
| | MW | MW |
| Consumption – power (10-year winters) | **2,984** | **4,092** |
| Production capacity | **5,145** | **7,510** |
| Transmission grid | 3,755 | 3,402 |
| Distribution grid | 642 | 1,715 |
| Onshore and coastal wind power | 582 | 2,233 |
| Offshore wind power | 166 | 160 |

***Table 4.1*** *Consumption (winter 2005/2006) and production capacity (nominal power) on 1 January 2006.*

A detailed overview of the installed production capacity as at 1 January 2006 in Eastern and Western Denmark can be seen in **Annex 1**.

The production capacities stated in **Annex 1** are the nominal capacities. When calculating the power balance, account is taken of the fact that for some of the units there is a difference between the nominal capacity and the electricity production which is actually available. In addition to meeting demand, production capacity must also cover the need for certain ancillary services.

The period up until 2015 is not expected to see the commissioning of new major power stations. According to experience, it takes about 10 years to plan and commission a major power station.

As at 1 January 2006, a total of 3,141 MW of wind power was installed in Denmark, of which 326 MW is supplied by the Horns Rev and Rødsand offshore wind farms. According to the so-called scrapping scheme, the 2005-2009 period must see the replacement of land-based wind turbines with new and larger-capacity wind turbines, cf. the energy-political agreement of 29 March 2004. Approx. 372 MW of capacity is covered by the new scrapping scheme. The scheme only allows for the scrapping of 175 MW in the 2005-2009 period.

It is assumed that new offshore wind turbines will be established from 2009 as a 200 MW offshore wind farm is expected to be commissioned at Horns Rev in 2009, while a 200 MW wind farm will be commissioned at Rødsand in 2010. For the purpose of the calculations, it is furthermore assumed that a 200 MW offshore wind farm will be established in Western Denmark in 2012 while an offshore wind farm will be established in Eastern Denmark in 2014. The last two offshore wind farms have not been adopted politically as yet.

### *4.1.3 Prices of fuel and $CO_2$ emission allowances*

The fuel prices are based on the IEA's most recent forecast, World Energy Outlook 2005. The prices are indicated in the document *Analyseforudsætninger 2006-2015* [Ref. 1]. The forecast is based on expectations of higher oil, coal and gas prices relative to earlier forecasts. This is caused by expectations of increasing energy consumption and increasing dependency on fossil fuels.

The IEA has calculated three scenarios: The Basic Scenario, Deferred Investments and World Alternative Policy. The reference calculations are based on the fuel price forecast for the basic scenario.

The reference calculations are based on a $CO_2$ emission allowance price of DKK 150 per tonne, corresponding to approx. EUR 20 per tonne. Furthermore, a tax of DKK 10,000 per tonne of $SO_2$ has been included.

### *4.1.4 Model tool*

On the basis of the assumptions, developments in production, consumption, imports and exports, fuel consumption and emissions in the 2006-2015 period have been analysed.

The calculations have been carried out using the SIVAEL model tool which optimises the operation of electricity and heating plants on an hourly basis. The simulations take account of the physical framework of the units and optimise the units on the basis of price signals, which means that the cheapest possible units produce the required electricity and CHP. It has been assumed that all electricity generated by local CHP units will be sold on market terms. In the calculations, wind turbine production is always guaranteed to be sold as the production price is set at zero.

The market prices in the Nordic countries and in Germany and the capacity of the interconnections determine the levels of exports and imports. The simulations include exchanges with neighbouring areas.

## 4.2 Results of reference calculations

The Great Belt power link is included in the calculations as from 2010. In the 2010-2015 period, power will flow westwards via the Great Belt power link for an average of approx. 2,000 hours a year. For the remaining just over 6,700 hours, power will be eastbound, with the link operating at full load for approx. 2,000 hours.

With the construction of the Great Belt power link, production by the power stations in Eastern Denmark will fall by approx. 1 TWh, while production by the power stations in Western Denmark will increase by approx. 1 TWh. This will lead to a fall in emissions as the power stations in Western Denmark are generally more efficient. Moreover, the commissioning of new offshore wind farms will reduce $CO_2$ emissions.

Production by the local CHP units and the consumption of biomass, waste, natural gas and oil are almost identical in the low-price and high-price developments as capacity is also fully utilised in the low-price development. On the other hand, production and coal consumption by the primary power stations are considerably higher in the high-price development as these power stations almost exclusively cover the increased electricity production for exports. See **Figure 4.1** and **Figure 4.3**, which show the distribution of electricity production and fuel consumption, respectively.

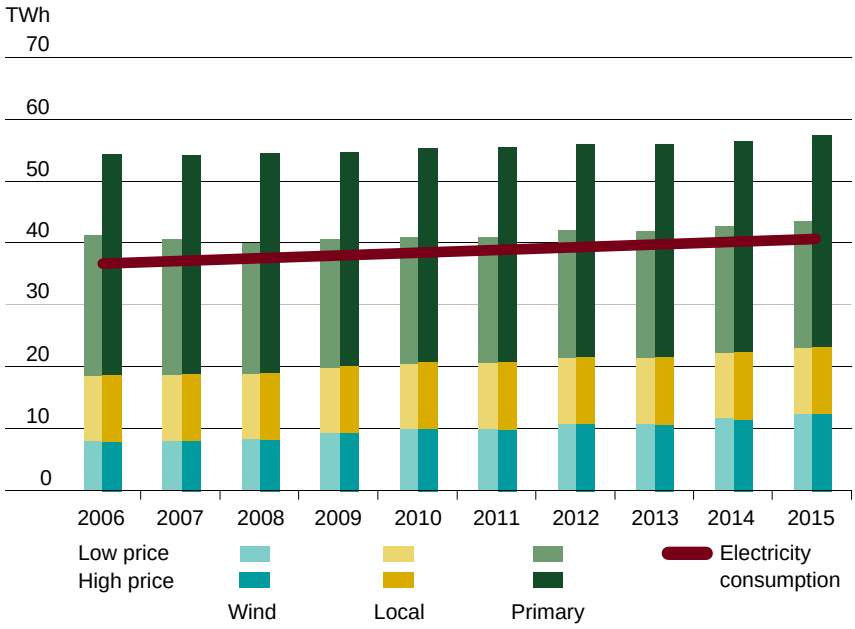



***Figure 4.1*** *Electricity production in low-price and high-price developments 2006–2015.*

**Figure 4.1** shows slightly increasing electricity consumption. The difference between total production and consumption is exported.

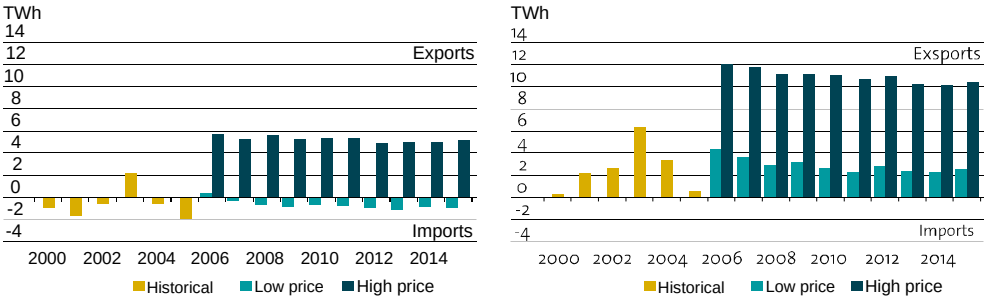



***Figure 4.2*** *Exchanges with neighbouring countries (for Eastern Denmark and Western Denmark, respectively).*

Exchanges with the neighbouring countries are shown in **Figure 4.2**, both historically and for the period up until 2015. As can be seen, exports and imports are affected by the low-price and the high-price developments. The high exports in 2002-2003 are attributable to low levels of precipitation in Norway and Sweden.

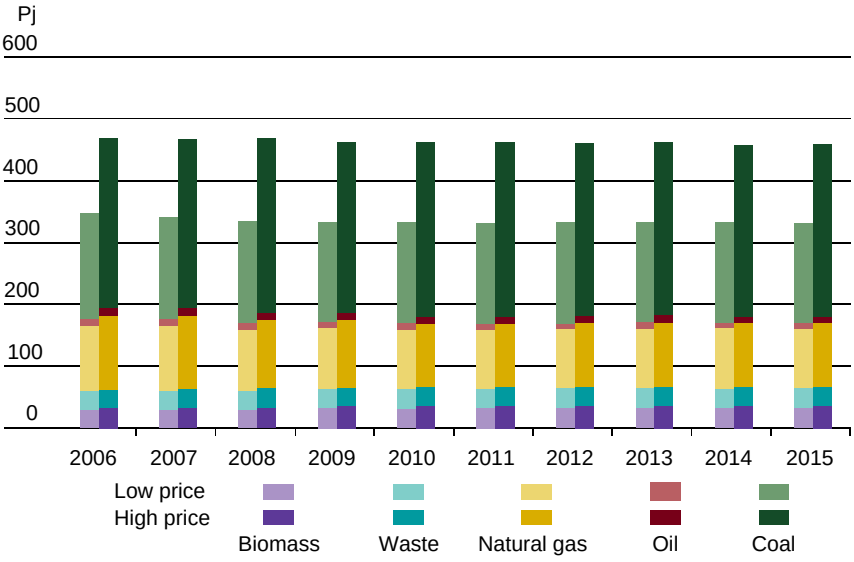



***Figure 4.3*** *Fuel consumption in low-price and high-price developments.*

**Figure 4.3** shows the fuel consumption by fuel type in the 2006-2015 period for the low-price and the high-price developments. The volumes of biomass, waste, natural gas and oil are almost identical, whereas coal consumption increases with higher exports. The increasing coal consumption in the high-price development leads to an increase in emissions and residual products.

Despite increasing electricity consumption total fuel consumption does not increase in the 2006-2015 period, as the increase in electricity consumption is covered by more wind power.

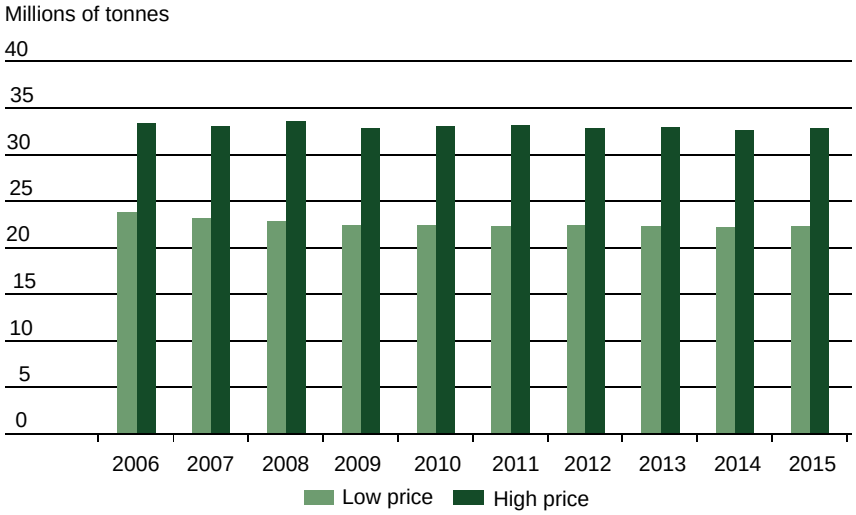



***Figure 4.4*** *$CO_2$ emissions in low-price and high-price developments 2006-2015.*

$CO_2$ emissions fall in the low-price development by 1.5 million tonnes from 2006 to 2015. In the high-price development, $CO_2$ emissions fall by 0.5 million tonnes.

The projections show total $CO_2$ emissions from electricity and CHP production in 2008-2012 of approx. 22 million tonnes per year in the low-price development and approx. 33 million tonnes in the high-price development. In the 2005-2007 period, Danish electricity and CHP generators hold combined $CO_2$ emission allowances of 21.7 million tonnes per year, see also section 4.3.

In summary, the reference calculations show that the electricity price has a significant bearing on both the volume of imports/exports and the level of $CO_2$ emissions. In future, it would be interesting to develop the calculations to include, eg, variations in fuel prices, $CO_2$ emission allowance prices and framework conditions and to extend the horizon from 10 years. This will be done in connection with Energinet.dk's future forecasting.

## 4.3 Environment and climate

### *4.3.1 The period from 2005 to 2007*

The environmental objective which dominates developments within the energy sector is Denmark's international commitments under the Kyoto Protocol. Since 1 January 2005, 377 Danish production units have thus been covered by the EU's emissions allowance directive, of which 255 belong in the electricity and heating sector. In the trial period for the emissions allowance directive (2005-2007) electricity and district heating generators in Denmark are granted total emission allowances of 21.7 million tonnes per year corresponding to approx. three quarters of the expected $CO_2$ emissions during this period.

By 1 July 2006 Denmark must submit a national allocation plan to the EU detailing an allocation key for emission allowances in the 2008-2012 period. This will clarify how large a share of the expected climate deficit must be financed by

electricity and CHP generators through reductions in the free emission allowances allocated. With the UN's 11th Climate Change Conference at the end of 2005, negotiations have been initiated concerning the contents of the climate strategy for the period after 2012.

A preliminary analysis shows that the electricity and CHP generators covered by the emission allowances in 2005 (including industrial CHP units) recorded $CO_2$ emissions of 19.2 million tonnes. The free emission allowances allocated to these units average 23.5 million tonnes per year in the 2005-2007 period. The reason for low $CO_2$ emissions in 2005 is high electricity imports. By comparison, Denmark had relatively high exports in 2003, which resulted in $CO_2$ emissions from electricity and CHP production of 28.1 million tonnes.

### *4.3.2 Fulfilment of commitments in 2008-2012*

In the 2008-2012 period, Denmark must reduce emissions of greenhouse gases by 21% relative to emission levels in 1990. In 2005 the Danish Environmental Protection Agency prepared a report on how far Denmark is expected to be from achieving the Kyoto target of 55 million tonnes of $CO_2$ equivalents per year [Ref. 2].

In this context, it was projected that Danish greenhouse gas emissions in the 2008-2012 period would be 72.3 million tonnes of $CO_2$ equivalents per year. The calculation of the climate deficit includes the impact of the funding allocated by the state for Joint Implementation (JI) and Clean Development Mechanism (CDM) projects in 2003-2008, which is expected to reduce the climate deficit by 4.5 million tonnes of $CO_2$ equivalents per year. The Danish climate deficit is thus expected to be 8-13 million tonnes of $CO_2$ equivalents per year, depending on whether account is taken of Denmark's assumed adjustment of the basic year to reflect imports.

As mentioned previously, the projections show total $CO_2$ emissions from electricity and CHP production in 2008-2012 of approx. 22 million tonnes per year in the low-price development and approx. 33 million tonnes in the high-price development (**Figure 4.4**). The electricity and CHP sector's need to buy emission allowances or reduce $CO_2$ emissions will thus depend on the way in which the burden is distributed in the allocation plan for 2008-2012. In any case, meeting the targets will be more difficult in the case of large electricity exports during this period.

### *4.3.3 Certificates and guarantees of origin*

Electricity customers are increasingly buying electricity with special environmental characteristics. Certificates and guarantees of origin are used to some extent today, but no common accredited system is available. If growth in environment-friendly electricity production is to be ensured, there is a need for increased focus on the credibility of the various systems. The fact that electricity is also traded across borders is a further complication.

Energinet.dk takes part in the joint European E-Track project which is aimed at developing a joint system of certificates and guarantees of origin for trading in electricity with special environmental characteristics. The work is being closely

coordinated with the Danish Energy Authority and will run until the end of 2007.

In parallel with this work, Energinet.dk is responsible for the establishment in Denmark of a reliable system for the issuing of declarations by electricity traders for electricity with special environmental characteristics. This work is being carried out in cooperation with the Danish Association for Electricity Trade (*Dansk Elhandelsforum*) and the Danish Energy Authority.

### *4.3.4 Life cycle analysis*

In the 1998-2000 period, the Danish electricity sector prepared a life cycle analysis (LCA) as such of the entire process from the procurement of fuel to the generation and transmission of electricity. The intervening period has seen many changes to the production facilities in the electricity sector, and thereby also to the environmental aspects of electricity production. Today, renewable energy contributes approx. 30% of electricity production with wind power alone accounting for approx. 20%.

The LCA study from 1998 must be updated to reflect these changes. Energinet.dk has initiated the identification of relevant parties from the electricity industry which will contribute to updating the study. Initial cooperation involves the Danish Energy Authority, Dansk Energi and some generators. The work will be completed in 2008.

## 4.4 Impact of new act on heating taxes

This section sheds light on the impact of a new act on changes in tax for heating production. The act is currently being considered by the EU. The new act makes it possible to install and use electric boiler at local CHP units for example. A description is given of how the variable heating production costs for a natural gas-fired CHP unit, a natural gas-fired peak-load boiler and an electric boiler are affected by the new rules. The consequences are illustrated by an example. **Table 4.2** shows the assumptions used for the calculations.

| | **CHP unit** | **Peak-load boiler** |
|---|---|---|
| Natural gas price (DKK/GJ) | 60 | 60 |
| Efficiency | 90% | 95% |
| Cm value | 0.7 | - |
| Variable D+V (DKK/MWh and DKK/GJ) | 60 | 0 |
| $CO_2$ tax (DKK/tonne) | 150 | 150 |
| Energy tax (DKK/GJ heat) (after new act) | 45 | 45 |
| Energy tax (DKK/GJ fuel) (before new act) | 51 | 51 |
| Fuel for district heating ($GJ^{fue}/GJ^{heat}$)[1] | 1.25 | - |

[1] Fuel for heating in combined production is calculated in accordance with the e-formula (it is assumed that electricity is generated at an efficiency of 65%, the rest is for heating production) or the h-formula (it is assumed that heating is generated at an efficiency of 125%, the rest is for electricity production).

| Taxes with electric boilers | Tax rules before legislative amendments | Tax rules after legislative amendments |
|---|---|---|
| Energy tax (DKK/MWh electricity) | 571 | - |
| Energy tax (DKK/GJ heat) | - | 45 |
| Electricity tariffs (DKK/MWh electricity) | 41 | 41 |
| PSO tariffs (DKK/MWh electricity) | 48 | - |

***Table 4.2*** *Assumptions eg for calculating consequences of new act on heating taxes. The existing tax rules are shown for comparison.*

No $CO_2$ price or tariff for electricity production has been included. At the given assumptions, the CHP units will engage in production at electricity prices in excess of DKK 320 per MWh. At electricity prices below DKK 189 per MWh, the electric boiler will be cheaper. In the range between DKK 189 and DKK 320 per MWh, the natural gas-fired peak-load boiler is the cheapest solution. See **Figure 4.5**.

With the adopted change to the energy taxes, it makes sense to use and install electric boiler (investment costs are relatively low). It is, however, necessary to consider the hours of operation.

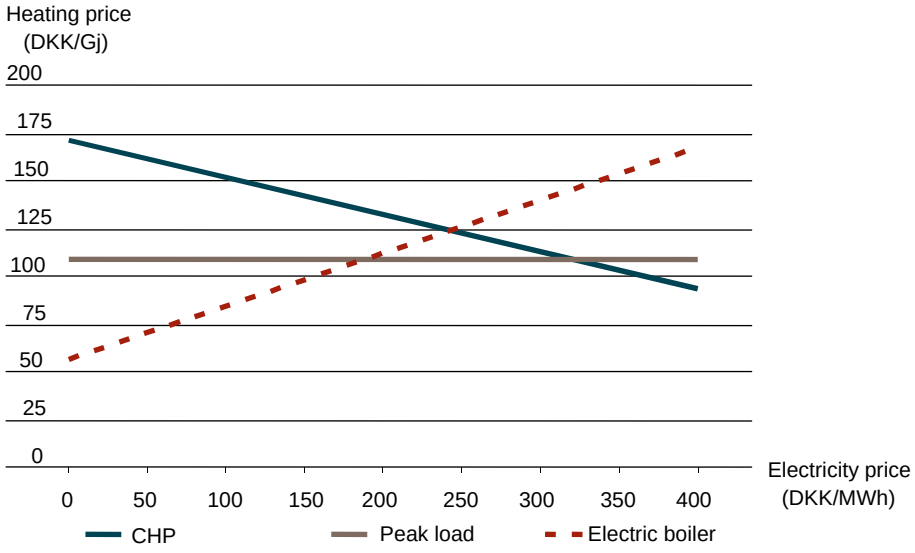



***Figure 4.5*** *Heating price as a function of the electricity price with the new heating taxes.*

**Example – hours of operation for electric boiler in operation in 2005**
The hours of operation of the various components of a CHP plant – CHP unit, peak-load boiler and electric boiler – have been assessed. The example is based on the hourly electricity prices in 2005 for the Western Danish price area. In Western Denmark, approx. 1,200 MW of natural gas-fired CHP capacity is installed.

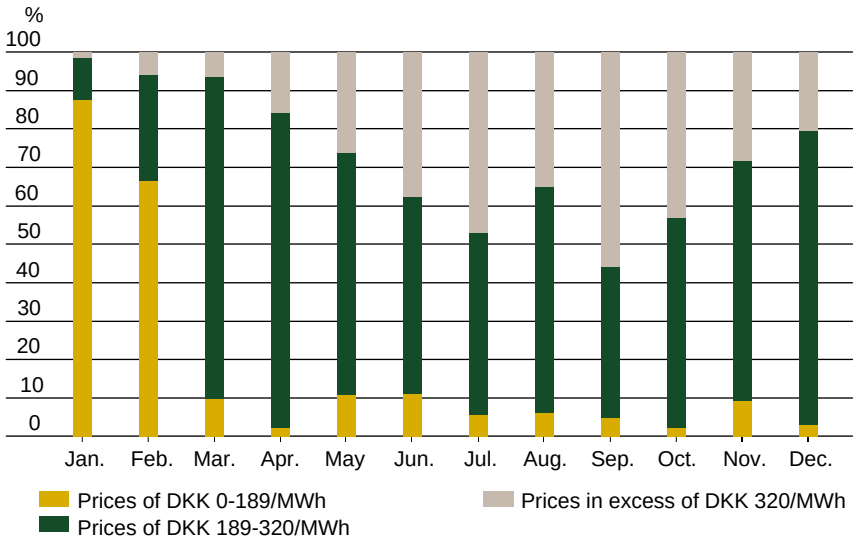



***Figure 4.6*** *Electricity price in Western Denmark.*

**Figure 4.6** shows a high number of hours of operation for the electric boiler (prices below DKK 189 per MWh) in January and February, while the number of hours of operation is relatively low for the rest of the year. This is probably not enough to make the investment in the electric boiler worthwhile.

The local CHP plants are able to offer their electric boilers to the regulating power market so that, when in operation, the electric boiler can be switched off. This corresponds to the upward regulation of production.

If, on the other hand, the electric boiler is not in operation, it can be switched on, which corresponds to a downward regulation of production. Several local CHP plants have expressed an interest in offering their electric boilers to the regulating power market, thereby increasing the return on any investment.

# 5. Security of electricity supply

As the TSO, Energinet.dk is responsible for the security of supply in the electricity system, both in order to ensure the availability of sufficient production capacity and to maintain the technical quality and balance of the interconnected electricity supply system.

Security of supply, safeguarding the electricity market and integrating environmentally friendly electricity production are fundamental concerns in the planning of the electricity transmission system.

## 5.1 Security of electricity supply in general

There is no generally accepted definition of security of supply, but in this context the concept relates to the quality of the electricity supply to consumers.

The technical assessment of security of supply comprises two fundamental concepts: *Security and adequacy*.

| **Security and adequacy** | |
|---|---|
| Security | *Security* is the system's ability to handle sudden disturbances such as electrical short circuits or the unexpected loss of system elements. The concept covers dynamic events. |
| Adequacy | *Adequacy* is the system's ability to meet consumers' total power demand and to satisfy their requirements as regards energy at all times, taking account of planned and reasonably expectable trips of system elements. The concept covers stationary conditions. |

***Table 5.1*** *Security and adequacy.*

Inadequate production capacity in the market may either be attributable to the non-availability of capacity (shortage of power stations) or to the fact that generators are more or less openly withholding capacity from the market through the exercise of market power. An assessment of production capacity must therefore look at both the existence of production capacity and its availability to the market.

A more specific assessment of security of supply builds on an understanding of the possible consequences for electricity consumers. Any inadequacy of system elements usually first becomes apparent in the form of economic consequences – electricity prices increase. If security is not as it should be, the risk of outages increases. Assessing security is a complex process because it depends on a large number of factors, including system adequacy.

| System element | Consequence of shortage |
|---|---|
| Production capacity | Higher electricity prices<br>Price peaks<br>Controlled disconnections |
| Fuel | Higher electricity prices<br>Controlled disconnections |
| Transmission grid | Splitting of the market |
| System security | Uncontrolled disconnections |

**Table 5.2** Consequences for consumers.

**Table 5.2** shows some of the consequences for consumers of the absence or reduction of the above-mentioned system elements. In the short term the market splitting, which results from capacity shortage in the transmission grid, will probably not be apparent to ordinary electricity consumers. On the other hand, uncontrolled disconnections which may follow from insufficient system security may have extensive consequences for consumers.

A stringent definition of security of supply will only categorise actual disconnections as reduced security of supply. However, this would mean that the energy price crisis in the 1970s, for example, would not be attributed to security of supply.

When applying a slightly broader definition it is, however, necessary to assess the future servicing of the market separately so as to ensure that the alarm is not raised because of price fluctuations which are nothing but normal market signals. A suitable share of demand response could contribute to reducing price peaks.

## 5.2 Security of power and energy supply

Computing power and energy balances is one of the tools used to assess security of supply. Below follows an overview of the security of power and energy supply for in the Nordic region, Germany and Poland and in Denmark.

### *5.2.1 Security of power and energy supply in the Nordic region*

Nordel's most recent computation of the energy balance for 2009 is shown in **Figure 5.1**. Similarly, the power balance for 2009/2010 is shown in **Figure 5.2**.

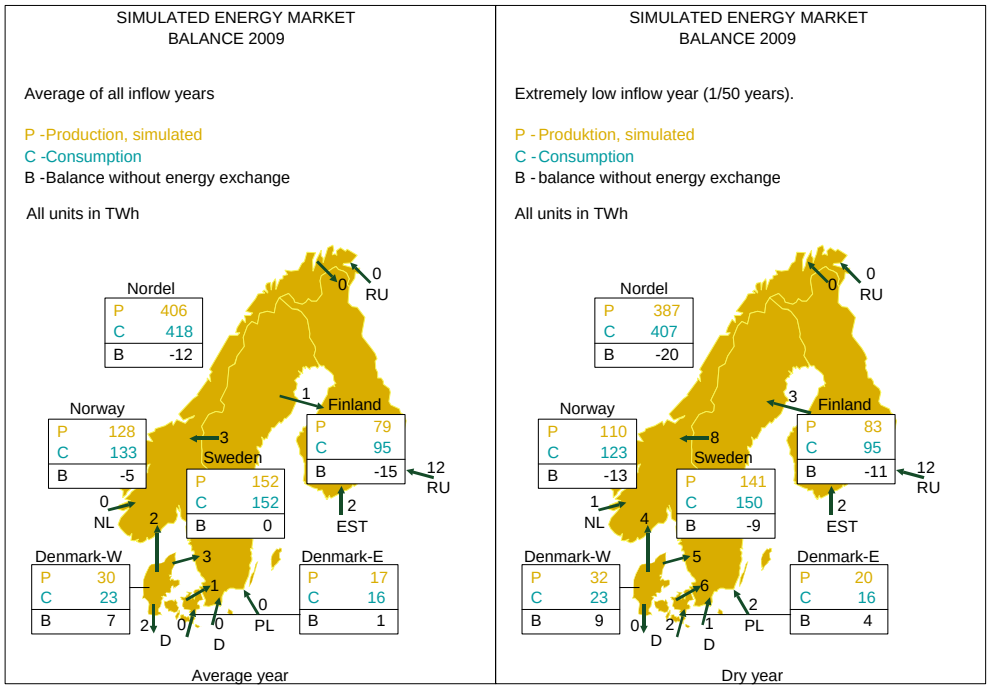



***Figure 5.1*** *Energy balance for Nordel 2009. Source: Nordel. The energy balance is computed for an average year and for a dry year. In calculating the figures for the individual areas, no account has been taken of possible exchange.*

In the event of a dry year, as that seen in 2002-2003, possible energy production based on hydropower may be reduced by up to 42 TWh. This reduction must be covered by production in Denmark and by imports from Russia, Germany, Poland and Estonia. The dry year situation will not materially affect security of supply in Denmark as a situation of shortages must be handled by the areas affected. The dry year will, on the other hand, have a significant bearing on the electricity price in the Danish areas.

As regards the power balance, a winter with very cold weather (10-year winter) will lead to a combined power deficit in the Nordic region. Denmark has a small power surplus, but the other countries expect to cover any deficits by means of imports. Imports are expected to come from Russia in particular and to a lesser extent from the UCTE area (see **Figure 5.2**).

In comparison with last year's figures for 2008/2009 (cold winter), Nordel's combined power balance has improved from -1,900 MW to -700 MW in 2009/2010. This is, among other things, attributable to considerable expansion of interconnections and production capacity, including nuclear power in Finland and nuclear power and CHP in Sweden. In its report on power and energy balances in 2009, Nordel's Balance Group concludes that production capacity in the Nordic region is sufficient to meet demand in normal, but not in extreme situations.

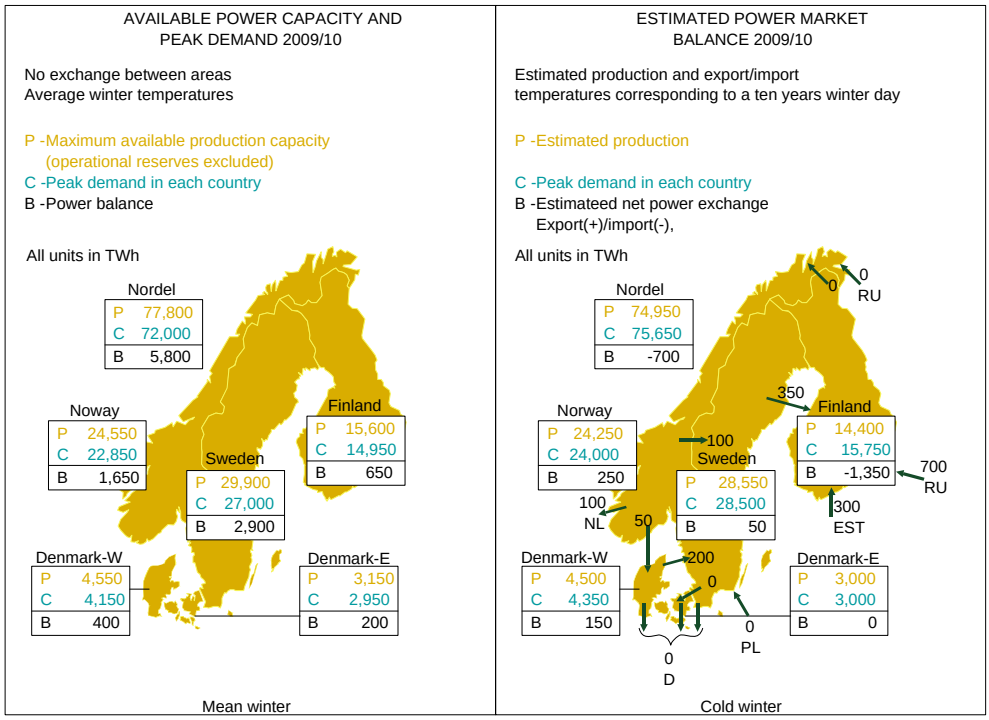



***Figure 5.2*** *Power balance for Nordel winter 2009/2010. Source: Nordel. The power balance has been calculated for a mean winter and a cold winter. In calculating the mean winter figures for the individual areas, no account has been taken of possible exchange. The cold winter figures cover the entire Nordel area, and possible exchange between the countries has been included (taking account of grid congestion).*

The power balance in Southern Sweden is of particular interest to the Danish electricity system due to the interconnection of Eastern Denmark with Southern Sweden. Southern Sweden is here defined as the area south of the so-called Cross-section 4 – south of Gothenburg in the west and Oskarshamn in the east.

Southern Sweden is characterised by electricity consumption which corresponds to two thirds of the total Danish electricity consumption. Following the decommissioning of Barsebäck Nuclear Power Station, production capacity in this area is far from being able to meet demand. Consequently, demand is met by imports from Northern Sweden via Cross-section 4.

The transmission capacity of Cross-section 4 often does not meet demand in Southern Sweden. This means that there is no capacity to cover transit from Northern Scandinavia to Denmark, Germany and Poland via Øresund, the Baltic Cable and the Swepol Link. A power shortfall in Eastern Denmark thus cannot be expected to be covered by imports from Sweden.

The power balance in Southern Sweden can be improved through additional investments in production and transmission capacity for the area. E.ON Sweden has just decided to build a new CHP unit in Malmö and to increase production capacity at Oskarshamn Nuclear Power Station. Svenska Kraftnät plans to strengthen Cross-section 4 with an additional connection from Central Sweden to Southern Sweden. The Great Belt power link will also contribute to alleviating

any power deficit in Southern Sweden/Eastern Denmark. It will, however, be a number of years before any of these initiatives are in operation.

Energinet.dk monitors developments in the power and energy balances in the Nordic region closely. The Nordel countries are currently implementing the EU's electricity market directive, including in particular the question of incentives to invest in new electricity production capacity. Regardless of whether new investments are initiated by the generators or as a result of tender procedures by TSOs, reliable forecasts of future power balances and valid criteria for system adequacy must be available, ie predicting when it may be necessary to initiate a tender procedure. The work to devise methods of assessing power balances and laying down system adequacy criteria is currently being undertaken by a Nordel working group headed by Energinet.dk.

### *5.2.2 Power balance in Germany and Poland*

The UCTE's System Adequacy Forecast 2005-2015 shows developments in the power balance for the coming 10 years in Europe. According to the UCTE forecast, the balance in Poland is good right up until 2015. Owing to congestion in the Polish transmissions grid, exports to Sweden may not always be possible. The balance in Germany is acceptable, but developments from 2010-2015 indicate that it will come under pressure. Other parts of the UCTE, especially southern areas, need imports from central parts of the UCTE, which further reduces resources available for exports to Nordel.

The UCTE forecast is based on a conservative assessment of the addition of new production capacity. On the other hand, the forecast does not take account of the fact that a large part of the existing capacity may be scrapped in consequence of the EU directive on large combustion plants.

Peak-load consumption in the Nordic area is expected to coincide with peak-load periods in the northern parts of the UCTE area. Imports from the UCTE may currently be used to cover winter peaks in Nordel, but this will probably no longer be possible in 2010-2015. This is particularly so if the EU directive on large combustion plants leads to additional scrapping of capacity in Germany and Poland. Energinet.dk is monitoring developments in production capacity in Northern Europe closely.

The expansion of wind power in Northern Germany also has a significant bearing on the demand for regulating capacity in connection with wind power forecasting errors. A surplus of wind power in the Danish system cannot always be dispatched southwards as Northern Germany often has the same problem.

### *5.2.3 Power balance in Eastern Denmark and Western Denmark*

Until the commissioning of the Great Belt power link in about 2010, Denmark will remain divided into two electricity systems. In the following, the power balances are therefore computed for Eastern Denmark and Western Denmark respectively.

Electricity consumption forecasts and nominal power station capacities can be seen from section 4. Scenarios and an overview of the installed production ca-

pacity as at 1 January 2006 in Eastern and Western Denmark can be seen from **Annex 1**.

The Danish power balances (normal and cold winter) can be seen from **Figure 5.2**, which also shows Nordel's power balance. In Western Denmark, the power surplus in a cold winter 2009/2010 is 150 MW, while Eastern Denmark has a power surplus of 0 MW. The balance for Eastern Denmark is based on the assumption that Unit 2 of Asnæs Power Station and Units 1 and 2 of Stigsnæs Power Station (totalling just over 550 MW) will be in operation after 2008.

The production capacity included in the power balance takes account of the fact that there is a discrepancy for most plants between nominal capacity and the electricity production actually available. Account has been taken of the delivery of CHP by reducing the nominal capacity of plants. The power balances do not include contributions from wind power to cover maximum consumption as there will often not be much wind on a winter's day with heavy frost and thereby no wind power production.

The nominal capacities in Eastern Denmark and Western Denmark are 5,145 MW and 7,510 MW, respectively. To calculate the production capacity available on a cold winter's day, approx. 1,200 MW (including wind power capacity of 748 MW) must be deducted from the nominal capacity in Eastern Denmark.

In Western Denmark, 2,393 MW is deducted corresponding to the wind power. In Western Denmark, the CHP units disconnect heating deliveries when the demand for electricity is high.

In addition to meeting demand, production capacity must also cover the need for ancillary services. In Eastern Denmark, 775 MW is reserved for this, and in Western Denmark 650 MW. Account has been taken of these ancillary services when calculating the balance.

In the period up until 2015, the power situation is affected in particular by the EU directive on large combustion plants coming into force in 2008. Large power station units which by then do not comply with the environmental requirements laid down in the directive may be in operation for a maximum of 20,000 hours in the period up until 2015 or be decommissioned altogether.

In the period leading up to 2015, the power balance in Western Denmark remains positive. Unit 3 of the Fynsværket Power Station will not comply with the EU directive in 2008 and has been registered for reduced operation from that time. Ensted Power Station will be renovated and its useful life extended until 2021. Projects have been launched to install new environmental equipment at the other units which currently do not comply with the EU directive (Units 3 and 4 of Studstrup Power Station and Unit 7 of Fynsværket Power Station).

Even though several power station units in Eastern Denmark have been renovated or will be renovated within the next couple of years (Units 1 and 2 of Amager Power Station and Kyndby Power Station), half of the power stations on Zealand are 30 years old or more.

Units 1-4 of H.C. Ørsted Power Station and Units 1-3 of Svanemølle Power Station – with a combined nominal capacity of 150 MW – are expected to be scrapped in 2008. Units 2 and 4 of Asnæs Power Station and Units 1 and 2 of Stigsnæs Power Station – with a combined nominal capacity of 826 MW – do not comply with the EU directive on large combustion plants, but have not been registered for reduced operation. It thus remains uncertain at present whether these units will be equipped with environmental equipment or whether they will be scrapped. Without these units, the power balance will be threatened, and new production capacity will be needed in Eastern Denmark from 2008.

It is therefore necessary to monitor the power balance closely, especially in Eastern Denmark. With a view to improving the power balance, Energinet.dk is engaged in promoting demand response, activating emergency supply units and – in the longer term – providing the physical possibilities (eg power station sites) and market incentives for constructing new production capacity.

## 5.3 Fuel supply

Fuel supply is an important aspect of security of supply. Energinet.dk's fuel supply activities are regulated by Danish Executive Order no. 917 of 13 November 2002 concerning fuel storage capacity with reference to the Danish Electricity Supply Act.

According to the executive order, Energinet.dk must regularly monitor the size of fuel stocks and assess whether they are sufficient to maintain electricity supplies for a period of three months should the fuel supply fail. Moreover, Energinet.dk must lay down plans on how to maintain electricity supplies in the event of failing fuel supplies to the country as a result of emergency situations or other extraordinary situations.

The report on fuel will be prepared as part of the sector emergency management plan and is expected to be published in August 2006.

## 5.4 Security of operations – access to ancillary services

Ancillary services are needed to maintain the physical balance and safeguard the quality of electricity in an interconnected electricity supply system. Ancillary services are supplied in the form of upward and downward regulation and are required to handle frequency and voltage variations, deviations from forecasts and trips of production and grid installations.

Whether each of the two Danish system areas balance can be seen from the level of electricity exchange on the AC interconnection between Jutland and Germany and the AC interconnection between Eastern Denmark and Sweden. The balance is measured by comparing planned electricity exchange with the actual exchange. Planned electricity exchange is determined on the basis of the electricity trade planned between two neighbouring system areas.

A balance may be maintained by regulating the actual exchange by means of ancillary services in Denmark or by adjusting the planned exchange in the form of electricity trade with neighbouring TSOs. The approach used depends on the operational situation in question and on what is the most cost-effective solution.

Today, ancillary services are purchased from generators in Denmark and from neighbouring TSOs. Ancillary services can be divided into spinning reserves and disturbance reserves.

Spinning reserves are used to maintain normal operations and are active during all hours of operation. Disturbance reserves are used to restore the electricity system to a secure state of operations within a reasonable time of a disturbance such as a trip of any power line or power plant unit.

### *5.4.1 Need for ancillary services*

The need for ancillary services will in reality vary according to the operating situation and the mix of electricity production and electricity exchange. The need for ancillary services for individual 24-hour periods can be determined one day ahead on the basis of production and trading plans etc.

Purchase agreements concerning ancillary services should therefore be devised so that it is possible to vary demand in relation to suppliers to ensure the optimisation of operations, the market and the economy.

The need for ancillary services is determined on the basis of:

- Choice of design criteria with regard to security of supply
- Design contingency and regulation scenarios
- UCTE rules and Nordel's System Operation Agreement
- Any agreements with neighbouring TSOs

**Design criteria**

The design criteria describe Energinet.dk's requirements as to the types of fault situations which it must be possible to handle.

Energinet.dk has elected to dimension the volume of disturbance reserves in each of the two Danish synchronous areas so that the electricity system can be restored to a secure state of operation within a reasonable time of the loss of one power line or production unit (n-1) in each of the two synchronous areas. This applies up until the commissioning of the Great Belt power link. In this context, secure state of operation means that the next fault can be tolerated. This design criterion also forms the basis of the UCTE rules and Nordel's System Operation Agreement.

**Design contingency and regulation scenarios**

The design contingency and regulation scenarios are determined on the basis of the worst-case situations which are deemed to be likely. The loss of one of the largest production units or the loss of an interconnection with full imports is central to determining the design contingency scenario. These currently include Unit 3 of Ensted Power Station, Unit 5 of Asnæs Power Station, one Skagerrak interconnection, the Kontek Link or one of the 400 kV interconnections across Øresund. The breakdown of any of these will be to the order of 550-620 MW.

Another important factor for the design contingency and regulation scenarios is the considerable volumes of wind power production. A strong wind front that arrives later or is weaker than forecast has the same effect on the electricity system as a trip of thermal units in operation. There will be a shortage of electricity production which must be compensated for. A strong wind front that arrives earlier or is stronger than forecast will, on the other hand, create a need for the downward regulation of production capacity or alternatively the upward regulation of electricity consumption.

**UCTE rules and Nordel's System Operation Agreement**

Via the UCTE set of rules and Nordel's System Operation Agreement, Energinet.dk is obliged to ensure the availability of the above-mentioned ancillary services. Energinet.dk assesses the need for manual upward and downward regulation reserves itself. As regards primary regulation, the frequency-controlled spinning reserve, the frequency-controlled disturbance reserve and the automatic reserve, the obligation has, however, been specified in volumes by the UCTE and Nordel respectively. In return, Energinet.dk is guaranteed a share of the total volumes of these types of ancillary services available in Central Europe and the Nordic region.

**Agreements with neighbouring TSOs concerning sharing of ancillary services**

Today Eastern Denmark and Sweden share a 600 MW fast disturbance reserve for breakdowns in the two system areas south of the Swedish Cross-section 4. This saves Eastern Denmark the purchase of 300 MW of fast disturbance reserve.

Eastern Denmark also shares 50 MW of frequency-controlled disturbance reserve with Vattenfall Europe Transmission via the Kontek Link.

**Volumes**

**Table 5.3** summarises the need for ancillary services in Denmark. The table is divided into reserve types.

| Reserve type | Western Denmark Current need | Eastern Denmark Current need | Energinet.dk Current need |
|---|---|---|---|
| **Normal operation reserves** | | | |
| Primary regulation (UCTE) | +/- 31.7 MW | 0 | +/- 31.7 MW |
| Frequency-controlled normal operation reserve (Nordel) | | +/- 23 MW | +/- 23 MW |
| Automatic reserve | +/- 140 MW | 0 | +/- 140 MW |
| Regulating power reserve (manual reserve) | +140/-160 MW | +/- 150 MW | +290/-310 MW |
| Reactive reserve/voltage regulation and short-circuit power | 3 primary units in summer period | 3 primary units | 6 primary units |
| **Operational disturbance reserve** | | | |
| Frequency-controlled operational disturbance reserve (Nordel) | 75 MW | 100 MW | 175 MW |
| Fast operational disturbance reserve/manual reserve (max. 15 min.) | 480 MW | 300 MW | 780 MW |
| Slow operational disturbance reserve (manual) | 0 | 300 MW | 300 MW |
| Possibility of dead start | 2 units | 2 units | 4 units |

***Table 5.3*** *Current need for ancillary services.*

### *5.4.2 Future need for ancillary services*

As mentioned above, the capacities of power production units and interconnections are of decisive importance to the need for ancillary services. An increasing volume of wind power production and increasing focus on the part of our neighbours on imbalances on the interconnections may lead to an increasing need for ancillary services in the long term.

Energinet.dk has initiated activities aimed at reassessing and optimising the total volume of ancillary services.

**Sharing ancillary services**

The construction of the coming Great Belt power link will enable the sharing of ancillary services between Eastern Denmark and Western Denmark, which will save purchases of 300 MW of fast disturbance reserves/manual reserves.

Any other agreements concerning the sharing of ancillary services via the Danish interconnections may also contribute to reducing the need for purchasing ancillary services. When such agreements are made, it must at the same time be ensured that the interconnections have sufficient capacity to transfer the volumes of ancillary services in question. A comprehensive analysis is currently being carried out under the auspices of Nordel concerning the Nordic reserves with a view to increasing joint use and sharing.

# 6. Electricity market

Energinet.dk is obliged to make a well-functioning market place available to players in the electricity market. A precondition for the functioning of the market is that transparent and non-discriminatory market rules are laid down for players and that the necessary infrastructure, including interconnections, is available. An important task for Energinet.dk is also the cooperation with neighbouring TSOs on market function.

## 6.1 Status of electricity market function

### *6.1.1 Eastern Denmark and Southern Sweden*

During the period from the fourth quarter of 2005 to the first quarter of 2006, spot prices in Eastern Denmark were regularly between DKK 500 and DKK 2,000 per MWh. The peak spot price for the period was reached at the end of November 2005. **Figure 6.1** shows the spot prices in Eastern Denmark and Sweden and the import trading capacity on the Øresund interconnector on 28 and 29 November 2005.

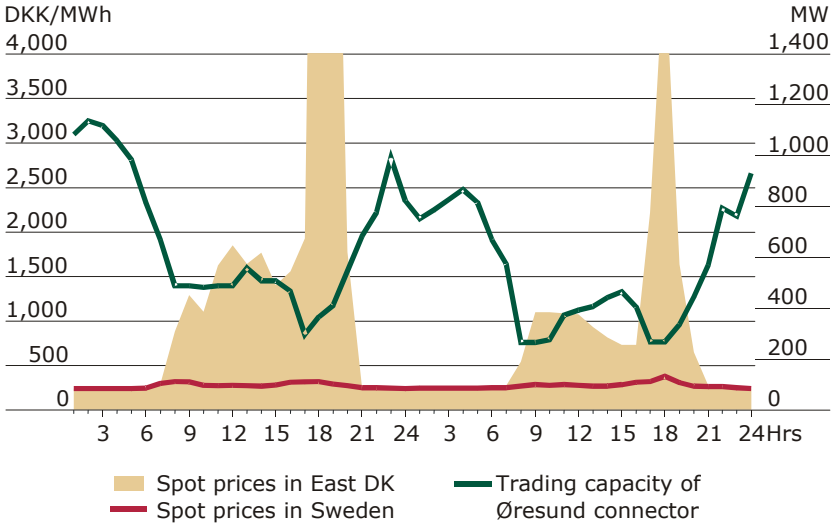



***Figure 6.1*** *Spot prices in Eastern Denmark and Sweden and the trading capacity on the Øresund interconnector on 28 and 29 November 2005. The nominal trading capacity for imports on the Øresund interconnector.*

The high prices are mainly attributable to the handling of internal congestion in Sweden. Due to the relatively low hydropower operating costs relative to the costs of thermal power during this period, the flow was often southbound from Northern Sweden to Southern Sweden, Eastern Denmark and the Continent.

Combined with a strained power balance in Southern Sweden, this sometimes causes congestion in the internal Swedish transmission grid (Cross-section 4), which means that the necessary capacity is not available for transporting the volume demanded from Northern Sweden to Southern Sweden. All other things being equal, this would lead to higher prices in Southern Sweden. However, Sweden elects to limit the trading capacity on the interconnection until the balance is restored in the Swedish system as one price area. For example, from

2004 to 2005, hours with limitation on the Øresund connector increased from 9% to 39%.

These administrative reductions in the trading capacity on the interconnections out of Southern Sweden result in low spot prices in Sweden. The consequential higher electricity spot prices are moved to Eastern Denmark. In addition to high spot prices in Eastern Denmark and available physical capacity on the Øresund interconnection, Southern Sweden has been characterised by available production capacity after the spot price calculations by Nord Pool.

Svenska Kraftnät and Energinet.dk have subsequently discussed possible solutions to this problem. In January 2006 Svenska Kraftnät suggested a solution which involved the merger of Eastern Denmark and Southern Sweden into one price area. It is proposed that internal congestion within this area, including on the Øresund interconnection, be handled by means of planned countertrade. In the opinion of Energinet.dk, the right solution from the point of view of the market is to handle congestion where it arises physically, and not to force congestion onto the interconnections in order to maintain one national price area.

In the opinion of Energinet.dk, the policy pursued by Svenska Kraftnät contravenes EU competition law. One of the conclusions of an analysis is that the policy of reducing capacity on the interconnections to Denmark in case of internal congestion has a negative impact on the Danish market and violates EU competition law.

Energinet.dk has raised the issue in Nordel as well as with the European Commission.

### *6.1.2 Germany*

The handling of congestion on the KONTEK-link interconnection (Eastern Denmark-Germany) is now covered by Nord Pool's market coupling. Moreover, the whole capacity of the interconnection is now available to the market (KONTEK price area). This has resulted in a closer coupling with the German market area and better utilisation of the interconnection.

So far, the number of players active on KONTEK has been low. Consequently, the spot price is sensitive to the bids actually made. Players in Germany can act both in the KONTEK price area and in the European Energy Exchange (EEX), which means that there is no common market optimisation. In the long term it would therefore make sense to "merge" the German price quotations to create a uniform reference price.

Trading on the border between Western Denmark and Germany also improved in 2005. On 5 October 2005, Nord Pool introduced the so-called CBO scheme (Cross Border Optimization). Under this scheme, capacity purchased via the day auction in the morning can be transferred to Nord Pool. In this way, such capacity can be included in Nord Pool's market coupling between Western Denmark and the KONTEK price area.

The CBO scheme is a step in the right direction but the cross-border trade can be made even more efficient. Prior to 5 October 2005, there were erroneous exchanges towards the low spot price in 25% of the hours as available capacity was auctioned off before prices where published by the exchanges. The introduction of the CBO scheme reduced this figure to 16% in the fourth quarter of 2005. The handling of the entire transmission capacity through market coupling between Western Denmark and Germany will improve the market function. Energinet.dk has raised the issue of improving trading between Germany and Western Denmark with E.ON Netz, the TSO south of the Danish/German border.

### *6.1.3 Market power*

One of the most important preconditions for a well-functioning market is that the market players are confident that the market price reflects the real value of the goods. The competition authorities play an important role as they are able to demand that measures be introduced to promote competition.

In November 2005, the Danish Competition Council decided that Elsam had abused its dominant position in the electricity market. From spring 2005 and until the Danish Competition Council's decision at the end of November 2005, the spot price in Denmark followed the high German spot price very closely. In its decision the Danish Competition Council stipulated that in certain situations a cap is put on the prices which Elsam can offer to Nord Pool, and that this will apply until 31 December 2008. Elsam has appealed against the decision.

In January 2006, the Danish Competition Authority initiated an investigation of Energi E2's conduct in connection with the pricing of wholesale electricity in Eastern Denmark.

## 6.2 Market for ancillary services

Historically, ancillary services have been supplied exclusively by the largest generators, Elsam and Energi E2. Since 1 January 2004, these services have been procured through open calls. However, it is still primarily the largest generators which have offered to supply these services.

In order to ensure as much competition as possible in connection with the supply of ancillary services, Energinet.dk is working to develop the models for the procurement of ancillary services. Many potential suppliers are not able to commit themselves to keeping reserves available for long periods of time. On the other hand, other suppliers will want more long-term agreements which will guarantee revenue if investments are required in order to make ancillary services available.

In its endeavours to create functional competitive markets for as many services as possible, Energinet.dk intends to limit the number of long-term agreements.

In 2006, the purchasing of manual reserves which can be supplied at 15 minutes' notice has been chosen as a focus area as a number of potential alternative suppliers have been identified for this service.

### *6.2.1 Focus on manual regulating reserves*

The players responsible for the production balance of the local CHP units are obvious suppliers of manual reserves. For more of these units to be activated, the times during which they are committed to supply must be relatively short.

The players responsible for consumption balance offer potential which has so far only been used to a modest extent and only in Eastern Denmark. They will be able to supply manual reserves for the system if the purchasing models are tailored to their properties. Demand response is described in further detail below.

In 2006 Energinet.dk will work to define and develop a proper market place for manual regulating reserves for implementation in the course of 2007. Other ancillary services will be procured through open calls with different duration as has been the case so far.

### *6.2.2 Emergency power units*

Emergency power units in consumption installations are a resource which up until very recently has been overlooked in the overall electricity system. These units can be started up at very short notice – typically as manual regulating reserves – and can reduce the installation's demand for power from the electricity system, thereby improving the system balance in situations with threatening shortages. Energinet.dk has launched two pilot projects which are investigating possible ways in which these units may be of benefit to the electricity system as a whole, and not just to individual installations. In both pilot projects, the units are used as manual regulating reserves.

## 6.3 CHP units in the electricity market

As part of the energy-political agreement of 29 March 2004, it was decided that all local CHP units in excess of 10 MW should join the spot market from 1 January 2005, and that all units in excess of 5 MW should be on the spot market from 1 January 2007. At present units with a capacity of less than 10 MW can voluntarily join the market.

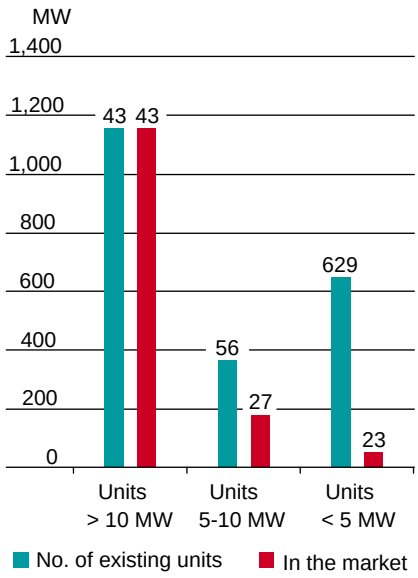



***Figure 6.2*** *Number of local CHP units in the market as at 1 April 2006.*

In addition to the spot market, the local CHP units can also take part in the reserve and regulating power market. Fifteen units currently supply upward regulation reserves, while an additional three units take part in the voluntary regulating power market.

## 6.4 Demand response

In a liberalised market, demand response is an important tool when it comes to ensuring a balance between electricity production and electricity consumption in critical situations. Demand response may thus relieve situations with critical power surpluses or deficits.

As no market player can be expected to invest in a power-generating unit which will probably only be running for a few hours a year, an obvious solution is to use electricity consumption to ensure a balance in the market in extreme situations.

Demand response involves allowing electricity consumption to be governed by the electricity price. This may, for instance, be done by shifting electricity consumption from times with high electricity prices to times with lower electricity prices. Demand response is not in itself synonymous with electricity savings, but experience shows that increasing awareness of electricity consumption on the part of end users has the indirect effect of reducing consumption. Another benefit may also be fuel savings and thereby environmental benefits if demand response can reduce production at power stations with low efficiencies.

Because of the low marginal costs, the many Danish wind turbines sometimes lead to very low spot prices. With this also comes an increasing need for ancillary services. Demand response can make it possible to handle more wind power in the electricity market, for instance by using electric boiler to generate district heating in periods with high levels of wind power-based electricity production. This may also bring environmental benefits.

### *6.4.1 Danish initiatives*

For electricity consumers to be subject to demand response, electricity prices must be communicated to consumers and meters must be able to register electricity consumption on an hourly basis. Today, all electricity consumers with consumption in excess of 100,000 kWh must register their consumption on an hourly basis. A number of grid companies have started the voluntary replacement of old electricity meters with new digital interactive meters. In many instances, the cost of the new electricity meters is expected to be recouped in the form of savings as the new meters can be read remotely. This applies not least where meters are due to be replaced. Energinet.dk recommends that all grid companies install new meters which are capable of registering electricity consumption at least by the hour. Many companies are currently looking at the costs of introducing and running the new meters and the appurtenant background systems.

However, the possibility of registering electricity consumption on an hourly basis is not enough. It is important to work in a targeted way within several areas in order to encourage demand response in the electricity market. Via its PSO R&D 2005 and 2006 programmes, Energinet.dk has granted funding totalling approx. DKK 20 million to eight research, development and demonstration projects on the control of electricity supply systems and electricity consumption. Among other things, the projects look at interactive meters for activating demand response; price-sensitive electricity consumption in the market for private consumers and small enterprises; demand response as reserve power (a demonstration project in the horticultural business); demand response and electricity production in industry and electricity consumption as a frequency-controlled reserve.

Considerable uncertainty attaches to the potential for demand response. A basic distinction must be made between the technical and the economic potential for demand response. The technical potential is defined as the consumption which it is technically possible to disconnect without insurmountable consequences. The economic potential is the most relevant target and expresses the volume of electricity consumption which it would be socio-economically attractive to disconnect. Any relevant computation of the economic potential for demand response must therefore be presented as a function of price developments – not least the number of price peaks. It is therefore difficult to calculate the potential for demand response precisely.

The background survey "Demand response in the Nordic Countries" has been prepared by Nordel as part of the so-called Power project. According to this survey, the potential for demand response in Denmark will be 500 MW, corresponding to approx. 8% of the maximum Danish power consumption. Owing to the extensive use of electric heating and large-scale electricity consumers within the aluminium and paper industries for example, Norway, Sweden and Finland offer potential for demand response of 31%, 18% and 20%, respectively, of their total power consumption.

All PSO-funded projects include the potential for demand response as an important element. A better basis for assessing the potential in Denmark is therefore expected to be available within a few years.

## 6.5 Interconnections

The interconnections play an important role as links between markets and are a precondition for competition in the Danish electricity market. The interconnections contribute to expanding market areas and increasing cross-border competition.

### *6.5.1 Level of exchange varies*

Denmark is situated right between two very different electricity systems – Nordel to the north and the UCTE system to the south. This means that considerable volumes of energy flow through the Danish electricity system, which in conjunction with the Danish use of the interconnections means that Denmark has a relatively high exchange capacity compared to its consumption and installed power station capacity.

**Figure 6.3** shows that the exchange of energy on the existing Danish interconnections varies considerably from one year to the next. Due to dry year conditions, the 2002-2003 period was characterised by energy shortages in the hydropower-based Nordic system with considerable northbound energy transports. The year 2005 was, on the other hand, characterised by relatively high levels of precipitation, resulting in larger southbound transports.

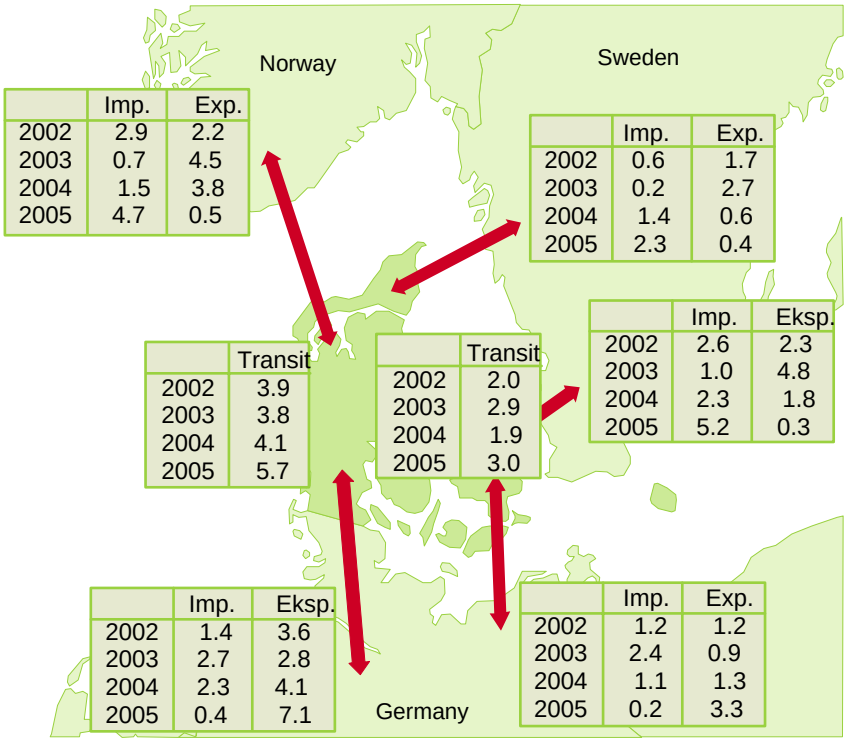



***Figure 6.3*** *Energy exchange with neighbouring countries and transit 2002-2005 (TWh). Imports and exports are relative to Denmark.*

The Danish electricity transmission system thus handles a considerable volume of transit between the Nordel and the UCTE systems. Under the auspices of ETSO, an agreement has been made between the European TSOs concerning payments for capacity use and grid losses.

### *6.5.2 Congestion rent and auction revenue*

When market demand for transmission capacity between two areas exceeds the available capacity, congestion rent or auction revenue is generated on the connection in question.

**Congestion rent**
Generators in area A export to area B but settle the exports with the electricity exchange at the low price in area A. Consumers in area B import from area A but settle the imports with the electricity exchange at the high price in area B. The price difference multiplied by the exchange capacity is called the congestion rent.

**Figure 6.4** shows an outline of the congestion rent and the auction revenue generated on the Danish interconnections. Today, the rent and the revenue are used to expand the connections, for counter purchases and to reduce grid tariffs.

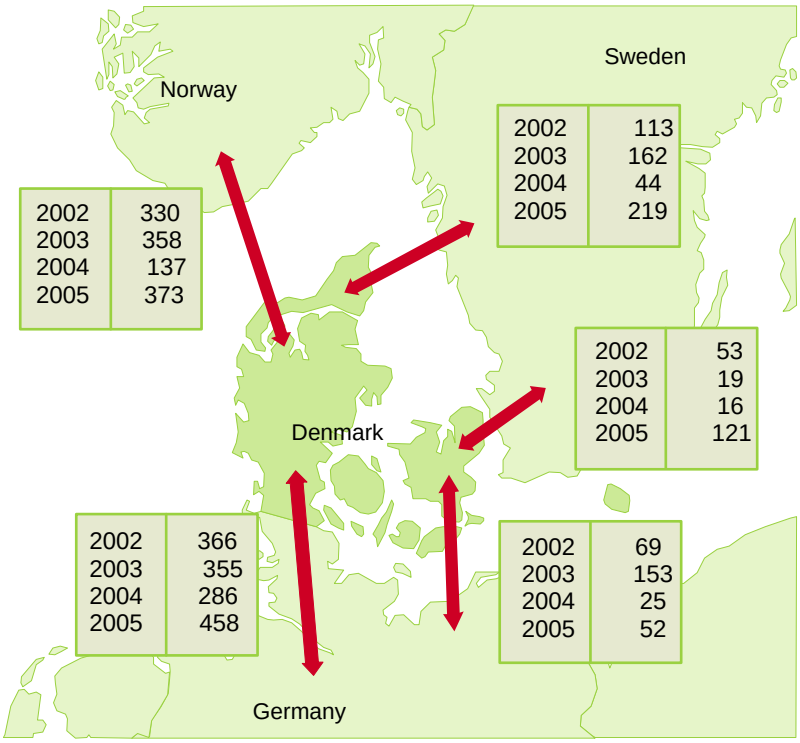



***Figure 6.4*** *Congestion rent and auction revenue on the Danish interconnections 2002-2005 (DKKm).*

All in all, congestion rent and auction revenue on the Danish interconnections totalled DKK 3.7 billion in the 2002-2005 period. The revenue is divided between the TSOs. During the same period, congestion rent in the Nordic market area totalled DKK 2.7 billion, of which DKK 1.9 billion related to the Danish in-

terconnections. During this period, Denmark received congestion rent of DKK 1.0 billion in the Nordic market area.

The congestion rent indicates that it may be socio-economically beneficial to expand the Danish interconnections with the neighbouring countries.

### *6.5.3 New exchange capacity*

Work is continuously going into making as much exchange capacity as possible available to the market as is technically possible. The existing interconnections offer scope for only limited capacity increases. It is therefore interesting to regularly assess the benefits of establishing new connections. In this context, it is also interesting to assess the situation in the neighbouring areas as this has a bearing on any decision to construct new exchange capacity.

Given the considerable volumes of hydropower generated in **Norway**, an interconnection to Norway would be interesting as it would make it possible to exploit the differences between the energy-dimensioned hydropower system and the power-dimensioned Danish CHP system. This would be very interesting from the point of view of integrating large volumes of wind power in Denmark.

The electricity system in Eastern Denmark is synchronised with the rest of the Nordic electricity system. The interconnection to **Sweden** is of decisive importance to the operation of the electricity system in Eastern Denmark.

In **Germany** the consequences of the planned expansion of wind power in the North Sea for the internal Germany transmission grid remain to be clarified. The German DENA study mentions plans for the period up until 2020 for up to 18.7 GW installed capacity in the North Sea and 1.7 GW installed capacity in the Baltic Sea. It also remains to be clarified how such an expansion will affect the internal German transmission grid.

The Dutch TSO (TenneT) and Statnett are currently constructing a 700 MW DC connection between Norway and the Netherlands for commissioning in 2007/2008. Consumption in the **Netherlands** varies relatively little over the year, but quite a lot over any 24-hour period, and there is therefore considerable difference between daytime and night-time prices. Electricity production in the Netherlands is largely based on natural gas, and the country is a high-price area relative to the Nordic countries. The Netherlands currently has a power deficit.

Due to surplus production capacity, the electricity market in **Poland** has historically been a low-price area relative to the Nordic region. Svenska Kraftnät, Vattenfall and the Polish TSO have established the Swepol cable between Sweden and Poland. The capacity is sold under annual contracts according to the "first-come, first-served" principle. At present, surplus capacity is not being available to the spot market.

**Nordel's priority cross-sections**

In 2004 Nordel agreed to work for an expansion of capacity on five priority cross-sections. These are shown in **Figure 6.5**. All in all the five connections

are expected to have a positive effect on the Nordic market area. The Danish connections are the Skagerrak 4 and Great Belt connections. The reinforcement of the Swedish "Cross-section 4" will also be of considerable importance for Denmark.

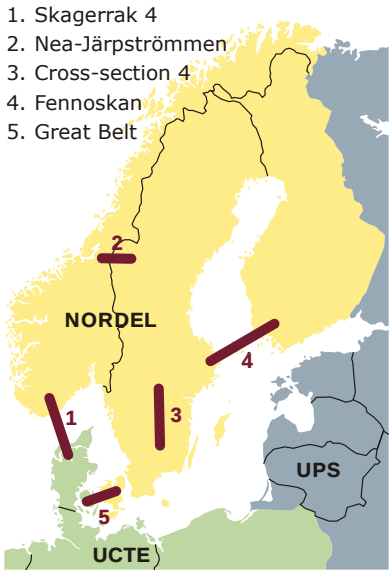



***Figure 6.5*** *The five priority grid reinforcement projects adopted by Nordel in 2004. The list is not in order of priority.*

**Skagerrak 4**. From the government's Energy Strategy 2025 it can be seen that the government is awaiting further documentation before making a decision concerning the possible construction of a new Skagerrak interconnection. Investigations are currently being carried out by Energinet.dk in cooperation with Statnett.

It would be possible to commission a 600 MW connection in 2012. The documentation is expected to be presented to the supervisory boards of the companies in third quarter of 2006.

**Nea-Järpströmmen** is a planned expansion of the interconnection between Central Sweden and Norway. A decision concerning the connection was made in February 2005 with expected commissioning in 2009. The planned transmission capacity after the expansion will be approx. 1,200 MW.

**Cross-section 4** is a connection between Central Sweden and Southern Sweden. In November 2005 Svenska Kraftnät decided to expand the transmission capacity of Cross-section 4 for expected commissioning in 2011. The current transmission capacity of Cross-section 4 is 3,700-3,900 MW. The transmission capacity is expected to be increased by 500 MW.

**Fennoskan 2**, which connects Central Sweden with Finland, was decided in February 2005 for expected commissioning in 2010. The current transmission capacity is approx. 550 MW, which will be expanded by 800 MW.

The **Great Belt power link** was decided by the Supervisory Board of Energinet.dk in December 2005. The plan is for the interconnection to be established as a 600 MW DC cable for commissioning in 2009/2010. The decision has been submitted for final approval by the Danish Minister for Transport and Energy.

# 7. Electricity transmission

## 7.1 Framework and terms for transmission planning

A well-functioning and adequate electricity transmission system is a precondition for the security of supply, the servicing of the market, the integration of renewable energy and the safeguarding of the power supply sector's contingency preparedness. The grid must therefore be able to meet a number of requirements under widely varying conditions. One of Energinet.dk's main tasks is to ensure that the electricity transmission grid is able to meet these requirements efficiently and cost effectively.

**Figure 7.1** shows the existing transmission grid.

The current grid planning framework was laid down with the so-called 'blue report': The Danish Ministry of the Environment and Energy's principles for the establishment and renovation of high-voltage installations (*Principper for etablering og sanering af højspændingsanlæg*) from 1995.

The most recent revision of the principles for the overall structure of the electricity transmission grid in Denmark took place in 1999 with the Danish Energy Authority's analysis of the long-term grid structure for the electricity transmission grid (*Analyse af den langsigtede netstruktur for eltransmissionsnettet*). Most recently the principles have been supplemented and modified with the government's Energy Strategy 2025 and an action plan for the future electricity infrastructure (*Handlingsplan for den fremtidige elinfrastruktur*) from June 2005.

According to the government's action plan for the future electricity infrastructure, the expansion of the electricity infrastructure must meet the electricity market's need for transmission capacity and support the increased use of renewable energy. The action plan stipulates, among other things, that:

- The future infrastructure must be planned so as to balance the concerns for security of supply, economy and the environment and the functioning of the electricity market. The expansion of the electricity infrastructure must support the integration of more renewable energy, with due consideration given to impacts on the landscape. In particular, continued expansion with offshore wind farms will put pressure on the power system and infrastructure as a high level of security of supply must be maintained at the same time.

- When the transmission grid is reinforced, technical solutions are applied that have a lifetime between 30 and 40 years. Current decisions concerning infrastructure investments must therefore remain valid when various developments take place which are part of the general framework set by the government and the Danish parliament.

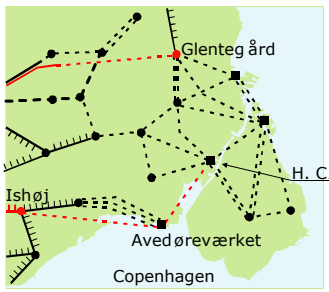
- Future wind power expansion is primarily expected to take place offshore. Wind power expansion is of prime importance to the demands

on the power system and hence also to the overall, long-term planning of the electricity transmission grid.

- Any possibilities for introducing renewable energy to the existing grid – with limited initiatives – should be fully examined and used to the greatest extent possible. In this context, an economic assessment must be made of possible short-term restrictions on offshore wind power production in particularly critical situations in light of the grid investments required.

- The principles for the establishment and renewal of high-voltage installations call for the placement of new 400 kV lines by means of overhead lines when they are run across open land and when this is not in conflict with particular national nature interests. According to these principles, 132/150 kV lines may also be established as overhead lines when so doing does not have major consequences for urban built-up areas or important nature interests.

- When new 400 kV overhead lines are set up, compensation underground cables at lower voltage levels are to be used when possible so that the total number of overhead lines at voltage levels above 100 kV is reduced.


- 400/150 kV or 400/132 kV substation or 400 kV coupling station
- 150/60 kV or 132/50 kV substation eller 150 kV eller 132 kV coupling station
- Power station with substation
- 150 kV or 132 kV single-circuit line
- 150 kV or 132 kV double-circuit line
- 150 kV or 132 kV cable
- 400 kV cable
- 400 kV single-circuit line
- 400 kV double-circuit line
- 400/150 kV or 400/132 kV combi line
- 220 kV double-circuit line
- 220/150 kV combi line
- 250 kV, 350 kV or 400 kV line
- 250 kV, 350 kV or 400 kV cable

Independent of no. circuits

Direct current HVDC

***Figure 7.1*** *Existing transmission grid beginning of 2006.*

## 7.2 Planning of transmission grid

Energinet.dk is responsible for the operation and planning of the transmission grid as a whole. The 400 kV grid and the interconnections are owned by Energinet.dk, while the 132/150 kV grid is made available to Energinet.dk by the transmission companies against a charge.

The transmission grid provides the physical background for an efficient international electricity market, the aim being for competition between generators to result in high quality and low prices. Moreover, it must contribute to the security of supply of the power system by ensuring the availability of transmission capacity and stable operation of both production units and consumer installations in a technically/economically optimum way for society. The transmission grid must be able to handle random supply and demand-side fluctuations and be robust in the face of contingency situations in the power system. Exchange via the nodes between the transmission grid and the rest of the power system is partly dependent on non-adjustable and unpredictable parameters. The system must be able to cope with this.

Contingency management, ie the ability to handle accidents, acts of terrorism etc., is generally provided for through the safety requirements defined as part of grid planning. Safety is ensured by means of the ring connections which enable extensive renovation work to be carried out and which reduce the system's vulnerability to external impacts. The design of installations is based on criteria which take account of the possible breakdown of components as a result of natural disasters or acts of terrorism. Concerning operation and maintenance, contingency management capacity is maintained to handle restoration and repairs.

In the following, the transmission grid's contribution to the security of supply is described as transmission reliability. Transmission reliability comprises a static part, which can be described as the adequacy or capacity of the grid, and a dynamic part which is the grid's ability to handle sudden disturbances. For a further definition of these concepts, see section 5 on security of electricity supply.

Grid planning is based on three principles:

- Long-term grid structure
- Grid code
- Socio-economic considerations.

An attempt is made to ensure that decisions concerning grid reinforcement are consistent with the plan for long-term grid structure – also called the basic grid.

## 7.3 Long-term grid structure

Work has gone into the design and determination of the extent of the long-term grid structure and the basic grid for a number of years. The most recent review took place after the appointment in 1997 of a ministerial working group assigned to solve a number of problems concerning the implementation of physi-

cal planning in connection with the expansion of the high-voltage grid. The outcome can be seen from the Danish Energy Authority's analysis of the long-term grid structure for the electricity transmission grid (*Analyse af den langsigtede netstruktur for eltransmissionsnettet*) from January 1999. This report is based on three scenarios for the development of the production capacity and consumption trends towards 2030. Two or three alternatives were devised for Western and Eastern Denmark, respectively, and in both regions the structure came to be based on rings.

### *7.3.1 Elements in the development of the grid structure*

Below follows a description of Energinet.dk's work on the elements in the grid structure.

The structure itself is based on the need for transmission between the various centres of production, consumption and exchange. The expected size of the grid is determined on the basis of the grid code based on specific assumptions concerning the production system, consumption and international exchange capacity as well as the exchange capacity of the coming Great Belt power link. The directly connected large production units, offshore wind farms and interconnections have the greatest bearing on the transmission grid capacity requirements. The growth rate of electricity consumption is low and has a minor bearing on developments in capacity requirements.

The fundamental assumptions for the power contributions from these units and connections are subject to continuous development. For example, earlier requirements that Energinet.dk must be guaranteed access to all centrally connected installations must be reviewed. It must be established in each individual case whether such guarantee is of socio-economic benefit.

For financial and technical reasons, the technology used for grid expansions are primarily 400 kV overhead lines. In so far as is possible, these lines are placed along existing cable routes for lower voltage levels. Pursuant to Executive Order no. 1463 of 19 December 2005 concerning Energinet.dk, new 400 kV overhead lines must be compensated for by cable laying at lower voltage levels, the aim being to reduce the total number of overhead lines at voltage levels above 100 kV.

Energinet.dk monitors prices for 400 kV cables closely. If prices become competitive, and the technical problems involved in long-distance cabling are solved, cable laying may be possible in the longer term at the highest voltage levels.

Energinet.dk will be working with scenarios. In addition to establishing the assumptions needed to calculate the demand for transmission capacity in the grid – and the impending review of the grid planning principles and grid code – the scenarios can be used to test the robustness of a long-term expansion plan for the transmission grid.

Important strategic elements in the design of the long-term structure are the use of ring structures, the parallel operation of the 400 kV and underlying grids and differentiated transmission security at the various hubs.

The status for the 400 kV structure and the basic grid can be seen from **Figure 7.5**. The time perspective is 25-50 years depending on developments in consumption, production and interconnections. The implementation of the installations is ensured through coordination of the individual reinforcements with public physical planning in general.

### *7.3.2 Connection of offshore wind turbines*

In the 'Action plan for offshore wind farms in Danish waters' (*Havmøllehandlingsplanen*) from 1997, the distribution and connection of offshore wind farms were based on a principle of geographical spread, including an even distribution between Eastern and Western Denmark. With reference to this action plan the then Danish government in 1998 ordered the power companies to construct the first five offshore wind farms. The first two wind farms were commissioned in 2002/2003. At the same time, the order concerning the construction of the remaining three wind farms was withdrawn.

As part of the follow-up on the energy-political agreement from March 2004, the government has invited bids for two offshore wind farms of 200 MW each at Horns Rev and Rødsand. Energi E2 was granted the contract for Horns Rev B. A consortium consisting of Energi E2, E.ON Sweden and Dong Wind won the contract for Rødsand 2.

Too much spread in the expansion of offshore wind power in terms of time and geography may lead to less optimum solutions from the point of view of connection and expansion of the transmission grid – both technically and financially. Long-term planning and socio-economic optimisation of investments in the electricity infrastructure are hampered in the current situation by the inability to incorporate future, as yet undecided offshore wind farms into the planning. Wind power expansion has a decisive bearing on the demands placed on the power system and thereby on the overall, long-term planning of the electricity transmission grid.

In 2005 the Danish Energy Authority started updating the offshore wind power expansion plan from 1997. Energinet.dk welcomes this initiative and at the same time urges the Danish Energy Authority to speed up the process and to include the issue of the derived heavy investments in the electricity transmission grid in its considerations. In the opinion of Energinet.dk, the work should be speeded up as much as possible for the sake of deciding on the strategy for expanding the transmission grid which contains the two wind farms already decided.

An offshore wind farm plan, with specific plans for the concentration of the next 3-4 wind farms at one or more specified locations, will enable more long-term and financially optimised grid connection of the two wind farms which have already been planned.

## 7.4 Grid code

The grid code is the second of the three grid planning principles, and its role is to identify any problems with adequacy (weaknesses, congestion) and security (stability) in the grid and to compare the quality of possible solutions to such problems.

Investigations concerning adequacy and security are based on three fundamental concepts:

- Identifying starting point
- Analysing contingency situation
- Mapping consequences.

Stationary investigations of a contingency situation include an investigation of the consequences of such a situation for the rest of the system in the event of the outage of a cable for example. Dynamic investigations, on the other hand, look at the immediate transition process, ie the outage of a particular power line for example.

The contingency situation (or outage) is introduced, and the consequences are quantified. If the consequences are shown by the investigation to be acceptable, the code has been complied with. If not, solutions to the problem identified must be found, investigated and assessed.

The selection of probable representative starting points and probable contingency situations is based on availability and fault statistics, among other things, as well as statistics on simultaneous outages in the transmission grid and the production system.

Results from such statistics can be computed in many ways. For example, average availability for Western Denmark is shown in **Figure 7.2**. Similar calculations have been discontinued in Eastern Denmark for some time, but were resumed in 2000. Energinet.dk is currently working on statistics for Denmark as a whole.

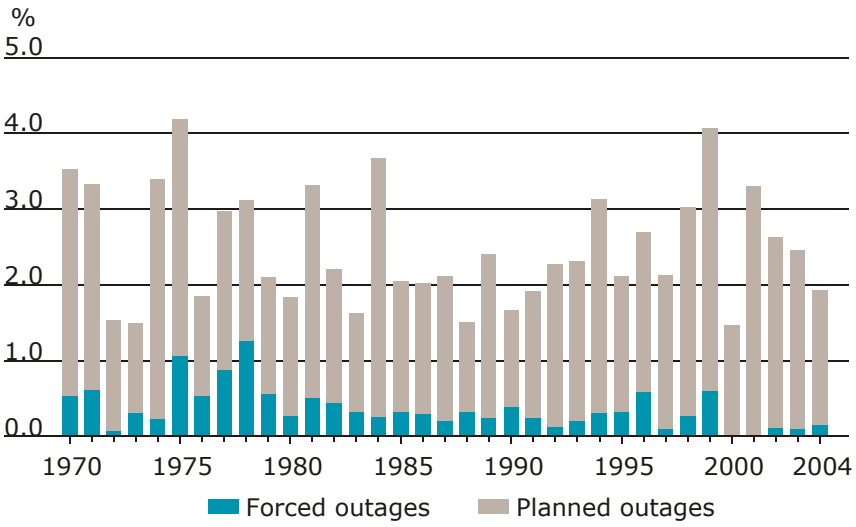



***Figure 7.2*** *The average outage of the transmission grid in Western Denmark divided into planned and forced outages in % of year total.*

It can be seen that the average outage for the transmission lines is approx. 2.5%. Variation in planned outage primarily reflects variation in construction activities from one year to the next.

**Figure 7.3** shows the number of simultaneous line outages in the annual review period from April to October in Western Denmark.

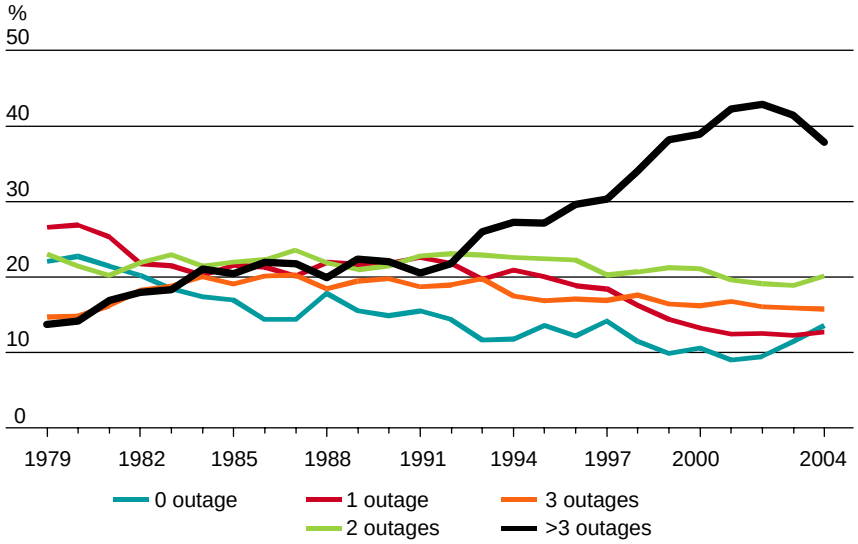



**Figure 7.3** Development in Western Denmark in the number of simultaneous line outages in the transmission grid during the period reviewed.

It can be seen that the duration of many simultaneous outages increased in the 1990s, while the duration of an intact grid was falling and more than halved during this period.

This indicates that there are no grounds for easing the grid planning criteria which specify the situations which the grid must be able to handle, and it is necessary to carry out regular analyses and assessments to establish whether the starting points and outage situations analysed are the right ones.

The quality of the grid is also reflected in the registration of non-deliveries of energy to consumers caused by the transmission grid. **Figure 7.4** shows the figures for the Nordic countries in 1994-2004. The figures are based on Nordel's statistics on system disturbances.

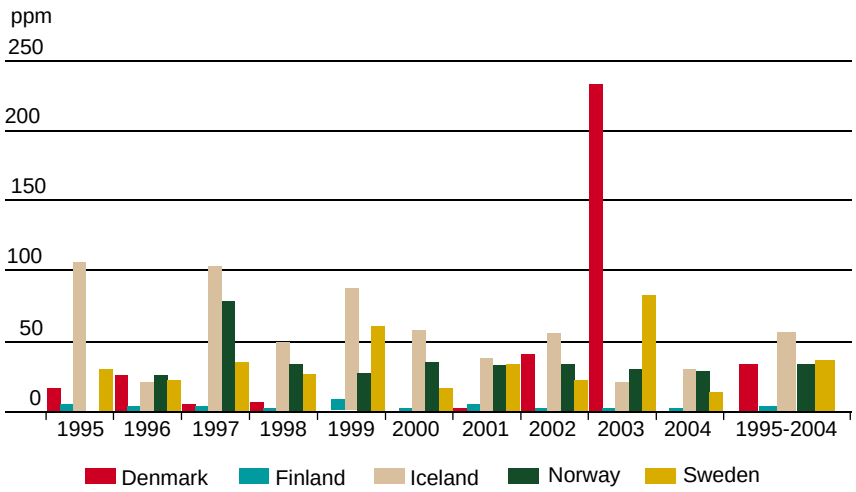



***Figure 7.4*** *Non-deliveries of energy in ppm of consumption per year for 1995-2004 and average for the period. The high Danish value in 2003 is attributable to a power cut on Zealand on 23 September 2003.*

Energinet.dk is working to develop tools for calculating the quality parameters for grid planning to enable a direct assessment of the reliability of the grid relative to measured values.

The former TSOs, Eltra and Elkraft System, did not apply the same grid codes. Work to harmonise these into national codes has been launched and is primarily aimed at harmonising the three basic elements: Starting point, contingency situation and consequences. Such harmonisation will provide a uniform basis for grid planning in Denmark as a whole, thereby enabling the planning and prioritisation of grid expansion on a national scale.

The harmonisation of Eastern and Western Denmark must take account of the geographical and organisational affiliations of the areas to Nordel and the UCTE, respectively.

Work is also going into incorporating the dimensioning of the so-called reactive power into the grid codes which describe the obligations of the grid companies. The aim is to harmonise requirements as regards the voltage-control properties of the production units and the dimensioning of the reactive resources of the grid.

### *7.4.1 Reactive power and short-circuit power*

**Reactive power**
Reactive power takes up capacity in the power grid. At the same time, it is a precondition for maintaining voltage and for voltage restoration after serious system disturbances such as blackouts.

The handling of reactive power is primarily effected through neutralisation, ie compensation and through procuring sufficient resources to establish and control the transmission voltage.

The introduction of the electricity market has made it less attractive for power stations to compensate for reactive power. The optimum use of all generator units must, however, still be ensured.

Wind power contributes to the reactive power problems. Local units can contribute to local solutions for the challenges created by wind power in the distribution grid.

**Reactive dimensioning**
Adequate reactive power must contribute to compliance with the other grid codes, eg by ensuring that shortage of reactive power does not delay voltage restoration after faults or lead to system disturbances and by ensuring that nothing hampers the efficient functioning of the market, the utilisation of production facilities and exchange with neighbours.

The systems 'crude' balance and regulation must be ensured by means of passive reactors and capacitors (in substations). These must ensure that dispatchable reactive resources (power stations and Energinet.dk's synchronous machines) are sufficiently controllable for maximum security of stable operations to be achieved.

As mentioned previously, Energinet.dk is working to harmonise the grid codes. This includes the dimensioning of reactive power - work that will be carried out in cooperation with the transmission and grid companies.

**Short-circuit power**
The short-circuit power is an expression of how the grid reacts to changes – how voltages and flows change when events occur. These may be short-circuits as such where the changes affect the relay protection, or coupling with reactive components where voltage changes affect the voltage quality.

In the transmission grid, the short-circuit power tends to be lower due to fewer large production units, and this is of particular significance to the voltage quality. At the lower voltage levels, the short-circuit power tends to be too high and must be reduced by means of special components to ensure that installations are not damaged in the event of short-circuits.

Energinet.dk monitors developments in the lower short-circuit power at the higher voltage levels and the consequences for voltage quality with a view to

introducing countermeasures in cooperation with the other players, if necessary.

## 7.5 Socio-economics

The current experience-based documentation for grid expansion with technical/economic comparisons of alternatives is supplemented with a purely socio-economic approach, with business cases forming the basis of any specific decisions made.

The grid codes are thus no longer the only rules determining expansion as the benefits of expansion must be compared directly with the costs involved. This means that improvements in security of supply, for example, including transmission reliability, must be assessed. Normally, transmission reliability will be considerably better than the resulting security of supply as faults in the distribution grid will normally lead to the more frequent disconnection of consumers.

Energinet.dk's review of the planning principles includes assessments of the probability-based calculation methods.

Differentiating security of supply is an important element of socio-economic optimisation. With the existing grid codes, larger consumption areas are ensured higher security of supply than the one corresponding to the outage of a single component (n-1). Similarly, security of supply is not as high for smaller island communities as it is for the rest of society.

Finally, it is important that the societally optimum expansion of the electricity transmission grid can take place independently of owner boundaries. Consequently, economic regulation must ensure that expansion can be realised where such expansion is most expedient from a socio-economic and technical point of view.

## 7.6 Ring connections

Below follows an outline of possible future expansion of the 400 kV transmission grid in the so-called ring connections. The need to expand the transmission grid, including the 400 kV connections on Zealand and on the west coast of Jutland, arises primarily as a result of potential increases in capacity on the interconnections and the connection of new offshore wind farms.


***Figure 7.5*** *Long-term 400 kV basic grid.*

### *7.6.1 Western ring in Jutland*

The need for the 400 kV Revsing-Endrup-Idomlund-Tjele ring in Western Jutland is primarily linked to the expected expansion of wind power in the North Sea.

Moreover, this 400 kV ring will make it possible to increase trading capacity between the hydropower-based areas in the Nordic countries and the CHP-based areas south of Denmark. For this purpose Energinet.dk and Statnett are investigating a new HVDC interconnection to Norway (Skagerrak 4). At the same time, Energinet.dk is looking into the possibility of upgrading – in cooperation with E.ON Netz – the German interconnection to ±1,500 MW or more. Finally, a 400 kV ring in Western Jutland is a precondition for making the most of the coming Great Belt power link.

The missing section of the 400 kV ring is between Endrup and Idomlund. With the establishment of this section, the existing 150 kV line between Lykkegård (near Esbjerg) and Struer can be removed on the section between Esbjerg and

north of Varde and again on the last section before Struer. The plan is for the rest of the 150 kV line to be routed on the same pylons as the new 400 kV line.

### *7.6.2 Northern ring on Zealand*

A northern 400 kV ring on Zealand (new Asnæs Power Station-Kyndby Power Station connection together with the existing Kyndby Power Station-Hovegård line) will improve operation flexibility in connection with outages due to operation and maintenance activities on the existing 400 kV line between Asnæs Power Station and Hovegård and contribute to maintaining security of supply. Moreover, there is a wish for the number of overhead lines in the open landscape to be reduced, while at the same time strengthening the 400 kV transmission grid for both east-west and north-south energy transmission.

The need for the new 400 kV connection between Hovegård and Asnæs Power Station via Kyndby Power Station arises from a number of factors:

- The connection will run parallel to the Hovegård-(Ishøj)-Bjæverskov-Asnæs Power Station section. The age and condition of this section will necessitate extensive renovation within a few years' time, requiring long-term disconnections.

- The establishment of an HVDC interconnection across the Great Belt will, together with the connection of the southern 400 kV ring to Herslev, increase the total capacity connected to the western section of the 400 kV grid on Zealand. The timing of the reinforcement of the Asnæs Power Station-Kyndby Power Station section will depend on the size of the future Great Belt power link as well as other expansion to the west and south of Bjæverskov.

In connection with the establishment of the ring, the scope of any decommissionings will be negotiated with the local authorities.

A new connection between Asnæs Power Station and Hovegård via Kyndby Power Station will also mean that two independent 400 kV cable routes from Asnæs Power Station and Kyndby Power Station are established, necessitating either the establishment of 400/132 kV transformation at Kyndby Power Station, or for parts of production to be moved to the 400 kV level.

### *7.6.3 Southern ring on Zealand and Lolland/Falster*

A fully expanded 400 kV AC ring connection (**A, Figure 7.5**) Bjæverskov-Rislev-Radsted-Vestlolland-Stigsnæs Power Station-Herslev would allow connection of all the elements in the offshore wind farm plan from 1997, ie up to 10 wind farms of 150 MW south of Lolland/Falster in addition to Nysted and Rødsand 2.

The rate of expansion of the 400 kV ring will depend on the future expansion of wind power production at Omø Stålgrunde or near Rødsand/Gedser. An initial grid change of the southern ring could be the establishment of a 400 kV double-circuit connection from Bjæverskov to Rislev and a combined 400/132 kV connection from Rislev to Radsted in step with the expansion of wind power at Rødsand/Gedser.

Once the volume of wind power connected to the 400 kV overhead line exceeds the largest production unit in Eastern Denmark, further reinforcement will be required. The expansion of wind power at Omø Stålgrunde may be a reason for establishing a combined 400/132 kV connection between Herslev and the Vestlolland substation near Nakskov. A 400/132 kV connection between Radsted and Vestlolland will be needed to complete the 400 kV ring. Concurrently with the reinforcement of the 400 kV grid between Bjæverskov and Radsted, the 132 kV grid to Lolland/Falster will be strengthened.

Depending on the assumptions made, an alternative (**B, Figure 7.5**) to the above-mentioned 400 kV ring may be relevant, ie a smaller 400 kV ring from Bjæverskov via Rislev and Stigsnæs to Herslev. Both alternatives will establish two independent 400 kV overhead line routes to Stigsnæs Power Station.

### *7.6.4 Øresund and metropolitan rings on Zealand*

In connection with the disconnection of one or both 400 kV interconnections to Sweden, the 132 kV interconnections to Sweden may contribute to maintaining security of supply in Eastern Denmark and to securing supplies to Northern Zealand, while at the same time contributing to improving preparedness levels in Eastern Denmark to avoid inexpedient islanding.

If it becomes necessary to replace the 132 kV submarine cables across Øresund out of concern for security of supply, the market and preparedness, two possible avenues have been identified. An assessment remains to be made of the most optimum solution on the basis of the following criteria: Security of supply, required investments, market conditions, environmental factors, construction time, robustness from the point of view of preparedness and local considerations.

The following two solutions are being considered:

1. Replacement of the existing 132 kV cables one by one with new 132 kV cables with estimated investments of DKK 170-200 million.

2. The establishment of a 400 kV submarine cable across Øresund between Copenhagen (Glentegård or H.C. Ørsted Power Station) and Southern Sweden (to Malmö for instance), which is deemed to require investments of DKK 700-800 million.

As can be seen, one alternative is considerably more costly than the other. The most expensive solution, ie a submarine cable across Øresund between Copenhagen and Southern Sweden, is preferable from the point of view of preparedness. A 400 kV cable will be routed close to Amager Power Station with a view to subsequent connection.

In addition, a need may arise for a 400 kV cable ring in Copenhagen, primarily if power production capacity in the area increases or in case of a significant increase in consumption in central Copenhagen. Such a cable ring and the transformation points will reduce the load on the 132 kV cable grid in the area,

and at the same time power stations in Copenhagen will be able to supply production directly to the 400 kV grid. Both factors will contribute to increasing operational flexibility and security of supply. The cable ring would consist of one 400 kV cable connection between Glentegård substation and H.C. Ørsted Power Station via Amager Power Station. The third transformation point between 400 kV and 132 kV in the metropolitan area will be established at Amager Power Station.

### *7.6.5 Transverse east-west connections in Jutland*

The regional plans include connections between Tjele and Trige in Central Jutland and between Revsing and Landerupgård in Southern Jutland (**Figure 7.5**). The first connection replaced the originally planned connection between Tjele and Randers. The connections will provide a higher degree of meshing of the 400 kV grid in Jutland, while at the same time increasing the east-west transmission capacity.

The timing of the construction of the section will depend on the exchange capacity on the interconnections to Norway and Sweden and their points of feed-in to the grid, on changes to the primary production capacity and on the scope and location of future expansion of offshore wind power production.

The interconnection to Norway is the most likely interconnection to the Nordic region to be expanded. Several possible feed-in points exit. The existing Tjele substation is expected to handle yet another terminal (Skagerrak 4) which may be operated with Skagerrak 3 as a secondary terminal. Major expansion can either take place in Idomlund in Western Jutland or in a new substation near Års in Himmerland.

Any expansion of the Great Belt power link with an additional 600 MW will in all probability lead to the construction of a 400 kV connection between Endrup/Revsing and Landerupgård. Both Endrup and Revsing are mentioned as the connection can be constructed between Endrup and Landerupgård on existing double-circuit pylons between Endrup and Revsing or alternatively between Revsing and Landerupgård with a 400 kV substation at the branching point near Revsing. Reservations must be made in respect of the necessary capacity for this exchange being available on the Great Belt power link.

Decommissioning of production units at Studstrup Power Station may result in a larger extent of transmission to the Aarhus region and thereby possibly a need for greater transmission capacity in the grid.

The future scope of offshore wind power expansion has not as yet been determined. In the opinion of Energinet.dk, the concentrated expansion of either Horns Rev or Rødsand may be advantageous from the point of view of harmonising grid expansion. This will probably not lead to the expansion construction of the Tjele-Trige section, but a decision to expand Horns Rev will probably lead to the construction of the Endrup/Revsing-Landerupgård connection concurrently with the Great Belt power link.

Tjele-Trige could be initiated by major offshore wind power expansion south of the island of Læsø in the Kattegat. This will depend on the meshing of the grid at the time when expansion commences.

## 7.7 Projects in progress

The Transmission Report and the System Plan lay down the overall framework for the electricity transmission installations to be constructed in Denmark. Current projects in progress comprise the expansion of Kassø-Revsing, the grid connection of offshore wind turbines at Horns Rev, the grid connection of offshore wind turbines at Rødsand and the Great Belt power link. These projects are described in greater detail in the Transmission Report 2006 (in Danish).

## 7.8 Supplying island communities

Following a number of recent projects which have assessed the security of supply for a number of Danish islands, including Bornholm and Læsø, the issue is described below.

The conclusion is that it is necessary from a socio-economic point of view to differentiate security of supply in Denmark. This applies to a number of islands where the distance to the rest of the transmission/distribution grid is great, and where consumption on the individual islands does not justify the construction of one or more connections so as to be able to maintain the security of supply guaranteed in the rest of Denmark.

What distinguishes these islands from the rest of Denmark is that a single trip of the grid at the highest voltage level will result in consumers being disconnected. In the rest of Denmark, the transmission grid is designed to ensure that a single fault does not result in the disconnection of consumers (the n-1 principle).

The islands have been divided into three sizes: Large, medium-sized and small islands.

**Large island**

Island with local, main power supply grid with local production and connection to neighbouring areas. The trip of a connection to a neighbouring area leads to consumers being disconnected, but the supply can be restored through the start-up of local production units.

The capacity of the production units must be sufficient for demand on the island to be met even in the event of the outage of the largest production unit. If connection to a neighbouring area is established, the outage of local production will not lead to the disconnection of consumers.

One example of a large island is Bornholm: Bornholm has a 60 kV submarine cable connection to Sweden. This connection can supply all of Bornholm. Moreover, Bornholm has a number of production units which can supply Bornholm if the cable connection to Sweden is down. Owing to the scrapping of old production units, it is necessary to establish new production capacity on Bornholm to

meet demand in situations where the cable to Sweden cannot be relied upon and where the largest production unit is disconnected.

On Bornholm maximum consumption at any time is approx. 55 MW.

**Medium-sized island**
Island with local, main power supply grid with either local production or connection to neighbouring areas. The outage of the connection to neighbouring areas or the outage of production units leads to the disconnection of consumers, and the supply cannot be restored immediately.

One example of a medium-sized island is Læsø: Læsø has a 20 kV submarine cable connection to Jutland. This connection supplies Læsø with power, and there are no production units on the island. This means that the outage of the cable to Jutland leads to the disconnection of all consumers on Læsø. In the event of a fault on the 20 kV cable, one of the DC connections between Jutland and Sweden can be used as a reserve. Changing over the cable connection from direct current to alternating current can take up to eight hours, and during this time Læsø will be without power. This method occupies about one third of the transmission capacity between Jutland and Sweden.

On Læsø maximum consumption at any time is approx. 3 MW.

**Small island**
Island with power supply grid with local production. The local power supply grid will typically be supplied by a single generator. The outage of this production unit will lead to the disconnection of all consumers until the supply has been restored.

One example of a small island is Brandsø: Brandsø has nine buildings, three of which are supplied with power from a diesel generator via a local grid. On Brandsø maximum production capacity is currently 50 kW.

# 8. Security of gas supply

## 8.1 The Danish gas system

In addition to the gas pipelines in the Danish section of the North Sea, transmission lines along the length of (Aalborg-Ellund) and across (Nybro-Dragør) Denmark and the distribution grids of pipe systems to consumers, the natural gas transmission system consists of a gas treatment plant and two subterranean gas storage facilities.

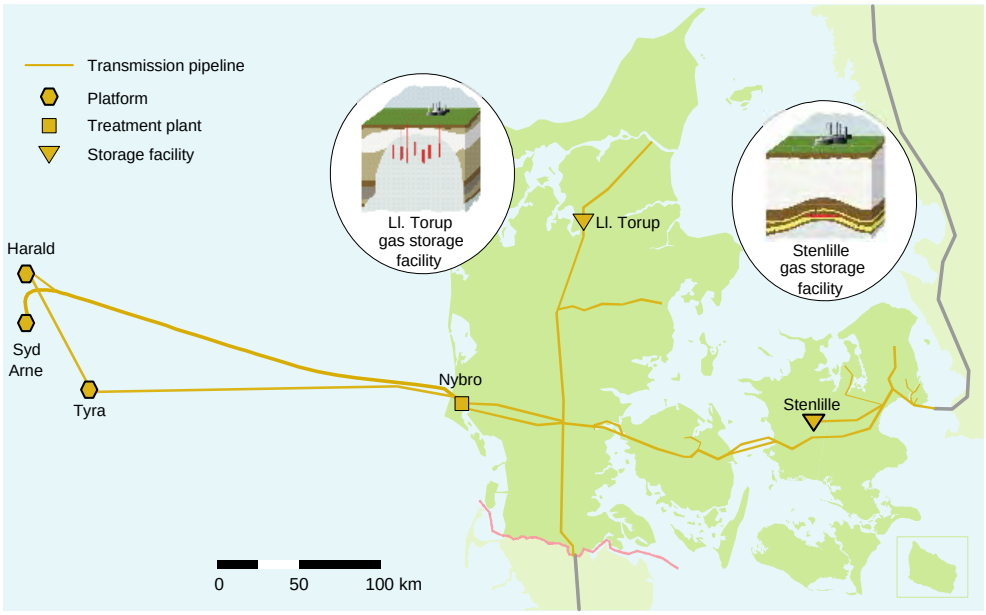



***Figure 8.1*** *The Danish gas system.*

The natural gas from the Danish section of the North Sea is transported through two offshore pipelines from the Tyra and Syd Arne fields to the shore north of Esbjerg at a maximum pressure of 138 bar. On land, the natural gas passes through a gas treatment plant in Nybro. Here, the quality of the gas is checked and metered, and pressure is reduced to the maximum pressure for land pipelines of 80 bar. The treatment plant can also reduce the content of impurities such as heavy hydrocarbons and remove any sulphur that might be present in order for the gas to comply with the agreed specifications. However, in such cases, delivery volumes are reduced (approx. 50%).

From Nybro, the gas is sent to customers in Denmark and in other countries or for storage at one of two subterranean natural gas storage facilities. The storage facilities are filled up during the summer months when gas consumption is low. As the weather gets colder and consumption starts to exceed the daily gas deliveries from the North Sea and Germany (commercial deliveries), production is supplemented with gas from the storage facilities. In principle, the shippers' daily orders within the reserved capacity determine the hourly input/output from the system (the commercial system), while Energinet.dk is responsible for the physical system balance, for example by means of the storage facilities and line-packing.

Meter and regulator stations have been established along the transmission pipelines for the purpose of supplying the local distribution grids. Their function is to preheat the gas, reduce gas pressure to that of the distribution grid, meter gas flow through the station and add odorant to the gas. A total of 42 meter and regulator stations and four meter stations have been established in the transmission grid, which is owned by Energinet.dk.

The distribution companies own the distribution pipelines and the meter and regulator stations belonging to the distribution system.

## 8.2 Security of gas supply in the long term

The security of gas supply is generally dependent on the following factors, both in the short and in the long terms:

1. The availability of gas, ie the availability of gas supplies (including gas from storage facilities) must be sufficient to meet consumer demand under normal as well as extreme weather conditions.
2. Adequate grid capacity, ie the gas grid must have sufficient capacity to meet consumer demand under normal as well as extreme weather conditions.
3. System integrity, ie the operational functionality of the system from production to consumer must be guaranteed.

According to the Danish Supply of Natural Gas Act, Energinet.dk, as the TSO, is responsible for the security of supply in the Danish gas market.

As the only Danish transmission company, Energinet.dk is responsible for the system integrity (3) of the Danish transmission system, ie the 80-bar system with adjacent systems (marine pipelines in the North Sea, transit exit points, the delivery points of the Danish exit zone and the storage facilities) as well as for ensuring adequate transport capacity in this system (2). On the other hand, Energinet.dk is not per se responsible for the availability of gas (1), except in situations of emergency where Energinet.dk must ensure the availability of gas for the Danish market, as necessary.

However, on account of the special supply situation for gas in the relatively short term (5-10 years), after which time the Danish natural gas reserves are no longer expected to meet the current demand, focus should be directed at securing the availability of gas for the Danish market. This applies not least in view of Energinet.dk's responsibility for long-term planning and the security of supply.

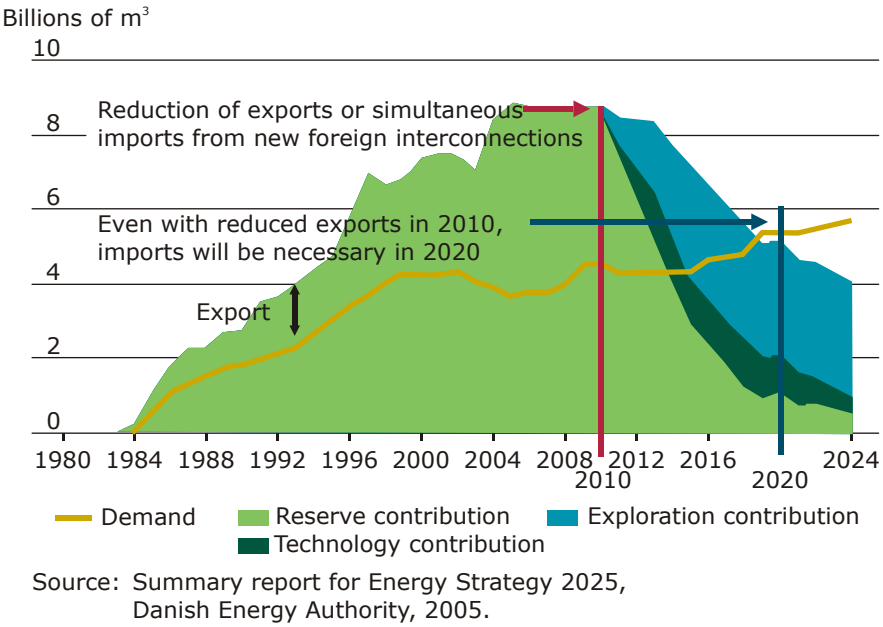



***Figure 8.2*** *Gas production from Danish section of the North Sea.*

As can be seen from **Figure 8.2**, gas production in the Danish gas fields in the North Sea is not expected to continue at the present level of about 9 billion $m^3$ per year for more than 5-10 years.

Section 10 on gas transmission sheds further light on the need to expand the gas infrastructure and establish (a) pipeline(s) to the European system.

With the implementation of the EU directive on security of supply, Energinet.dk would like the distribution of roles and responsibilities in the Danish gas market to be assessed and clarified in further detail in view of the long-term security of supply. It is, among other things, necessary to decide how to ensure the availability of natural gas for the Danish market once the Danish reserves in the North Sea are exhausted. A central question in this context is whether responsibility for the necessary long-term investments in gas infrastructure in Denmark rests with private investors, other commercial players or Energinet.dk – and on what conditions.

As regards emergency management when faced with accidents, operational disturbances or other types of interruptions of supply, the Danish Supply of Natural Gas Act does not specify the content or scope of the handling of security of supply, but this has been made operational through the security of supply targets reported to the Danish Minister for Transport and Energy by Energinet.dk.

## 8.3 Objectives – emergency supplies

Supplies to the Danish gas market are largely based on only one physical source of supply and one supply route (the Tyra-Nybro pipeline). This means that Denmark must meet higher contingency preparedness requirements than many other countries which have several major sources of supply. Energinet.dk

is only responsible for the security of supply in the Danish gas market, but must also make capacity available to maintain transit.

During the 26 years of operation of the Danish natural gas system, no serious faults have occurred in the transmission system, neither in the marine pipelines nor in the land-based facilities.

**Security of supply objectives**
Energinet.dk has two objectives for the security of supply of the Danish gas market which in combination set the dimension for the reserve emergency management level in emergency situations.

- One objective concerns short-term events with requirements being made as to how fast gas must be supplied from other sources. In practice, this objective places demands on the withdrawal capacity of the gas storage facilities.
- The other objective concerns events of a longer duration with requirements being made as to the safeguarding of physical deliveries in the event of long-term interruptions. In practice, this objective requires the procurement of a certain volume of gas from alternative sources as well as the availability of a certain volume of stored gas.

In March 2001 the overall objectives for the security of supply were reported with the following design events for Energinet.dk's emergency management:

- Short-term events. Under normal supply conditions as well as abnormal supply conditions, ie complete interruption of deliveries from the largest supplier, Energinet.dk must have access to sufficient withdrawal capacity from the storage facilities to be able to maintain supplies to consumers with uninterruptible emergency supply for three consecutive days in Denmark down to daily average temperatures of -14°C.
- Long-term events. Under normal supply conditions, ie complete interruption of deliveries from the largest supplier, Energinet.dk must have sufficient volumes to maintain supplies to consumers with uninterruptible emergency supply in Denmark for up to approx. 60 days (corresponding to the expected repair time after the breakdown of a marine pipeline) during a winter with "normal" temperatures.

**Design basis for normal situations**
Prior to the introduction of the new market model on 1 January 2004, the Danish transmission grid was designed to handle the supply to all consumers in Denmark down to daily average temperatures of -14°C. Statistically, a day with an average temperature of -14°C occurs approx. once every 20 years. Today, Energinet.dk designs the system on the basis of the shippers' capacity orders and Energinet.dk's own assessment of expected domestic sales at -14°C. This assessment is based on the shippers' annual orders, but Energinet.dk's assessment also includes expectations concerning orders for monthly, weekly and daily products.

### *8.3.1 Fulfilment of objectives*

Today the gas transmission system receives gas through the two offshore pipelines with the following possible deliveries in normal situations:

- Tyra-Nybro pipeline approx. 26 million m³/day
- Syd Arne-Nybro pipeline approx. 13 million m³/day

Today, only a total of 23 million m3/day is supplied via the Nybro pipeline, of which some 1-2 million m³/day is supplied via the Syd Arne pipeline. The Syd Arne pipeline thus has plenty of capacity for use in emergency situations. In a worst-case scenario the supply from the largest supplier is disrupted, ie the supply via the Tyra-Nybro pipeline fails.

Energinet.dk is currently covering the risk of interruptions by the following contingencies in case of delivery failure:

- Emergency supply from Tyra and Harald via the Syd Arne-Nybro pipeline
- Supplies from Germany via the DEUDAN pipeline
- Supplies from Danish gas storage facilities.

Energinet.dk has therefore concluded an emergency supply agreement with DONG, which enables the supply from Tyra via Harald through the Syd Arne-Nybro pipeline of 7 million m³/day to the Danish market.

**Table 8.1** shows the technical maximum capacities of the storage facilities in Stenlille and Ll. Torup.

| | Storage volume in millions of $m^3$ | Withdrawal in millions of $m^3$/day | Injection capacity in millions of $m^3$/day |
|---|---|---|---|
| Stenlille | 360 | 10.8 (1) | 2.4 |
| Ll. Torup | 400 | 14.4 (2) | 3.6 |

***Table 8.1*** *Maximum capacity – gas storage facilities.*

The maximum withdrawal capacity of the Stenlille storage facility, which is of the aquifer type, is determined by the capacity of the wells and the current gas volume. The withdrawal capacity of the Ll. Torup storage facility is determined both by the current gas volume, the capacity of the Ll. Torup-Egtved pipeline and the pressure in the rest of the transmission system.

In addition to deliveries through the Syd Arne pipeline, the emergency supply strategy entails that Energinet.dk has reserved storage volume of 165 million $m^3$.

For the purpose of handling short-term interruptions of supplies from the North Sea, Energinet.dk has reserved withdrawal capacity from the storage facilities to compensate for the failing deliveries. Moreover, Energinet.dk is able to use the gas volumes which are naturally stored in the gas pipelines themselves – the so-called line-pack.

In addition to the alternative gas deliveries available to Energinet.dk, Energinet.dk has entered into cooperation agreements with the three neighbouring system operators (DONG Energy, Svenska Kraftnät and BEB), which also helps to secure supplies.

Finally, the Rules for Gas Transport contain a number of conditions which ensure that in certain situations, Energinet.dk can influence or make arrangements for the supply and consumption of gas to optimise the security of supply and the gas system. This applies, among other things, to consumers with interruptible emergency supply, reduced nomination, reduced capacity, emergency supply and force majeure.

Any decisions concerning the means by which Energinet.dk secures supplies are based on the premise that the effects of any technical problems on the market should be minimal. The specific supply and weather situation and the actual status of the natural gas system are important parameters for the timing and sequence of use of the various measures, for which reason it is not possible to detail in advance when and how the individual measures must be used.

In the event of major interruptions of supplies from the North Sea, a number of measures will be taken to secure the supply to the Danish gas market. This will take place in the following order:

- Deliveries from storage facilities
- Use of line-packing of land-based pipelines and marine pipelines
- Discontinuation of shippers with interruptible emergency supplies.

Energinet.dk's emergency supply obligations apply only to the Danish gas market, but in so far as shippers ensure the availability of gas for transit in the entry points (see also section 9.2.1) or from storage facilities, Energinet.dk will seek to make the necessary transport capacity available.

# 9. Gas market

## 9.1 The European gas market

There is in reality no single European gas market, but the situation on the various national markets in Europe is characterised by a number of common factors.

Most European countries are net importers of gas. Imports come primarily from Russia, Norway, Algeria and Morocco. A growing proportion of imports is LNG-based (Liquefied Natural Gas, gas cooled down to -160°C), but most of the gas reaches the European markets via pipelines. Domestic production is falling throughout Europe, while considerable increases are expected in consumption and thereby imports in the coming years. By 2030, the European Commission expects 80% of the EU's gas consumption to be covered by imports. Today, imports account for just over 50% of consumption, with 25% of gas imports coming from Russia.

Europe is thus becoming increasingly dependent on deliveries from, for example, Russia and LNG imports. There is increasing concern that the instability of these deliveries – owing to the transit of the pipelines through a number of countries – will lead to situations with gas shortages in Europe and thereby increasing prices.

These concerns have come to the fore following the gas crisis between Russia and the Ukraine in January 2006. The situation led to markedly reduced deliveries especially to the East European countries which are dependent on Russian gas and increasing prices in many places in Europe.

A number of major infrastructural projects are currently being planned which are aimed at bringing more gas to Europe. New pipelines are thus being planned for example between Northern Europe on the one hand and Russia and Norway on the other, and between Southern Europe on the one hand and Northern Africa and the Middle East on the other. Moreover, a number of LNG port facilities are being planned and projected in both Southern and Northern Europe.

The market situation in Europe is characterised by national markets with limited cross-border spot trade, and there is as yet no single market for natural gas in Europe as such. Prices do not follow common trends, considerable regional gas price differences continue to be seen, and cross-border day-to-day trading based on spot trading is of no major significance in Europe. One reason for the lack of cross-border spot trading is general capacity shortages, especially on the borders, as well as a lack of interoperability between the different national systems.

One symptom was the considerable price differences seen in winter 2005/2006 between prices in the UK/Belgium and prices in the rest of Continental Europe. Prices in the UK increased dramatically for some periods of time as a result of increasing demand and the limited supply of gas. No gas was exported from the European markets.

There are, however, signs that interconnected regional markets are developing. Levels of activity in the European hubs are increasing, and the TTF (Title Transfer Facility) in the Netherlands and Zeebrugge in Belgium, in particular, are developing into well-functioning trading places. One sign is that for periods of time in winter 2005/2006 prices at Zeebrugge, which is physically located at the Interconnector connection to the UK, were considerably higher than prices at the TTF which is connected to the systems in Germany, the Netherlands and France. Energinet.dk uses the Dutch price at the TTF for settling imbalances in the gas system.

At a European level, work is going into strengthening compatibility between the systems in the individual countries. The aim is to increase the scope for exchanging gas between regional hubs and to solve the problems of cross-border interoperability.

## 9.2 Status for the Danish gas market

The Danish natural gas market was liberalised on 1 January 2004. Today, all consumers are free to choose their gas supplier, and the market is open to new players.

The European Commission has since 2002 been looking at the degree to which the liberalisation of the natural gas market has been implemented in a satisfactory way in the individual countries. During the first three years, Denmark continued to do extremely well, and in 2004 Denmark was right at the top, partly due to the fact that the gas market had, in principle, been opened completely. In 2005, Denmark no longer scored the highest. This was due to the inadequate opening of the market and focus on a number of factors which are critical for developments in relation to other countries.

The Danish gas market is commercially divided into a wholesale market and a retail market. In the wholesale market, the so-called shippers transport gas via Energinet.dk's gas transmission grid to the Danish market, for storage at the two subterranean storage facilities and to Sweden and Germany as transit. In the retail market, the so-called gas suppliers supply gas to end users via the distribution networks.

### *9.2.1 Wholesale market*

At the beginning of 2006, the wholesale gas market had five active players (shippers), one of which has a market share of more than 85% of total transports. Competition remains limited. The new players in the wholesale market are primarily German and Swedish companies reselling gas at the GTF (Gas Transfer Facility, Energinet.dk's electronic transfer facility) or sending gas to Sweden as transit. So far, the new players' market share is limited, but increasing.

Most of the gas sold in Denmark or sent as transit to Sweden and Germany continues to be traded on long-term contracts. The long-term contracts are, however, gradually being relaxed. Most recently, the Danish Competition Au-

thority has ordered HNG/MN and DONG to cancel parts of a long-term contract. As a result, HNG/MN is no longer obliged to solely use DONG as a shipper.

A limited, but increasing share of gas trading is taking place via the GTF where shippers trade gas bilaterally. In 2005, between 3% and 7% of total gas volumes were traded via the GTF, which must be seen as the first step in the direction of an actual market place for gas trading.

In connection with the merger with Elsam, DONG Energy has been ordered to release 400 million $m^3$ for sale on the Danish market via the GTF. This corresponds to just over 10% of total gas volumes consumed in Denmark. All other things being equal, this will increase the liquidity of the Danish market for bilateral trading in gas.

Moreover, it is possible to trade capacity and balancing services via Energinet.dk's CTF (Capacity Transfer Facility) and BFT (Balance Transfer Facility). There is currently no appreciable trading in these secondary markets.

Shippers gain access to Energinet.dk's gas transmission grid by ordering capacity into the system (entry) and out of the system (exit). See **Table 9.1**.

| **Entry and exit** | |
|---|---|
| Entry points | The entry points are where the gas enters Denmark, ie in Nybro (from the North Sea) and in Ellund (from Germany). |
| Exit points | The national exit zone corresponds to the Danish market. Exit points are where the gas is exported out of the country: Ellund (to Germany) and Dragør (to Sweden). |

***Table 9.1*** *Entry and exit points in the Danish market model.*

Access to the gas transmission grid is regulated. Shippers can enter into capacity agreements with a term of one day, but most of the sold capacity is currently sold on annual capacity contracts. Capacity payments amount to approx. 75% of the shippers' total payments for grid access. Moreover, shippers pay for the actual volumes transported (25%).

A total of approx. 8.2 billion $m^3$ of gas is transported through Energinet.dk's gas transmission grid a year, of which approx. 4.2 billion $m^3$ of gas is transported to the Danish market and approx. 1 billion $m^3$ as transit to Sweden. Total transit to Germany amounts to approx. 3 billion $m^3$.

In emergency situations, Energinet.dk is responsible for delivering gas to the Danish market. Transports to the exit zone are therefore subject to emergency supply payments. Shippers must, on behalf of consumers, order either primary (uninterruptible) emergency supplies or secondary (interruptible) emergency supplies. Transports involving primary emergency supplies are guaranteed gas deliveries in emergency situations for up to 60 days. In the event of an emergency situation, the transports ordered with secondary emergency supply will be shut down. The costs incidental to providing this sort of cover are reflected

in a tariff for primary emergency supply, which is approx. three times higher than the tariff for secondary emergency supply.

### *9.2.2 Retail market*

Shippers in the wholesale market deliver gas to the gas suppliers which supply three main groups of end users in Denmark. The main end-user types are power stations using gas for heat and power production, industrial companies etc. and consumers with non-daily meter readings (using gas for production etc. and primarily small-scale business customers, private consumers (single-family houses)) with monthly or annual meter readings. The three largest power stations (Avedøre II, Skærbæk and H.C. Ørsted) are directly connected to Energinet.dk's transmission grid.

So far, very few private consumers have elected to change suppliers. Competition in this consumer segment is thus limited. Large-scale industrial customers and CHP generators are increasingly electing to change suppliers to obtain better prices and terms. Most of the changes of suppliers have thus taken place within this group.

The largest consumers in the Danish gas system are the primary power stations and the local CHP units which use gas heat and power production. The primary power stations receive most of the volumes consumed under legacy long-term contracts and only a smaller proportion of volumes from alternative players in the wholesale market. With the merger with Elsam, DONG Energy has taken over ownership of the primary power stations, and thereby the largest gas consumers. Vattenfall will take over the power station Fynsværket (where Unit 3 may be gas-fired) and the gas-fired CHP units in Hillerød and Elsinore.

### *9.2.3 North Sea gas fields*

All gas transported through Energinet.dk's gas transmission grid comes from fields in the North Sea. Denmark is a net exporter of gas, corresponding to approx. 100% of domestic consumption. There are no physical gas imports to Denmark, but there are some commercial imports via the Ellund entry point.

DONG Energy owns the marine pipelines connecting the gas fields in the North Sea with Denmark, the Tyra and Syd Arne pipelines, and thereby owns most of the gas from the DUC fields. DONG Energy exports some of the gas to the Netherlands via the NOGAT pipeline and sends the rest to Denmark via the Tyra pipeline (either as transit or for domestic consumption) and sells the gas to shippers, to end customers or to gas suppliers in the Danish market.

### *9.2.4 Storage facilities*

Gas is delivered at a reasonably constant flow from the North Sea, but consumption varies over any 24-hour period and especially over the year. It is therefore necessary for the shippers to use the two Danish gas storage facilities in Ll. Torup and Stenlille. DONG Storage owns both the two physical storage facilities, but they function commercially as a single virtual storage point in the Danish gas market model. The shippers' access to storage services is subject to terms negotiated with DONG Storage.

In connection with the European Commission's approval of the merger between DONG and Elsam, DONG Energy has, as mentioned above, been ordered to divest one of the storage facilities. The sale of one of the storage facilities to Energinet.dk is currently being negotiated.

## 9.3 Main issues

Two years after the opening of the gas market, the Danish market for natural gas trading remains characterised by limited competition. However, a number of necessary steps have been taken to ensure future developments. The wholesale market is characterised by particularly limited competition with one dominant player and low liquidity.

A liquid and competitive wholesale market is a precondition for consumers benefiting from the advantages of competition.

A number of main issues hamper the effectiveness of competition in the gas market in Denmark.

### *9.3.1 Barriers to market access*

The market remains characterised by market failures which may be perceived as barriers to market access for new players:

- Lack of transparency concerning the gas price (no real market price).
- Existing ties in the end-user market – very few customers change suppliers, which indicate that market shares are "locked".
- Concentrated ownership in all parts of the chain from production to consumption (DONG Energy owns marine pipelines, storage facilities and distribution).
- Terms and conditions of access to infrastructure – for example Energinet.dk's capacity ordering system and DONG Storage's capacity ordering system require investments in IT systems, administration and trained personnel.
- Lack of harmonisation of rules and terms in neighbouring systems (interoperability).

Energinet.dk is continuously working to increase the flexibility of the capacity system for shippers.

### *9.3.2 Need for more sources of supply*

In reality, there is only one supplier of gas in Denmark, and new shippers in the Danish market have therefore limited possibilities of procuring large gas volumes from suppliers other than DONG Energy. This limits the effectiveness of the market.

Alternative pipelines and thereby new sources of supply – eg via pipelines to new or existing pipelines such as Europipe II, the proposed connection between Germany and Sweden – Baltic Gas Interconnector – or to the pipeline in the Baltic Sea proposed by the Russians – North European Gas Pipeline – will improve competition and liquidity in the wholesale market for gas trading in Den-

mark. However, all these infrastructural projects have a longer time horizon. The North European Gas Pipeline will probably not be commissioned until 2012.

In this context, it is paramount that the "market" starts as early as possible in new pipelines and that all players are granted equal access to the infrastructure. One possibility is for Energinet.dk to become the co-owner or operator of new infrastructural connections, thereby ensuring that investments in new infrastructure are in line with the interests of the market as a whole. Another possibility is for legislation to be introduced stipulating objective and non-discriminatory access to new marine pipelines.

### *9.3.3 Limited liquidity*

Liquidity in the Danish gas market is very limited when measured in relation to the volumes traded. Just over 6% of total consumption in Denmark is traded via the GTF. This can be attributed to the fact that there is one primary source of supply and to the fact that much gas is traded under legacy long-term contracts.

The limited liquidity is a problem as effective trading requires sufficient liquidity. It is therefore not possible at the moment to obtain a Danish market price for gas.

In other words, an effective market place – and thereby a market price – are conditional upon sufficient volumes of gas being offered for sale by several sources of supply, and upon the presence of a sufficient number of buyers. Alternatively, a player may be given the role of market maker, launching the market via daily bids to buy and sell.

For the conditions for gas trading to improve in Denmark, liquidity must be increased. This can be done by appointing a market maker, by releasing gas from long-term contracts and by establishing new pipelines to alternative sources of supply.

### *9.3.4 Incomplete unbundling*

Incomplete unbundling continues to characterise infrastructural activities and commercial trading activities in distribution, upstream pipelines and storage facilities. Such incomplete unbundling hampers the possibilities for new players to compete in the market. What is needed is complete unbundling – alternatively increased regulation of the terms of access, including the price of access.

The problem was pointed out in the European Commission's benchmark report from 2005 by the European gas sectors.

### *9.3.5 Limited scope for imports*

A coherent and effective European gas market with gas flowing freely between the countries under spot contracts remains a relatively far-off prospect. This is, among other things, due to the continued lack of effective "interoperability" between national transmission grids, hampering the transportation of gas across borders in the short term. The lack of interoperability is primarily caused by different rules and regulations, but also by differences in the gas quality etc.

Moreover, there is a general capacity shortage in the individual systems (congestion), especially in cross-border points, and the terms of access to the individual transmission grids for new operators – so-called third-party access – remain poor. This is, in particular, a problem in countries where the separation of trading and infrastructure activities is not complete, eg in Germany and France.

There is thus a lack of transparency as regards available capacity and other terms of access to the gas infrastructure, and capacity is often tied up in long-term contracts. These contracts are in many cases made by the formerly bundled monopolies prior to the liberalisation process [Ref. 3]. This makes is difficult for new players to acquire free capacity and enter the market [Ref. 4], which in turn hampers the transportation of gas through Europe to the Danish market.

### *9.3.6 Current initiatives*

Energinet.dk is continuously working to improve the market situation for gas trading in Denmark. Current initiatives include the following:

- New emergency supply concept. The existing emergency supply concept should be revised as a number of problems with regard to the level of interruptibility and the scope for procuring gas in emergencies have been identified. Among other things, it is thought that shippers in their capacity orders state a far higher share of secondary emergency supply than what could actually be interrupted in an emergency situation.

- Implementation of online capacity ordering in Energinet.dk's capacity system. Online capacity ordering increases flexibility and facilitates administration for shippers when ordering capacity in Energinet.dk's gas transmission grid. The system is expected to be implemented after April 2007.

- Analysis of tariff model/capacity ordering model in Denmark. Energinet.dk has launched a comprehensive analysis of the payment structure etc. with a view to ensuring that the system facilitates effective competition in the Danish market for trading in natural gas, while at the same time ensuring the efficient utilisation of the infrastructure.

- Increased harmonisation of terms with neighbouring systems. Energinet.dk is working continuously in a European context (EASEE gas) and together with BEB in Germany and the TSO in Sweden to harmonise terms etc. in the various systems.

### *9.3.7 Future initiatives*

Energinet.dk is working to create an efficient market for gas trading in Denmark based on the constant monitoring and development of the market model, including support for a market-based reference price. A number of main problems hampering this development have been identified. Energinet.dk's ongoing strategy work is to contribute to resolving or reducing the impact of the main problems and improving the situation.

### *9.3.8 More sources of supply*

Energinet.dk is analysing the need for more infrastructural connections to Denmark, and thereby more sources of supply. A project has thus been launched which is aimed at identifying the need for new pipelines to Denmark from the point of view of security of supply and from the point of view of the market. The project is also aimed at developing a strategy for Energinet.dk's future role in infrastructural investments.

### *9.3.9 Increased liquidity*

Energinet.dk is working for a market-based reference price of gas in Denmark. This requires increased liquidity – both in the form of larger volumes of gas and in the form of more buyers and sellers in the gas market.

Energinet.dk is therefore in favour of DONG Energy (or possibly Vattenfall) being appointed market maker. This must take place in dialogue with both DONG Energy (or Vattenfall) and with the relevant authorities.

At the same time, Energinet.dk will work to expand the market, reduce barriers, harmonise rules and procedures with neighbouring TSOs and thereby, all other things being equal, increase liquidity and improve the possibility of a market-based reference price. Work going into harmonising terms with the neighbouring systems in Northern Germany and Sweden (balance rules, tariff models, interoperability) must therefore be intensified. This must take place in closer dialogue with the neighbouring TSOs. This will at the same time reduce the barriers to cross-border spot trading. Finally, Energinet.dk will continuously monitor activities in the GTE (the EU's stakeholder organisation for gas transmission companies) to ensure that the large foreign gas transmission companies do not hamper market developments.

# 10. Gas transmission

Like the electricity transmission grid in the electricity sector, the gas transmission system provides the physical framework for meeting demand and requirements pertaining to security, emergency management, the market and the environment in the gas sector. A well-developed gas transmission system is a precondition for access by more suppliers and therefore for a well-functioning market. It is also a precondition for access to gas reserves 25-50 years into the future, and thereby for maintaining security of supply.

Below follows an outline of the principles governing the dimensioning of the gas transmission system and how Energinet.dk ensures system balance. The capacity of the transport system is reviewed, and a description is given of the need for new gas infrastructure is described once the Danish North Sea gas reserves can no longer meet the demand for natural gas in Denmark.

## 10.1 Forecasting transport

Energinet.dk designs the transmission system on the basis of a number of assumptions concerning deliveries to the entry points, demand at the exit points and storage facilities.

**Table 10.1** gives a brief description of the assumptions underlying the forecast for winter 2005/2006.

The forecast for winter 2006/2007 will be prepared in autumn 2006.

| | Entry (millions of $m^3$/day) | Exit (millions of $m^3$/day) |
|---|---|---|
| Exit zone Denmark | | 26.7 |
| Dragør | | 5.2 |
| Ellund net | | 7.1 |
| Nybro | 22.8 | |
| Stenlille storage facility | 8.1 | |
| Ll. Torup storage facility | 8.1 | |
| **Total net** | **39.0** | **39.0** |

***Table 10.1*** *Forecast net transports at -14 °C, winter 2005/2006.*

It is estimated that total net transport at -14 °C is approx. 39 million $Nm^3$/day.

Deliveries from Nybro are made up of 21.5 million $Nm^3$/day from Tyra and 1.3 $Nm^3$/day from Syd Arne.

It is assumed that the total withdrawal from the storage facilities is 16.2 million $Nm^3$/day with 50% coming from Stenlille and 50% from Ll. Torup. Optimised distribution of withdrawals is used to achieve the highest possible pressure in the grid.

Ellund sees net transports of 7.1 million $Nm^3$/day corresponding to 295,000 $Nm^3$/hour (354,000 exit minus 59,000 entry).

In the exit zone Denmark, volumes are stated as what is expected by Energinet.dk at an average temperature of -14 °C. This corresponds to the design temperature for the grid. Shippers have reserved annual and monthly capacities which are considerably lower than what Energinet.dk has estimated as the maximum volumes, but shippers are able to place supplementary orders for capacity on a weekly and daily basis in the event of extreme winter temperatures which are below normal-year temperatures (approx. -8 °C).

In winter 2005/2006 maximum net transports amounted to 32 million $m^3$/day, with the maximum off-take in exit zone Denmark being 21 million $m^3$/day. The 24-hour period seeing maximum off-takes coincided with maximum transports in exit zone Denmark and exit zone Dragør (6 million $m^3$/day), but not in exit zone Ellund (7 million $m^3$/day). Transports to Sweden are normally temperature-dependent like transports to exit zone Denmark, whereas transports to Germany are dependent on other factors. Consequently, maximum transports to Germany do not necessarily occur at the same time.

## 10.2 Capacity in the gas transmission system

The gas transmission system is expected to be able to handle the estimated transport volumes in the coming winter 2006/2007, both as a whole and at the various points (entry, exit transit and M/R stations in exit zone Denmark). There is generally available capacity. Capacity limits, however, do affect a number of sections, and Egtved-Ellund deliveries can be critical. Whether the demand for transport capacity can be met on the section depends on commercial deliveries at the entry point Ellund.

As in 2005/2006, net transports in 2006/2007 are expected to total a maximum of 39 million $m^3$/day. The total possible net transport volume can be increased to approx. 43 million $m^3$/day, but total volumes are dependent on the interplay between entry and exit volumes and withdrawals from storage facilities.

### *10.2.1 System operator storage and emergency stocks*

Energinet.dk has reserved storage volumes of 35 million $m^3$ and withdrawal capacity of +/- 1.8 million $m^3$/24 hours. Moreover, in abnormal operating situations that have not developed into emergency situations as such, Energinet.dk is able to utilise the combined physical storage capacity to supply all shippers.

Energinet.dk has reserved emergency supplies of 130 million $m^3$ and a withdrawal capacity of 19.6 million $m^3$/day.

### *10.2.2 Deliveries to Nybro*

Only approx. 23 million $m^3$/day are expected to be delivered in entry Nybro. Prior to 2004 when gas was delivered directly from Tyra to the Netherlands, deliveries were up to 26 million $m^3$/day, and it is thus possible to handle larger volumes at entry Nybro. If necessary, transport volumes from Nybro-exit zone Denmark or Nybro-exit Dragør may therefore be increased.

### *10.2.3 Transports to and from Germany*

In winter 2005/2006, the reserved transport capacity in exit Ellund has been close to the limit for possible transports in the event of full utilisation of other

reserved capacities and expectations as regards exit zone Denmark. However, capacity orders in entry Ellund have compensated for the high exit orders. Actual transports to Germany have therefore been somewhat less than the physical capacity.

Against this background, Energinet.dk will introduce a interruptible product for the coming winter. If a need should arise in the longer term for additional physical capacity from Denmark to Germany, an expansion of the system on both the Danish and the German side should be considered.

#### *10.2.4 M/R stations*

All M/R stations have the capacity necessary for handling the volumes purchased by the regional distribution companies. Energinet.dk makes annual assessments of possible volumes purchased by all stations, and any increases in consumption or pipeline configurations in the distribution grids which may change the distribution of consumption on individual stations will be coordinated with the distribution companies on an ongoing basis.

At the extreme ends at Lynge, Aalborg and Dragør, the M/R stations must be able to deliver the necessary volumes at an inlet pressure of 45 bar, which is the lowest assumed pressure in normal situations. In emergency situations, it is assumed that transmission system pressure may fall to 35 bar, but the necessary deliveries via the M/R stations will at the same time be reduced due to the interruption of consumers.

### 10.3 Expansion of Dragør border station

In 2004, expectations were that gas consumption in Sweden would increase to such an extent that the capacity of the Dragør border station could be exceeded by winter 2006/2007. An expansion project was therefore launched, and by 1 October 2006, the station's capacity will have been increased from 286,000 $m^3$/hour to 360,000 $m^3$/hour at an inlet pressure of 45 bar. The station's capacity may be increased to 540,000 $m^3$/hour at the very moderate cost of installing an additional meter.

### 10.4 Information concerning capacity and capacity utilisation

On its website, Energinet.dk publishes data concerning capacity and capacity utilisation (operating data) in the individual entry and exit points. These data are updated on a monthly basis.

According to the EU regulation on good practice for transmission system operation, it must be possible to reserve transmission capacity online on the basis of the ongoing updating of capacity utilisation. Energinet.dk will not be able to comply with the regulation this year as it will require extensive IT development. Energinet.dk will draw up a plan as soon as possible on how to comply with the regulation.

## 10.5 Need for new gas infrastructure

*10.5.1 Reservations of land for potential capacity expansion*
Energinet.dk has made sure that it will be possible to expand the east-west transmission system capacity. A national planning directive has been adopted for the establishment of compressors in Egtved in Jutland, in Langeskov on Funen and in Avedøre on Zealand.

In the event of a need for increased transport to Zealand/Dragør, a compressor station will initially be established in Langeskov as a first step.

*10.5.2 Expansion need 2007-2015*
Denmark is currently supplied with natural gas from the Danish gas fields in the North Sea only. These reserves are not expected to be able to meet Danish demand in 5-10 years' time, and it will therefore be necessary to establish a transmission pipeline between Denmark and the European gas system with a view to procuring supplies from Norway and/or Russia.

Historically, natural gas transports have been through pipelines – and this will probably continue to be the case as pipeline transport is the most economical solution when large volumes need to be transported over distances of more than 2-3,000 kilometres.

The Danish onshore transmission system still has available capacity and can be expanded by approx. 3 billion $m^3$/year at moderate costs. The system has been prepared for such expansion. The capacity can be used for increased transit (Sweden, Germany) or to increase domestic consumption, for example through the conversion of coal-fired power stations and the increased use of natural gas in the transport sector.

However, any significant increase in the use of natural gas in Denmark will at the same time necessitate the construction of pipelines to new foreign gas producers, ie pipeline connections to Norway/Russia or LNG via sea transport. New pipelines are necessary in any event as the Danish North Sea gas reserves are not expected to be able to maintain a production of the current approx. 9-10 billion $m^3$/year for more than 5-10 years. Moreover, the new connections will increase the security of supply and enable competition in the Danish gas market.

The most obvious solutions currently seem to be:

- A pipeline to the Norwegian gas fields by connecting Europipe II and the Danish west coast.

- Connection to the Russian gas fields by establishing the Baltic Gas Interconnector from Northern Germany to Southern Sweden/Avedøre.

- An indirect connection to the Norwegian gas fields via Sweden, if the Kårstø-Oslo-Gothenburg pipeline is established.

- Connection to the Russian gas fields through direct or indirect connection to the North European Gas Pipeline from Russia to Germany via the Baltic Sea.

- Deliveries from a large LNG storage facility in Eastern Denmark (Stigsnæs).

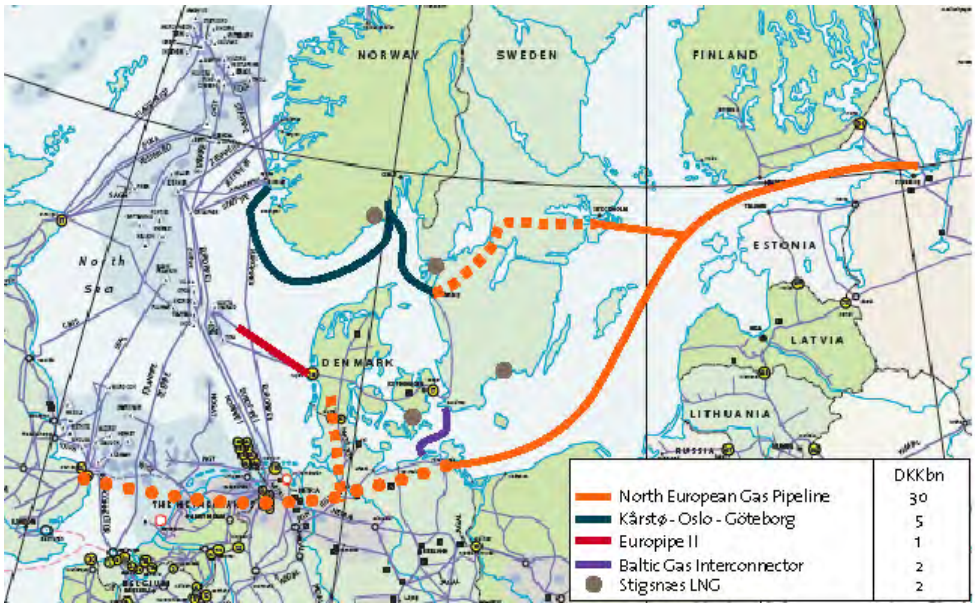



***Figure 10.1*** *International gas pipelines.*

The Danish natural gas transmission system is virtually isolated from the rest of the European integrated system. Looking just 10 years ahead, the situation in Denmark will probably be quite different. Natural gas supply is therefore no longer just a national issue in Denmark, and as regards the infrastructure, security of supply, environment and market conditions, natural gas has become subject to substantially increased focus within the EU.

The EU also anticipates a sharply increasing need for gas supplies from non-member states – not least Russia – in the coming decades. It goes without saying that Denmark is interested in supporting EU endeavours to ensure market development and security of supply in the gas market at a European level.

Ten years is, in reality, a very short time perspective for major expansions of the natural gas infrastructure, and it is therefore absolutely necessary that decisions are made within a short time span which can clarify the distribution of responsibilities and roles in connection with securing the necessary infrastructure for natural gas deliveries to the Danish market once gas supplies from the North Sea are phased out.

# 11. Preparedness

The executive orders concerning preparedness in the electricity and gas sectors came into force on 1 February 2005. The executive orders formalise the requirements set out in the provisions of the Danish Electricity Supply Act and the Danish Supply of Natural Gas Act concerning "suitable preparedness" on the part of the companies.

At the same time, Energinet.dk was given a number of new tasks concerning the coordination of contingency preparedness activities in the sectors. These tasks include the preparation of guidelines for sector companies, the approval of their summary contingency preparedness plans, the supervision of the companies' contingency preparedness planning, the organisation of exercises and the handling of major crises in the sectors.

**Risk and vulnerability analysis**

Energinet.dk has conducted a risk and vulnerability analysis for both the gas and the electricity side with focus on maintaining supplies. Both analyses showed that there was a need to update the crisis management organisation. Moreover, the analysis has resulted in a decision to establish remote monitoring of more valves on the north-south gas transmission pipeline in Jutland and to considerations concerning increased standardisation of new substations with a view to streamlining and reducing the cost of keeping spare parts in stock.

A crisis management organisation has subsequently been established, enabling the call-in of a crisis staff group, and a decision has been made to establish special rooms for the crisis staff group. Moreover, detailed preparedness plans have been drawn up for relevant functions in a contingency situation as well as security plans for classified units.

**Coordinating preparedness activities**

In the second half of 2005, the companies in the electricity and gas sectors appointed a number of security managers and preparedness coordinators. At the same time, the lists of operational contacts have been updated.

The possibility of several companies joining forces in their contingency preparedness activities has been exploited. Smaller companies have been particularly interested in the possibility of engaging in joint planning with a larger company in their local areas. All in all, this means that there are currently 67 preparedness coordinators in the electricity sector and four in the natural gas sector in addition to Energinet.dk's own coordinator.

In summer 2005, Energinet.dk drafted a set of guidelines concerning the preparation of summary contingency preparedness plans, detailed contingency preparedness plans and security plans. By the end of May 2006, most companies had submitted their summary contingency preparedness plans, and agreements have been made with the remaining companies. Energinet.dk is currently considering the plans with a view to approving them.

**Classification**
In February 2005, Energinet.dk for the first time classified electricity and gas sector installations according to their importance for maintaining electricity and gas supplies in the systems as a whole or to larger regions. This classification was revised in February 2006, resulting in a lower classification for a number of production units.

**Contingency situations**
On 22 December the electricity cable between Sweden and Bornholm was severed. This meant that until the cable had been repaired in February 2006, supplies were less secure on Bornholm. This resulted in brief power cuts for some consumers. In cooperation with the utility on Bornholm, Energinet.dk is currently reassessing the volume of ancillary services on the island. Energinet.dk has bought the Bornholm cable at a price of DKK 12.5 million and takes over any compensation which may result from pending court cases concerning the two most recent instances of cable damage.

On 19-21 January 2006, all of Denmark experienced freezing rain resulting in galloping overhead lines and the trip of some line sections. A total of 140,000 consumers were disconnected because of the ice storm. Most consumers were disconnected for less than an hour. The hurricane on 8 and 9 January 2005 resulted in a number of disconnections of the electricity supply, especially in Northern Jutland. Overhead lines at all voltage levels were damaged. In Eastern Denmark, the hurricane primarily affected the distribution companies' networks, in particular in the Greater Copenhagen area.

In addition to the above events, the companies in the electricity sector reported a total of nine events in 2005, including eight instances of vandalism. Moreover, six long-term outages of large production units and classified transmission installations were registered as well as two significant outages in other countries.

In the gas sector 517 events were registered, all in the form of third-party damage to pipelines, distribution pipelines or service lines. Furthermore, the distribution grid suffered two instances of damage, while North Sea supplies were disrupted on ten occasions. The considerable difference between the number of events and incidents registered in the electricity sector and the gas sector is attributable to the fact that any damage to or digging into gas pipelines requires the calling of the fire brigade, whereas this is not the case for the electricity sector. Consequently, damage to or digging into power cables at lower voltage levels is not registered as contingency situations.

**Planning supervisory visits**
By February 2008, Energinet.dk must have visited all companies in the electricity and gas sectors. An analysis is being carried out with a view to identifying a suitable way of conducting these supervisory visits. In autumn 2006, a plan for the first round of visits is expected to be sent out to the relevant companies.

**Contingency preparedness planning**
Contingency preparedness must be incorporated as an element in the future planning of any expansion of the electricity and gas systems. All expansion proposals will, when relevant, contain an assessment of consequences from the

point of view of preparedness, while preparedness will also be considered in connection with future work on the quantification of security of supply.

# 12. Long-term development of the electricity and gas systems

As the TSO in Denmark, Energinet.dk is responsible for developing the electricity and gas systems to ensure that they live up to short-term as well as long-term objectives concerning security of supply, the environment and the functioning of the market.

This raises a number of challenges in connection with decisions concerning both the operation of the electricity and gas systems and the design of the transmission systems. Decisions made today concerning the design of the transmission grid will affect the scope for living up to these objectives in both the short and the long term.

Central elements in the handling of these challenges are:

- Development of scenario analyses
- Development of analysis tools to assess the interplay between electricity and gas
- Development of new system architecture for electricity
- Integration of large volumes of wind power
- PSO-financed research and development.

## 12.1 Scenario analyses

In future, Energinet.dk will use long-term scenario analyses as an important tool to shed light on the robustness of decisions made in relation to various future scenarios. Scenario analyses will thus form part of the basis of Energinet.dk's planning.

Energinet.dk is already taking part in a number of scenario-related tasks, which may serve as a natural starting point. These are tasks involving a high degree of cooperation with other players in the electricity and gas sectors. They include cooperation with other TSOs, with work just having started under the auspices of Nordel on developing a set of Nordic scenarios, and the ERP (Energy Research Programme) project on electricity and gas infrastructure (see section 12.3).

Moreover, Energinet.dk is taking part in the project "The future Danish energy system", which is headed by the Danish Board of Technology. The project was launched in 2005 and is expected to be completed in 2007. The keystone in the project is a so-called Future Panel composed of members of the Danish Parliament representing all political parties. The Future Panel is headed by a steering committee of representatives of a number of Danish players within the energy sector – companies, institutions and organisations.

As part of the project, five scenarios have been developed to shed light on possible developments of the future Danish energy system in 2025. In addition to a reference scenario, the scenarios each focus on the implementation of massive savings and volumes of biomass, gas and wind. The scenarios thus illustrate the extreme consequences of different choices of technology and thereby also present a number of different challenges for the rest of the energy system. The

scenarios have been presented to the Future Panel, which has subsequently laid down the framework for a scenario that combines the elements from the other scenarios. The next step will, among other things, be a more detailed look at the so-called combination scenario, including the means of achieving it and detailed analyses as well as the preparation of a contribution to the debate on the EU's Green Paper on the basis of the experience gained in the project.

For Energinet.dk it is, for example, interesting to check the robustness of the long-term electricity and gas infrastructure against a number of possible future scenarios. Investments made must live up to requirements in the short term, while at the same time ensuring robustness in the face of changing conditions over the coming decades. Factors of uncertainty include fuel prices, $CO_2$ prices, the speed with which technological advances are made and become available and general developments in society.

The electricity and gas transmission systems interface with large parts of the rest of the energy sector. In addition to the electricity and CHP production units, this also applies to the demand side (via demand response, for example) and the district heating sector. The intention is therefore to continue the scenario work in broad cooperation with other players, both nationally and internationally.

### 12.2 Interplay between electricity and gas

A precondition for the joint incorporation of electricity and gas in the long-term planning is the possibility of analysing the interplay between the two systems. An ERP-financed (Energy Research Programme) project has therefore been launched aimed at establishing sets of data and analysis tools and using these data and tools to analyse key challenges in the gas and electricity sector in Denmark. Focus is on the challenges involved in such interplay and the mutual interdependence of the two line-based energy supply systems. The need for such analysis tools has grown as a result of the liberalisation of both the electricity and the gas sector and as a result of the increasing use of natural gas for electricity and CHP production.

An analysis is being carried out of incentive structures in the two markets for the handling of security of supply (short and long term), capacity expansion and socio-economic efficiency. Moreover, the impact of framework conditions for the sector in the form of tariffs, taxes and duties is being assessed. The analyses are based on an hour-by-hour operating model for the system.

The project is being implemented in cooperation between Risø National Laboratory, the Technical University of Denmark, DGC and Energinet.dk.

### 12.3 New system architecture for the electricity grid

A new system architecture will be needed for the safe and efficient management of the electricity system with a growing share of local production.

A number of pilot projects have been launched which are all concerned with the optimum integration of local production into the electricity grid. The driving vision is to turn the local generators, which are non-regulated, passive electric-

ity production units, into regulatable assets to the Danish electricity system. If this succeeds, the potential is enormous for using these units for everything, from reactive power control in the medium-voltage grids to the supply of all types of ancillary services which are normally only offered by the primary power station units. In the long term, this will contribute to increasing security of supply in the electricity system.

The fundamental idea is to double the existing distribution grid with a high-speed data communication network with distributed intelligence. If such smart grids can be defined for suitably delimited areas, such an area or cell could ultimately be considered as a fully controlled virtual generator. This virtual generator will then be able to offer all types of ancillary services to the distribution and transmission system operator. Finally, such virtual generators could optimise operations in their own cell, which will in turn increase the security of supply for consumers in the area.

### *12.3.1 Cell project*

A promising possibility is a new architecture with the local grids as cells responsible for local monitoring and control of selected functions. This is being studied in the so-called cell project. Energinet.dk started the project in 2004, and it is being carried out in close cooperation with Sydvest Energi Net, the American company Spirae and the German company Energynautics.

The coming measuring, control and monitoring system must be able to handle a number of challenges: It must be possible to run local production units in accordance with the signals and demands of the market, it must be possible to control reactive power locally under normal operating conditions, and there must be access to accurate measurements from the local grids. Moreover, it must be possible to selectively disconnect production or consumption in critical situations. Accurate measurements must in advance be able to describe the consequences of connections and disconnections at the lower voltage levels. Finally, system restoration must be possible after blackouts, even when there are no intact interconnections to other synchronous areas.

The first phase of the project was completed with promising results in October 2005. There is international agreement that the new architecture is a promising development path, which is supported by international developments in hardware and standardisation activities.

The next step is taken in 2006 with the aim of testing and demonstrating that the monitoring and communication properties required for local cell operation are present. Concurrently with these activities, the cell regulator prototype is being developed.

**Holsted as test area**

With a view to clarifying the number, geographical spread and regulation-technical possibilities of CHP units, wind turbines and suitable load radials in a local cell, the first phase of the project has selected an example, the 150/60 kV substation in Holsted and the underlying 60 kV distribution grid in Southern Jutland. The selection has taken place in close cooperation with Sydvest Energi

Net and is also being done in close cooperation with the owners of local CHP units and wind turbines in the area.

### *12.3.2 Advanced use of online measurements*

A new measuring principle based on accurate time signals from GPS satellites paves the way for a number of attractive possibilities for online monitoring of the transmission grid, warnings of critical operational situations (which may lead to blackouts), verification of static and dynamic calculation models etc. Research and development is needed to develop both the measuring method and applications.

Energinet.dk and Ørsted•DTU will work together on a measuring system for Western Denmark based on commercially available PMUs (Phase Measurement Units). The purpose is to analyse and evaluate collected data and to develop methods of estimating the short-circuit power in the transmission grid.

### *12.3.3 Relay protection of local CHP units*

On the basis of the massive feeding-in of local CHP and wind power production, it is no longer viable, from the point of view of operations, that a considerable number of local CHP units are often disconnected because of transmission grid faults. A general study of the relay protection of local CHP units was initiated in 2004 with a view to reducing the number of units disconnected as a result of grid faults.

The study comprises a mapping of the existing generator protection of the units and a reassessment of the protection principles, comprising both generator installations and their connection grids.

With a view to initially concentrating the study on the largest local units so as to create an overview, the study covers only local CHP units in Jutland with capacity in excess of 25 MW. There are ten such units.

### *12.3.4 Generator data and models*

With a view to performing accurate dynamic analyses of the Danish electricity system, it is necessary to be able to devise dynamic calculation models of not just the large primary power station units, but also of all larger local CHP units and in the long term also of all large concentrations of wind turbines.

An extensive collection of dynamic generator data from all owners of the primary and large local CHP units has thus been initiated with a view to mathematical modelling of these units.

The status of this very comprehensive work which was initiated in 2002 under the auspices of Eltra is that at the end of 2005 all dynamic data for all the primary power units and for approx. half of all local CHP units with capacity in excess of 10 MW in Western Denmark had been collected. Moreover, the mathematical models for these units have been designed and used in connection with Energinet.dk's advanced system analyses.

Energinet.dk is now starting a similar process for the system in Eastern Denmark.

## 12.4 Integrating wind power into the electricity system

With increasing volumes of wind power in the electricity system, Energinet.dk is facing an ever greater challenge of maintaining security of supply and the technical quality of the system.

Denmark currently has total installed capacity of 3,100 MW, including 325 MW of offshore wind power. Both the existing large Danish offshore wind farms (Horns Rev with 160 MW and Nysted with 165 MW) are directly connected to the transmission grid. They are subject to technical specifications, including requirements for the uninterrupted operation of the offshore wind farms in the event of a short-circuit fault in the transmission grid (this property is called ride-through). These requirements have contributed to the development of the wind turbines' ability to supply ancillary services. The development of the wind turbines has at the same time created a need for access to well-documented models which can simulate the interplay between the wind turbines and the electricity system.

As part of the energy-political agreement of 29 March 2004, bids were invited for two offshore wind farms. Both offshore wind farms must have an installed capacity of approx. 200 MW with expected commissioning in 2009 and 2010.

### *12.4.1 Offshore wind turbines in Northern Germany*

Concurrently with the expansion of offshore wind power in Denmark, wind power expansion is taking place elsewhere in Europe. This applies, in particular, to Northern Germany where a large proportion of new wind power is expected to be installed in the North Sea and the Baltic Sea with connections to the German 400 kV grid near the Danish/German border. According to the German DENA study, a total of 20 GW will be installed by 2020. The installation of such large volumes of wind power raises a number of issues such as grid reinforcements and voltage stabilisation.

In low-load periods in 2010, the study expects to see considerable German exports to neighbouring countries (7-9 GW). This may have an unfavourable impact on the security of operations and electricity trading in Denmark. The German TSOs and the wind power companies are currently discussing new provisions concerning the connection of wind turbines which take account of the problems of integrating wind power.

### *12.4.2 International cooperation*

In March 2006, fourteen European TSOs from the UCTE, Nordel, the UK and Ireland launched the European Wind Integration Study (EWIS). The object of the study is to analyse the European aspects of grid planning, system operation, market integration, connection rules and legislation. The study will be conducted in 2006-2007 with the first report being published in December 2006. Energinet.dk takes part in this study, ensuring coordination with Nordic (Nordel) interests, among other things.

The UK is an EU member state which has a lot of focus on renewable energy, primarily in the form of large offshore wind farms.

As is the case in Denmark, the UK TSO, National Grid UK, has formulated a set of technical specifications which wind turbines must meet to be connected to the grid. Moreover, the development of dynamic wind turbine models for stability analyses has been put on the agenda. National Grid UK has therefore started working extensively with other UK and Irish TSOs and wind turbine manufacturers to design dynamic wind turbine models. Vestas, GE Energy and Siemens are among those that have shown an interest. Energinet.dk has been invited to take part in the cooperation. This offers an opportunity to gain insight into the most recent ride-through solutions developed by the world's leading wind turbine manufacturers. Such knowledge is essential to the grid connection of new Danish offshore wind farms.

## 12.5 PSO-financed research and development

Energinet.dk administers the ForskEL programme which ensures that research, development and demonstration projects are carried out within environmentally friendly electricity production technologies. These technologies must not be commercial, but must offer potential for financial sustainability in the long term. The projects are financed via a PSO rate collected by the TSO from electricity consumers.

As a result of the energy agreement of March 2004, the PSO funding available was increased to DKK 130 million a year up until and including 2008. In addition to the ordinary project call for DKK 100 million, an additional call for DKK 30 million was made for realisation by 1 January 2006. A comprehensive description can be found at www.energinet.dk.

### *12.5.1 Call 2007*

In the call for 2007 Energinet.dk is allowing the possibility of granting funding of for instance DKK 25-40 million to a single large project or consortium. Moreover, it is recommended that applicants prepare a first proposal for a business strategy for their technology.

With a view to increasing awareness of the focus areas, three main tracks have been identified – combustion technology and integrated energy systems, fuel cells and energy-carrying technologies and incorporated and distributed RE technologies (**Table 12.1**).

| | |
|---|---|
| A | Combustion technologies and integrated energy systems<br>- Waste and solid biofuels<br>Waste and biomass, thermal combustion<br>Waste and biomass, thermal gasification<br>- Integrated energy systems<br>Production of liquid biofuels<br>Production with cascade systems (series processes for optimised fuel efficiency)<br>- CHP systems<br>Natural gas-fired CHP (environmental improvements)<br>Mini and micro-CHP (developing technology)<br>Solar power in CHP systems<br>- Other technologies<br>Including, eg, biogas (production and combustion) |
| B | Fuel cells and energy-carrying technologies<br>- Fuel cells<br>Fuel cell technologies (developing technology)<br>Fuel for fuel cells (hydrogen, methanol and ammonia)<br>- Energy carriers<br>Natural gas (optimising use of natural gas for electricity and CHP production)<br>Hydrogen (production, handling and storage)<br>Use of liquid biofuels in electricity and CHP systems<br>- Other technologies<br>Including, eg, biogas (refining and gas upgrading) |
| C | Incorporated and distributed RE technologies<br>- Photovoltaic cells<br>- Wind power<br>Wind turbines, especially offshore-related problems<br>- Incorporation of RE in the electricity system (especially wind power)<br>Price-elastic electricity consumption (communication and optimisation)<br>Control and regulation (electricity system, redesign and increasing volumes of RE)<br>- Other technologies<br>Wave energy<br>Other environmentally friendly electricity production technologies |

***Table 12.1*** *Focus areas for PSO R&D call 2007. RE: Renewable energy.*

The item "Other technologies" must ensure that Energinet.dk is able to receive applications which do not immediately fall under one of the other focus areas.

The call for 2007 is expected to be approved by the Danish Minister for Transport and Energy in June 2006.

# 13. References


Ref. 1 Analyseforudsætninger 2006–2015, Energinet.dk, www.energinet.dk.

Ref. 2 Danmarks klimapolitiske mål og resultater, Miljøstyrelsen 2005 www.mst.dk/udgiv/publikationer/2005/87-7614-685-5/html

Ref. 3 DG Competition: Energy Sector Inquiry, 16 February 2006.

Ref. 4 European Federation of Energy Traders (EFET): Benchmarking Gas Transmission Access Systems in Europe: a trader's perspective, 9 February 2006.

# 14. Annexes

**Annex 1.1**
Nominal power production capacity units in Eastern Denmark on 1 January 2006 supplemented with assumptions.

| Units | Power Nominal MW | Commis-sioned Year | Decom-missioned Year | Comments |
|---|---|---|---|---|
| Amager Power Station Unit 1 | | | | To be recommis-sioned in 2008 |
| Amager Power Station Unit 2 | 91 | 1972 | | |
| Amager Power Station Unit 3 | 250 | 1989 | | |
| Asnæs Power Station Unit 2 | 147 | 1961 | | deNO$_x$ measures before 2008 |
| Asnæs Power Station Unit 4 | 270 | 1968 | 2008 | Can start up subject to two months' no-tice |
| Asnæs Power Station Unit 5 | 640 | 1981 | | |
| Avedøre Power Station Unit 1 | 250 | 1990 | | |
| Avedøreværket Unit 2 | 560 | 2001 | | |
| H.C. Ørsted Power Station Units 1-4 | 79 | 1954-65 | 2008 | |
| H.C. Ørsted Power Station Unit 7 | 82 | 1985 | | |
| H.C. Ørsted Power Station Unit 8 | 24 | 2003 | | |
| Kyndby Power Station Unit 21 | 260 | 1974 | | Life extension |
| Kyndby Power Station Unit 22 | 260 | 1976 | | Life extension |
| Kyndby Power Station Unit 41 | 18 | 1973 | | |
| Kyndby Power Station Units 51 + 52 | 126 | 1973 | | |
| Masnedø Power Station Unit 31 | 70 | 1975 | | |
| Svanemølle Power Station Units 1-3 | 71 | 1953-58 | 2008 | |
| Svanemølle Power Station Unit 7 | 60 | 1995 | | |
| Stigsnæs Power Station Unit 1 | 143 | 1966 | | deNO$_x$ measures before 2008 |
| Stigsnæs Power Station Unit 2 | 266 | 1970 | | deNO$_x$ measures before 2008 |
| **Total, Energi E2** | **3,667** | | | |
| Østkraft | 88 | | | |
| **Total, including Østkraft** | **3,755** | | | |
| Local units | 642 | | | |
| Wind power | 748 | | | |
| **Total installed capacity** | **5,145** | | | |

***Table 14.1*** *Nominal power production capacity units in Eastern Denmark on 1 January 2006 supplemented with assumptions. The times of decommissioning and deNO$_x$ measures indicated are assumptions and do not reflect decisions made.*

**Annex 1.2**

Nominal power production capacity units in Western Denmark on 1 January 2006 supplemented with assumptions.

| Units | Net power | Operating period | | Comments |
|---|---|---|---|---|
| | Continu-ously, MW | In opera-tion | Expected to be de-commis-sioned | |
| Ensted Power Station Unit 3 | 626 | 1979 | 2021 | Incl. 40 MW bio |
| Fynsværket Power Station Unit 3 | 269 | 1974 | 2016 | On natural gas and coal |
| Fynsværket Power Station Unit 7 | 372 | 1991 | 2021 | deNOx 2008 |
| Fynsværket Power Station Unit 8 | 36 | 2009 | 2029 | Biomass from 2009 |
| Nordjyllandsværket Power Station Unit 2 | 285 | 1977 | 2017 | In operation |
| Nordjyllandsværket Power Station Unit 3 | 380 | 1998 | 2028 | |
| Skærbæk Power Station Unit 3 | 392 | 1997 | 2027 | |
| Studstrup Power Station Unit 3 | 350 | 1984 | 2016 | deNOx 2008 |
| Studstrup Power Station Unit 4 | 350 | 1985 | 2016 | deNOx 2007 |
| Esbjerg Power Station Unit 3 | 378 | 1992 | 2022 | |
| **Total, Elsam** | **3,402** | | | |
| | | | | |
| **Local units** | **1,715** | | | |
| **Wind power** | **2,393** | | | |
| **Total installed capacity** | **7,510** | | | |

***Table 14.2*** *Nominal power production capacity units in Western Denmark on 1 January 2006 supplemented with assumptions.*

Unit 3 of the Fynsværket Power Station is in limited operation from 2008 to 2015, ie max. 20,000 hours of operation during this period.


50
100
0
150
160