THE FUTURE OF THE DANISH OIL AND GAS SECTOR

How do we ensure an optimal use of our resources?
UNOFFICIAL TRANSLATION

OF

‘THE FUTURE OF THE DANISH OIL AND GAS SECTOR’

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1. Executive Summary

1.1 An industry of great importance to Denmark
The Danish subsoil still holds a large potential of oil and gas which should be exploited for the good of society for the years to come.

Denmark has already produced oil and gas for more than 40 years, and the sector has a large impact on the Danish society. There is a continued need for oil and gas, and society has an interest in securing the most appropriate utilization of the oil and gas resources in the Danish part of the North Sea. The sector makes a positive contribution to society through substantial tax payments and a large number of work places shared between the oil and gas producers and the many supplier companies. In addition to this, the recovery of oil and gas in the Danish subsoil contributes to increasing the self-sufficiency in Denmark and secures a larger independence of energy imported from abroad. As the only EU country, Denmark is today a net exporter of oil and gas.

Thus, a process has been initiated to produce a long-term oil and gas strategy, providing recommendations for the optimum use of resources. The purpose of the process is to explore the possibilities, challenges and barriers to the industry, and formulate a coherent long-term strategy.

This report is the result of that process. The work has been performed in cooperation between authorities and the industry, in order to make sure that the most appropriate solutions have been found.

1.2 Investments and cooperation on infrastructure
The Danish production of oil and gas is at a crossroads these years. Oil and gas has been produced in the North Sea since 1972, but production has halved since 2004, where it peaked.

Large parts of the infrastructure for production and transport of oil and gas have been operational for many decades. As a result, certain facilities require increasing degrees of maintenance, while others need to be renewed. Because of this, a series of major investments in infrastructure in the North Sea must be expected in the coming years. Optimum use of the total resources of oil and gas requires an extensive infrastructure.

With the agreement of 23 March 2017 between the state and DUC, a foundation has been provided meaning among others that the Tyra reconstruction project can be sanctioned, and a substantial part of the gas infrastructure will thus continuously be able to be used for many years.

Likewise, there is a need for investments in exploration, whilst also enhancing the development and use of new technologies, an example is the Danish Hydrocarbon Research and Technology Centre - DTU, as new knowledge can improve the potential in the North Sea significantly. At the same time, there is a series of marginal projects which are currently not realizable due to technical or economic barriers. The bulk of possible future discoveries on the Danish shelf is expected to increase the number of marginal projects further. These marginal projects have the potential to contribute significantly to Danish production of oil and gas in the future.

It is a major task to secure the continued development and utilization of Danish resources, and in these years a number of major decisions in the oil and gas industry are to be made. As a result, there are a number of central challenges which should be resolved through close dialogue between the industry and the authorities

1.3 Main conclusions
The strategy process has demonstrated that substantial quantities of oil and gas, which have significant value to society, are still present in the Danish shelf. In other words, there is a large potential, that can be exploited.

At the same time, a series of challenges and barriers have been identified, which must be addressed to better utilize this potential. If Denmark is to benefit from a larger portion of the potential, these challenges and barriers must be the focus of dedicated work.

A series of explicit recommendations have been produced, containing suggestions for initiatives and actions to address several of these challenges.

The analysis has provided the following main conclusions:

**MAIN CONCLUSIONS:**

1. Geological potential
   - Denmark still has a substantial potential of app. 3 billion barrels of oil equivalents (boe). The fact that it is technically possible to recover that quantity does not necessarily mean that it is commercially attractive to recover. It has been estimated that just over half of this potential can be recovered with the existing technology and an optimum use of the infrastructure.

2. Technological potential
   - Part of the 3 billion boe are not identified as of today or cannot be recovered by known technologies. If the technologies identified in the strategy work can be developed and used on a commercial basis, it will be possible further recover up to 1.2 billion boe. It is estimated that by using these technologies, about 34 percent of the present discoveries of oil and gas could be recovered. The technologies will in that case increase the recovery rate with 7 percentage points from the present expected 27 percent.

3. Small discoveries and infrastructure
   - Much of the remaining potential is made up of relatively small discoveries of which more than half is currently not profitable to produce. 90 percent of the potential volume is within a distance of 25 km from the existing infrastructure.
**MAIN CONCLUSIONS (cont.)**

- Within relevant areas in the North Sea, the design and use of infrastructure should be optimized through cooperation with the aim of maximizing the commercial production of oil and gas. This area cooperation must be coordinated in a forum under Oil Gas Denmark with participation of all license holders in an area and with the Danish Energy Agency as observer. Through regular dialogue, an increased level of transparency on plans for future production and capacity can be supported. It is a prerequisite for the optimum use of existing infrastructure, which is simple for all companies to use existing infrastructure on predictable and reasonable terms, called third-party access. Thus, a clear framework for third-party access should be developed.

4. **Investments and costs**
- By substantial cost reductions, technological development and further investments, it is possible to increase the commercial potential significantly. It can among others be supported by an increased and enhanced cooperation in the sector, e.g. in connection with a joint development of simple and standardized development solutions aimed at safe, flexible and cost-effective development of marginal projects and cheaper wells.

5. **Workforce**
- There is a need to secure a qualified work force also for the next decades, if the potential is to be exploited. There should be a continued focus on education, attracting and retaining the right competencies. This can, among other ways, happen by increasing cooperation between the oil and gas industry and relevant educational institutions, greater focus on technical and scientific educations, increasing knowledge of the industry and by securing Danish competitiveness on the international job market.

Note: Word explanations and definitions are listed in the end of the report.

The work has been organized within a number of areas of action. In section 1.4, a list of the five areas of action and the related concrete recommendations have been described.

As conceived, the recommendations directed at the authorities are cost neutral, meaning that they can be realized within the assigned budgets.

We would like to encourage that an assessment is being made of the Committee’s recommendations and that a possible implementation is initiated with the aim of creating more stability regarding the future framework conditions in the oil and gas industry, and a support to ensure that the necessary investments are made.

Copenhagen, June 2017

On behalf of the Committee,

Martin Hansen, Chairman

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**Optimization of recovery of oil and gas from the North Sea**

1.6 Overview of focus areas and recommendations
2. Background

2.1. Production of oil and gas is very important to Denmark

The production of oil and gas from the Danish part of the North Sea has had a significant impact on Danish economy. Since the first oil was produced from the Dan field in 1972 and up to 2015, more than 3.8 billion barrels of oil and gas have been brought to shore. This has up to and including 2015 provided a contribution of app. 415 billion Danish kroner for the Danish state.

The sector estimates that app. 15,000 employees are engaged in the industry, including highly skilled engineers and scientific specialists along with specialized offshore employees with skilled or other technical background.

For years oil and gas production has created a surplus on the balance of trade, and as the only country in the EU, Denmark is a net-exporter of oil and gas. At the same time production of our own oil and gas reduces the need for energy produced under different standards for the environment, safety and health. Furthermore, the production is of importance to our security of supply, as it reduces Denmark’s dependence on imports of oil and gas.

Oil and gas will also play an important role in Denmark’s energy supply for many years to come. It is a natural extension of the Danish parliament’s decision from 2012 regarding the North Sea oil, emphasizing that the Danish resources of oil and gas must be exploited to deliver the maximum possible benefits for the Danish society and socio economics. The industry fully supports this ambition.

However, a prerequisite for production of remaining resources is substantial new investments in exploration, development of new and existing fields as well as renewal of aging infrastructure.

2.2 The mandate for developing an oil and gas strategy for the North Sea

In 2013 the former government’s service review of conditions for producing hydrocarbon was concluded. This review examined the tax related framework conditions for hydrocarbon production.

In relation to the conclusion of the service review of conditions for producing hydrocarbon, a joint statement was issued from the license holders on behalf of the Danish Underground Consortium (DUC) as well as the former government. In the joint statement, it is stated that an analysis of the potential, cost and the need for investments will be conducted as part of a joint long-term strategy for increasing production in the North Sea on a commercial basis.

The work was initiated based on the following mandate:

Mandate for developing an oil and gas strategy for the North Sea

In the joint statement from the government and the license holders (on behalf of DUC) of 26 February 2013 it is stated that “the government will work with the industry to formulate a long-term strategy for optimizing the production of oil and gas from the fields in the North Sea on a commercial basis.”

In the government’s growth plan for energy and climate from October 2013 it is stated that the government will:

- “Work with the industry to formulate a long-term strategy for optimizing the production of oil and gas from the fields in the North Sea on a commercial basis.
- In relation to the work on the strategy, it will benefit from the parties in the Danish Underground Consortium establishing a new Danish research center, which will cooperate with Danish and foreign research environments.”

Based on the service review of conditions for producing hydrocarbon from March 2013, the future fiscal terms for exploration and production have been established.

Oil and gas production from the Danish part of the North Sea is of significant importance to the Danish economy. The existing infrastructure provides the possibility that smaller discoveries can be commercially produced by using excess capacity on existing facilities. A very large share of existing production facilities and pipelines are very old, and therefore expensive to maintain. There is a need for an overall assessment of the requirement for renovation and renewal, to create the best possible foundation for the continued optimization of production of remaining oil and gas in the subsurface.

Production forecasts assume that on average, 26% of oil present in the subsurface can be produced. A one percentage-point increase in the recovery rate is expected to increase production by approximately 20 million m3. At an exchange rate of 5.50 DKK/USD and an oil price of 100 USD/barrel this corresponds to a production value of about 70 billion DKK.* The potential is thus very substantial.

There is a need to make an overall evaluation of the current condition of the industry, and to formulate a strategy for future exploration and commercial production of Danish resources. The strategy must focus on efficiency improvements and reduction of cost, including the consumption of energy in the production. Experience from other North Sea countries must be part of this evaluation.

The strategy must be based on a foundation that is justifiable in terms of safety, health and the environment.

For the analysis, a steering committee will be established with the participation from the Ministry for Climate, Energy and Building, the Ministry of Finance, the Danish Energy Agency, the Ministry of Business and Growth, NordoeFonden and representatives from the industry appointed by Oil
Gas Denmark. The Danish Energy Authority acts as committee chairman. The committee will establish work groups to conduct parts of the analysis.

The committee must, on the stated background, conduct an analysis of:

1) The potential for oil and gas production from the Danish North Sea. Forecasts for production from known fields and discoveries as well as the possibilities for new discoveries must be part of the assessment. Furthermore, an evaluation of the potential for increasing recovery rates from known fields on a commercial basis through research and development projects, as well as the potential for growth in businesses affiliated with oil and gas production, must also be part of the assessment. Cost associated with enhancing recovery must be examined.

2) Coordination of renewal and renovation of existing infrastructure for producing, processing and transporting oil and gas. The analysis will examine how framework conditions can ensure that future infrastructure accommodates:
   a) Ensuring flexibility due to insecurities regarding the size of reserves.
   b) Minimizing the cost of investment and operation.
   c) Minimizing the energy consumed for processing and transportation purposes in the production of oil and gas. As part of this it must be assessed if delivering electricity from onshore facilities is appropriate. If plans of establishing infrastructure for electricity supply in the North Sea are put forward internationally, this must be part of the analysis.
   d) Optimizing the coordination of production between operators and between processing facilities both onshore and offshore.
   e) Optimizing access to use facilities on reasonable terms for third parties.

3) The possibilities for ensuring that highly educated workers with the necessary skills in exploration, production and affiliated businesses are available also in the future. It is important, that the oil and gas industry has access to skilled workers. As part of the strategy, recruitment for the sector must be mapped, and in relation to this it must be analyzed if and how young people can be attracted to educations that are relevant to the oil and gas industry.

4) Framework for future exploration. Areas with potential hydrocarbon deposits are offered on a regular basis. The 7th licensing round is currently about to begin, and is expected to be concluded in the beginning of 2015. Based on, among other things, the experience from the 7th licensing round, the future structuring of licensing rounds within the boundaries of the Subsoil Act must be reconsidered, in order to ensure the maximum level of exploration activity.

The analysis must result in a report with recommendations for the government.

The work must be concluded by the end of May 2015.

* It is noted that the oil price is significantly lower than 100 USD pr. barrel today.

The deadline for completion of the work has since been postponed as it proved to be more extensive than expected.

This report contains brief descriptions of the work, as well as the conclusions and recommendations resulting from the analysis.

2.3 Contribution to society

The production of oil and gas from the Danish part of the North Sea is of great importance to society. Production entails tax revenue for the state, and positively affects the rate of employment and economic growth. At the same time, Danish production of oil and gas will significantly prolong the period where Denmark is self-sufficient in energy.

2.3.1 Tax revenue

Oil and gas production from the Danish part of the North Sea has significantly impacted Danish economy. The proceeds from oil and gas from the North Sea has in total contributed about 415 billion DKK to the state budgets. The government’s proceeds from production in the North Sea come from different forms of taxation, as well as proceeds from government participation. In 2015 the contribution was about 9.3 billion DKK 1, see figure 1.

![Figure 1: State Revenue 1982-2015 (state participation through Nordsoefonden from 2005)](image)

Source: Danish Energy Agency

1. Finance Act accrual (in respect of the year in which they were paid)
2.3.2 Security of supply

While the EU-countries’ dependence on imports of natural gas from especially Norway and Russia approaches 70%, Denmark has produced gas from its own fields in the North Sea since the 1980's, and has exported natural gas to Sweden and Germany in particular. Since 1993 Denmark has been a net-exporter of both oil and gas.

Based on the present prognosis for future recovery from the North Sea, it is expected that Denmark, except for a few single years, will remain a net exporter of oil and gas until after 2030.

Danish production from the North Sea and the infrastructure in the North Sea and on land has meant that deliveries of oil and gas to Danish society have been stable and well-functioning for many years. Oil and gas continues to be a significant source of the Danish energy supply, see figure 2. This also shows that more than half the Danish energy demand is expected to be covered by oil and gas in the foreseeable future.

![Figure 2: Gross energy consumption dispersed on fuels](Source: Danish Energy Agency, 2015)

2.3.3 Employment

During the last 50 years, the oil companies have invested in exploration, development and operation of the Danish fields.

The oil industry has significant importance to job creation in the countries surrounding the North Sea, where it is estimated that several hundred thousand people are either directly or indirectly employed in the oil industry.

The oil and gas sector consists of both hydrocarbon producers and several suppliers. The sector estimates that in Denmark app. 15,000 people (equivalent to 12,700 working full-time) are employed in the industry, including a number of highly educated engineers and scientific specialists as well as specialized offshore workers with skilled and other technical backgrounds.

The workforce is highly mobile across borders and is affected by the different countries’ framework conditions for recruiting and the salary and employment terms of businesses. The share of foreigners is relatively high compared to other businesses, which among others reflects an internationally oriented business.

More than 300 Danish companies deliver goods and services to the operators on the Danish continental shelf, and regionally the presence of the offshore industry in the Region of Southern Denmark is a significant engine for growth. Furthermore, the subcontractors to the offshore industry are exporting a growing volume of goods and services to foreign oil and gas companies.

2.4 The challenges in the Danish shelf

A major task is to secure the continued development and utilization of Danish resources, and in the years ahead a series of crucial decisions must be made in the oil and gas industry. Because of this, the industry and the state should work closely together on solving a string of central challenges.

One of the key reasons to the many challenges is that Danish subsoil is a mature area when it comes to both exploration, production and infrastructure.

Figure 3 highlights that Denmark in terms of exploration is a mature area. The figure shows the accumulated resources (expected final recovery) from discoveries made since the first exploratory drilling operation in 1966 up until 2010. Data for discoveries from the latest five years is classified and cannot be illustrated. In comparison, the accumulated production in the Danish shelf is shown.

The largest discoveries are usually made early on in an area’s exploration history. As the shelf matures, the success of exploration will diminish. New discoveries are regularly made, though often of a smaller size. It is a major challenge to commercialize these discoveries.

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Figure 3: Discovery curve for the Danish shelf and accumulated production

Source: Danish Energy Agency

Production from the Danish North Sea has declined during the past years, again due to the Danish subsoil being mature with many ageing fields. This is illustrated by the curve for the accumulated production flattening out.

At the same time, major challenges are attached to ageing infrastructure and fields, leading to increasing cost for operation and maintenance, among other things. Investments and reduced cost may contribute to make it commercially viable to produce a large share of the quantities in the subsoil.

The oil and gas industry is international, and other countries around the North Sea face similar developments in their oil and gas industries with falling production and investment. Thus, the sector meets fierce competition for investment, both among North Sea countries and globally.

The sector has from time to time had challenges recruiting workforce with the required technical and scientific competencies.

2.4.1 Assessment of potential

In the strategy process the potential of oil and gas in the Danish part of the North Sea is estimated at around 3 billion barrels of oil equivalents (boe), see an explanatory list of terms at the back of the report. In comparison, it can be mentioned, that up until 2014 a total of 3.8 billion barrels of oil equivalents have been produced in the Danish part of the North Sea.

The estimated potential includes new discoveries due to exploration, technological development of new methods and the potential from known fields, see figure 4 and sections on focus areas 1 and 2.

Figure 4: Potential in the Danish part of the North Sea

Source: Data from the strategy process – potential as of media 2015

Note: by reporting potentials and volumes in boe, gas is converted to the same energy unit as oil.

Recovering these quantities is estimated to be technically feasible, however, this does not necessarily mean they are commercially viable.

In Denmark, much of the oil and gas is trapped in very dense chalk formations or thin layers of sandstone. This makes the recovery of the hydrocarbon difficult. In certain types of deposits, the hydrocarbons are deposited in very deep layers under high pressure and with high temperatures. This results in a series of new, often difficult, technical demands and challenges.

The Danish Energy Agency periodically – typically once a year - publishes a production prognosis, illustrating the Danish Energy Agency’s estimate of the future production of oil and gas in Denmark. In August 2016, The Danish Energy Agency published a production prognosis to which an amendment was published in April 2017.

Meanwhile, The Danish Energy Agency’s prognosis has been based on a different systematics than the one used in the strategy work, which is why the potentials from the prognosis and from the model work are not fully comparable.

The Danish Energy Agency’s prognosis cannot be compared with the full potential of 3.0 billion boe, ref. figure 4. The reason being that the full potential is expressing the technically possible recoverable volume without considering an economic estimate. To a certain extent, the Danish
Energy Agency’s prognosis takes the projects’ economic viability into account, therefore it cannot be directly comparable to the full potential in figure 4.

The Danish Energy Agency’s prognosis is - with significant reservations - more in accordance with the commercially weighted potential in the strategy work’s Growth scenario (ref. p. 27 ff.), in which a full reconstruction of the Tyra field’s installation has been taken into account. The Danish Energy Agency’s prognosis is somewhat higher than the commercial potential in the Growth scenario. The reason for the difference between the Growth scenario and the latest prognosis is as follows:

- The growth scenario’s calculations have been made in 2015, while the Danish Energy Agency’s latest prognosis has been made early 2017. Hence, different project portfolios have been used and different technical and economic data for the involved projects, including different risk assessment. The reason for this is that new information and new data have been received for a number of the projects in comparison to what had been the preconditions for the strategy work.
- The prognosis does not use a probabilistic approach but is based on a number of evaluations of the expected future production.
- In the strategy work a systematic economic evaluation has been made for all projects. This is not quite the case for the Danish Energy Agency’s prognosis, in which an economic screening of merely some of the projects has been carried out.
- The division of the prognosis’ potential into reserves, contingent, technological and exploration resources cannot be directly compared with the division of the potential in the strategy work.

2.4.2 Ageing infrastructure and fields
In the Danish part of the North Sea production is currently ongoing at more than 60 platforms and a few subsea installations, distributed across 19 fields, see figure 5. The majority of the fields experience falling production, as they have been in production for an extended number of years.

Large parts of the existing infrastructure have been operational for decades. The advanced age of the installations means that there is a higher need for investments in maintenance and in certain cases for the establishment of new installations.

The unit costs have in general been increasing in the North Sea area.

Exploiting the potential requires accessible infrastructure for production and transport to shore. This requires, that it is economically viable to expand, operate and maintain the infrastructure, as well as conditions for access to the infrastructure must be predictable and reasonable.

Because of this, it is important that the potential in the Danish shelf is fulfilled, while the necessary infrastructure in the North Sea is available. Thus, a working infrastructure is necessary to ensure that e.g. the economic viability of new, smaller discoveries, by utilizing the capacity of existing facilities. The resources in such discoveries will not be economically viable without the necessary infrastructure and as a result are at risk of being lost.

Increasing cost for maintenance and operation might limit the time that production from certain facilities remains economically viable. The timeframe can, however, be extended by linking new discoveries with the facilities, as production from these will contribute to reducing the unit cost.

2.4.3 Level of cost depend among others on the oil price
The cost is a determining factor in how much of the potential can be commercially produced. A lower level of cost in the recovery of oil and gas will further increase production from the North Sea, as it will become more profitable to produce more of the remaining resources.

At higher oil prices, the companies’ income from sale of oil and gas increases. Experience shows, however, that the demand for drilling rigs, production facilities etc. increases with the oil price, resulting in rising prices, and thereby raising cost. On the other hand, lower oil prices will see
Demand fall, which leads to falling prices. The historical development in oil prices is shown in figure 6.

The accessibility of the individual discoveries and the size of production also impact the level of cost and by that the average production costs. When a field has been in production for several years, production of remaining oil and gas resources become increasingly difficult. Because of this, cost rises and possible benefits due to economies of scale are lost due to lower production. On the other hand, the average production cost is reduced at production from more easily accessible resources or from benefits due to economies of scale from increased volumes.

In mature fields, such as the Danish, water production increases as oil and gas production decreases. This is a factor in raising unit cost. Furthermore, it leads to falling production not necessarily freeing up processing capacity on facilities for other discoveries and fields.

The companies are already working determinedly on reducing cost, also through further industry collaboration. However, major cost reductions are required if it is to have a significant impact on total production. Reduction of operating costs will primarily impact the value of current production and the lifetime of the production facilities. Reduction of capital cost, especially drilling cost and the oil price, will primarily influence exploration and development.

Operational costs of oil and gas production in a number of North Sea countries have been rising throughout a number of years up until 2014, as shown by Wood Mackenzie. The analysis pointed to the rising operational costs in Denmark as a result of field maturity and ageing infrastructure. The same rising trend is seen in cost for development, including cost for wells.

The sharp fall in oil prices in 2014 has led to a significant decrease in global investments in oil and gas. The companies have had increased focus on reduction of costs for both operating and developing. Along with the declining demand this has led to a decrease in capital cost.

In general, the oil industry is very capital intensive and the cost related to exploration, development and operation of facilities are high. Several of the new and advanced techniques available to the industry today are expensive to use. The high cost may inhibit investment in wells and development of new discoveries, which might already be economically marginal due to technical complexity or low volumes of recoverable resources. A central challenge in regard to cost is therefore to develop cheaper solutions aimed at developing marginal projects. The heaviest cost items are include wells, constructing facilities etc.

With lower cost and increased phasing-in of new fields production from the fields will be possible for a longer period. This creates the possibility of producing a larger quantity of economically viable oil and gas from the fields, and thereby attaining benefits from economies of scale.

2.4.4 Cooperation on infrastructure

Balanced agreements on third party access can be organized for the benefit of all parties. Such agreements will improve utilization of resources as well as improving the utilization of the infrastructure and the lifetime of facilities can be extended. Third party access to existing facilities should also be part of the considerations on removal or renovation of facilities to extend their lifetime, to ensure the optimum utilization of resources. During the strategy process some companies have, however, pointed to a series of difficulties in giving third parties access to existing facilities.

On the other hand, some operators have experienced that third-party companies show up at negotiations on access to infrastructure with expectations that are not immediately realizable.

In practice, it might take several years to conclude negotiations on third party access. This often leads to the reduction of value of a discovery, as the income is postponed. Also, a long period of negotiation could go as far as leading to sub-optimum use of the infrastructure.

Challenges related to third party access are also known in other countries surrounding the North Sea. This is, among other things, addressed in the Wood reports’ recommendations for the UK, where it is made clear that the increasing necessity of producing small and marginal discoveries by attaching them to existing infrastructure creates a need for owners of infrastructure and processing facilities to make it available for potential third-party users.

2.4.5 Skilled workers

A mapping made in relation to the strategy work in collaboration with the industry of the employment and recruitment situation in the Danish oil and gas industry in 2015, shows that despite

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Figure 6: Historical development in oil prices

2016 prices have been calculated on the basis of the consumer price index
Source: Danish Energy Agency

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falling production and oil prices, the industry may face a series of recruitment challenges, in particular in relation to technical and scientific disciplines.

The challenges of the industry have previously been related to lack of knowledge of the possibilities of employment in the industry in the workforce and among students. Furthermore, there has been a large demand for relevant candidates. Such a problem in supply is shared with a number of other businesses and is, among other things, due to an inadequate flow towards technical and scientific educations.

The challenges of recruiting skilled labor in the future may again become a barrier for growth in the North Sea. The mapping points at a risk of shortages within a number of disciplines and an increased need for employment towards 2030.

2.5 Perspectives for oil and gas in the North Sea countries
The North Sea countries have produced oil and gas since the 1970’s. Even though it is the same region, there are major differences in the possibility of discovering oil and gas, the type of discoveries, their size and the recovery rate. There are also differences in infrastructure, ownership structure, cost, legislation etc.

2.5.1 The importance of oil to the North Sea countries
Oil and gas plays a significant role to all the countries surrounding the North Sea, see figure 7.

Norway is the world’s third-largest exporter of natural gas and the tenth-largest exporter of oil. The UK production of oil and gas covers almost half the national demand, and as the only country in the EU, Denmark has been a net-exporter of oil and gas for an extended number of years. In the figure below, the countries’ production of oil and gas has been converted to boe (barrels of oil equivalents).

Figure 7: Production from North Sea countries 1965-2015

Source: Wood Mackenzie
Note: The North Sea is defined as: Central Graben, Norwegian-Danish, North-, Mid- and South North Sea, West of Shetland and Moray Firth.

2.5.2 Geological differences in the North Sea
A vast potential for production of oil and gas remains in the North Sea, but the estimated quantity of oil and gas in the different countries varies considerably. This strategy process demonstrates that there is a technical potential of about 3 billion boe in the Danish North Sea. According to different records an estimated 4-9 boe remains in the British North Sea and about 21-26 billion boe in the Norwegian North Sea.4

In the oil industry, the North Sea is regarded as a mature area, and the expectations for the size of future discoveries are moderate.

The majority of Danish production comes from dense chalk fields and thin layers of sandstone, which are difficult to produce. The recovery rate is smaller for limestone fields compared to sandstone fields, which make up the majority of the Norwegian fields. The recovery rate indicates the share of present volumes expected to be recovered. Denmark has compared to our neighbors a larger share of fields consisting of dense or deep reservoirs under high pressure and with high temperatures. A report from oil consultants Wood Mackenzie shows, that 70% of the Danish fields are challenging.5

4 Data from DECC in the UK from 2014 and NPD in Norway from 2014.
5 From OGD Summit 2014, Wood Mackenzie presentation and numbers from DECC, NPD and ENS.
In comparison that number is only 30% in Norway and 56% in the UK. It is noted that there may be variations in the countries’ definitions of “challenging” fields.

2.5.3 Framework conditions in the remaining North Sea countries
In recent years, the governments in the other North Sea Countries have launched a number of initiatives to adjust the framework to the area’s maturity and the expectations for future productions. As the countries have different potentials and challenges, different political initiatives are aimed at different areas.

Norway has for instance launched an initiative to attract investments to increase exploration activity. Here, focus is in particular on the leverage of technology development and testing.

However, in Norway, changes to fiscal frameworks are rare.

In the UK rules on Investment Allowance as of 1 April 2015 have replaced the previous more field based British schemes which provided extra deductions for investments in fields with specific characteristics. In the Netherlands, a specific tax deduction for investments in marginal gas fields has been EU approved for the period 2010-2016, to create an incentive to recover marginal and poorly accessible resources.

3. Optimization of recovery of oil and gas from the North Sea
The strategy process has shown that large volumes of oil and gas, which are very valuable to society, remain in our subsoil. This leaves a large potential, which should be exploited.

During the strategy process a series of challenges and barriers have been identified; those should be addressed in order to better utilize the potential. This has resulted in specific recommendations with suggestions for initiatives and actions, which may contribute in reducing or removing these barriers.

Evaluations, conclusions and recommendations have been gathered as five focus areas, see figure 8 along with a detailed overview in section 1.4.

The overarching frame is a wish for enhancing investments in the Danish sector with the aim of optimizing the recovery of oil and gas.

The general objective for focus area 1 and 2 is to increase the potential in the Danish area. The objective for the focus areas 3 to 5 is to reduce barriers to enable exploiting the full potential.

Many of the recommended initiatives should be seen as linked. For example, minor fields are usually only profitable to produce, if they can be linked to existing infrastructure. A prerequisite for this is the continued development and maintenance of existing infrastructure, thereby extending the lifetime of the facilities. Another prerequisite is the ability to swiftly and flexibly agree to reasonable terms and conditions for third party use of the infrastructure. At the same time, the lifetime of the infrastructure is dependent on reducing cost for, e.g. drilling of wells and developing marginal fields. In doing so the recovery rate can be increased and economy of scale can be obtained.
Links between elements of the work

Throughout the strategy process, a workgroup was established within each focus area. As part of the work all workgroups and operators have supplied data for an economic model, which has been used to analyze the potential for commercial production in the Danish part of the North Sea, see figure 9. The analysis work was carried out during first half of 2015. A more detailed description of the model can be found in chapter 3 in the section on focus area 3. The results of these simulations also make up the foundations for some of the recommendations.

The initial quantities of oil and gas in the subsoil are estimated through a geological assessment. The geological potential is made up of the quantity of oil and gas present, which is yet to be discovered. This quantity can be increased through further exploration, which contributes to improved knowledge.

GEUS, Geological Survey of Denmark and Greenland, have been chosen to conduct a consolidation and assessment of the mapped geological potential, as well as the un-mapped potential in so-called “white areas”. In addition to the account given by GEUS, the oil companies in the trade organization Oil Gas Denmark (OGD) have made an assessment of possible un-mapped potentials in so-called “white areas”. Trade specific terms are described at the end of the report.

The account shown below is founded in the account given by GEUS, made in 2014/15. In addition to this, OGD’s independent account of “white areas” has been added. The accounts received have subsequently been processed, and further data have been added.

The collective assessment of present quantities related to exploration potential is 2.3 billion boe. From this, it is estimated that 0.7 billion boe is technically viable to produce, see figure 10.
The account of the exploration potential has been used in the further work in the economic model, and is part of the modeling of the infrastructure. This work is described further in focus area 3. The identified prospects and leads are characterized by being relatively small, but an estimated 90% of the potential volume is located within 25 km of existing infrastructure, improving the possibilities of commercial production.

Faster maturing of prospects, meaning a shortening of the time span between the granting of permits and the start of production, will increase value. The increased value is due to earlier production as well as increased production, whilst it is possible to utilize existing infrastructure.

**ASSESSMENT**

Knowledge of geological conditions in the subsoil forms the foundation for further developing the recovery of oil and gas in the Danish part of the North Sea. The exploration potential seen together with the existing infrastructure in the North Sea is of major significance in regard to whether new discoveries will be commercially viable. It is assessed that a significant exploration potential of 0.7 billion boe remains in the Danish North Sea. As a result, exploration activities should be supported in order to locate remaining quantities, so they may be produced whilst the infrastructure is available.

Knowledge of the subsoil is a prerequisite for exploration. Improved data might contribute to making it more attractive for new as well as existing actors to conduct exploration in Denmark. At the same time, a more thorough assessment of remaining resources in the Danish North Sea is an important element in strengthening further exploration in Denmark. By making a complete reinterpretation of the area, where all accessible data is included, a systematic account of remaining resources can be produced. In doing so, we might attract more resourceful oil companies, and further investments and knowledge can be drawn to the Danish area.

The account of oil and gas quantities present and resources will at all times be a reflection of the existing level of knowledge. Further knowledge about the potential is continuously obtained in the shape of new and improved geophysical data, new interpretation methods, new technical possibilities and data from new wells. To incorporate these dynamic effects, it is necessary to periodically conduct new assessments of the geological potential on a uniform, standardized foundation, in order to make an account of further potential for oil- and gas exploration in the North Sea.

At the same time, it is important that an attractive exploration environment is created, where innovation and generation of ideas is furthered and supported.

In some areas of the Danish part of the North Sea, the age and quality of seismic data is insufficient to generate new prospects. Experience shows that collecting new seismic data with higher and better resolution of especially deeper levels can support identification of new potential.

The frequency of licensing rounds for awarding license for exploration and production should be increased, so that exploration efforts are accelerated, and new discoveries have the possibility of being attached to existing infrastructure. To enhance the oil- and gas industry’s interest in the Danish North Sea, promotion of the area should be intensified.

**RECOMMENDATION**

**Recommendation A: Facilitating an effective and attractive exploration environment**

To facilitate and support an attractive exploration environment in Denmark and promote the Danish area, it is recommended:

A.1. That periodical evaluation of the total resource potential in the Danish part of the North Sea are conducted, adjusted to the timing of licensing rounds. Evaluation of resources is to be conducted by GEUS following further agreement with the Danish Energy Authority (DEA). Furthermore, the DEA and GEUS should establish a standardized method for reporting in cooperation with the industry. Reporting should include data and possibly commercial assessments of fields, discoveries, prospects and leads.

A.2. That regular licensing rounds are conducted, and that promotion of the Danish area is strengthened. The relevant authorities – The DEA and GEUS – and Nordseefonden should carry out this work in cooperation with other stakeholders through, among other things, developing new attractive exploration models and an account of the remaining potential.

A.3. That GEUS and the DEA, with regard to a possible change of the accessibility to existing data, collect experiences from comparable countries regarding:

- access to released data, including different models for e-trading
- free data for different stakeholders, e.g. consultants, small and larger companies.
- The period of confidentiality of data collected in permits

A.4. That the industry in cooperation with GEUS establishes a dialogue with the seismic industry to investigate the possibilities of facilitating the collection of new and better seismic data.
The technological potential is comprised of the additional quantity of hydrocarbon that is assumed to be producible through the development of new and improved technologies.

As part of the strategy process it has been estimated how large quantities of oil and gas that potentially can be produced from known oil- and gas fields through the application of new technologies. The potential has been estimated without taking the commercial viability of production into account. The collective present quantities related to technology and known fields are estimated at about 18 billion boe, see figure 11.

Development and application of new technologies have been a prerequisite for increasing production of oil and gas from Danish fields in the North Sea. Since the start of Danish oil and gas production in 1972 about 3.8 billion boe have been produced. The production corresponds to 21% of the oil and gas discovered. The industry is currently expecting to produce about 1.1 billion boe from known oil and gas fields, see figure 11. This will bring the recovery rate up to 27%.

If the technologies identified in the strategy process can be developed and applied on a commercial basis, it will be possible to recover even more of the total potential. This share is estimated to be about 1.2 billion boe from the projects included in the models, see figure 11. It is estimated that if these technologies are applied, about 34% of the currently discovered oil and gas can be recovered. The technologies will thus increase the recovery rate by 7 percentage points from the current expectation of 27%.

If the recovery rate is to be further increased, it will require development of completely new technologies. Such technologies must be developed for the specific conditions present in the Danish oil and gas reservoirs, and will require a substantial research and development effort. As the technologies are not known, their effect cannot be estimated. However, a one percentage point increase in the recovery rate could increase total production by about 180 million boe of the total quantities present.

The economic model shows that there is a large potential in increasing production from known fields. Half of this potential is profitable through known technology, the current cost levels and the prices assumed in the model. This is true for, among other things, technologies that grant better access to oil and gas in the reservoirs.

Further development of these technologies, with a focus on improving well technologies and developing technologically simple platforms and pipelines, can further increase this potential. In both cases the aim is to lower the cost of investment.

**ASSESSMENT**

Facilitating new technologies is important in realizing a larger share of the potential, as development and application of new technologies is an important prerequisite for reducing cost. New technology will especially be able to contribute to a higher recovery rate, for instance through a significant reduction of well cost.

Facilitating the application of new technologies holds a large potential.

The industry participates in generating ideas, developing and testing new technologies. The work is often conducted through partnerships with research institutions and universities in the early stage of a development program, whilst supply companies and other oil companies often act as partners in the later stages during testing and application of new technologies.

In the early stages of a development program for new technologies there are relatively few barriers to continuing development. In the later stages of a development program, where testing of new technology in producing fields is conducted, there is a risk that project development stalls as cost and commercial risks increase substantially.

When testing new technology in the North Sea, considerations must be made for the substantial risk of negatively affecting ongoing activities and expected production. Furthermore, the involved actors must be willing to invest in the testing. It will be strongly conducive to the application of new technology if mechanisms for handling such risks and barriers to investments could be established.

**Figure 11: Technology and known fields: present quantities for potentials from technology and known fields, respectively**

*Source: Data from the strategy process*

*Note: Present quantities in figures 10 and 11 are related to exploration potential and technological and known field potential respectively. Therefore, these quantities are not the same.*
is assessed that projects with substantial potentials are inhibited by the fact that several of the assessed technologies are awaiting field testing.

Based on the strategy process it is expected that the technological areas most likely to have an impact on cost reduction, thereby furthering the possibility of projects being carried out, are simple wells and platforms as well as new concepts for pipelines. In addition to this, it is expected that production from oil fields can be increased through technologies improving water injection. A large part of these technologies is known today, but they are yet to be tested in the conditions present in the Danish part of the North Sea before they can be applied on a larger scale.

Cooperation between industry and research institutions
The Centre for Oil and Gas – DTU was established by the Technical University of Denmark (DTU) and Maersk Oil and Gas, which is the operator for DUC. The center is meant to contribute to a common effort between the Danish government and the Danish oil and gas industry to develop a long-term strategy for optimizing oil and gas recovery from the Danish part of the North Sea on a commercial basis. The center is the partnership between five of Denmark’s leading research institutions: Technical University of Denmark, University of Copenhagen, Aarhus University, Aalborg University and GEUS. For now, the center is funded by the partners in the DUC.

The center has made a series of suggestions to utilize the competencies in the center. These suggestions include:

- Stimulating an environment for innovation that will generate ideas and mature knowledge and technologies towards application in cooperation between operators, subcontractors and universities.
- Strengthening a coherent and international research and education environment in Denmark.
- Developing and presenting overall hypotheses for how new research and technology may contribute to increased oil and gas production in the Danish part of the North Sea.
- Cooperation with operators to identify barriers to large scale testing of new technologies, as well as identifying mechanisms whereby subcontractors and operators may reduce cost and risks incurred in relation to demonstrating technologies in offshore fields.

The assessment is that the center can contribute to further generation of ideas and maturing new technologies, as well as support the cooperation between industry and research institutions. Other research institutions in the North Sea area, engaged in subjects relevant to Danish reservoir types, can also be part of such an effort.

RECOMMENDATION

Recommendation B: developing and facilitating new technologies

To support and focus the development and application of new technologies, it is recommended to:

B.1. examine the possibilities for facilitating field-testing of new technologies through reducing technical and economic risks. The possibilities are suggested to be elucidated through cooperation between the industry, the research institutions and the relevant authorities.

B.2. to emphasize the challenges related to the transfer of technologies from research institutions to commercial use. By defining and selecting research projects, and during the project, emphasis should be placed on clarifying obstacles to commercial use. This can happen in a partnership between research institutions and the industry.

Recommendation C: Utilizing the research center

The participants in the strategy process all accept the recommendations made by the center, and thereby recommend that:

C.1. emphasis is placed on the development of new technologies and methods such as simple wells and new concepts for pipelines as well as techniques for improved water injection. Developments in these areas are important examples of research with a large potential for increasing production. Companies, research institutions and suppliers should focus on development within the above-mentioned areas, which are expected to have the largest potential for cost reduction and increased production.

C.2. establishment of possibilities for participation by the remaining parts of the Danish oil and gas industry (other than the DUC members) in the work conducted by the research center.
An infrastructure has been established to enable production, processing and transportation of oil and gas from the North Sea. The infrastructure includes platforms with wells and processing facilities, where the production is separated into oil, gas and water. Furthermore, the infrastructure includes a large number of pipelines for transport between platforms and for transporting the produced oil and gas to shore. Onshore there is a gas treatment facility in Nybro and an oil terminal and a fractionation plant for oil in Fredericia.

Because of this, the close to 60 platforms and a few submerged installations in the North Sea are to a greater or lesser extend interdependent, see figure 5.

Production of oil and gas in the Danish part of the North Sea commenced in 1972. A significant share of the current production facilities and pipelines are aging, making them expensive to maintain. A functioning infrastructure is necessary to also make new smaller, discoveries commercially viable through utilizing capacity on existing facilities. Such discoveries will not be commercially viable without infrastructure, thus there is a risk of loss of the resources.

Methodology and conditions for modeling
An economic model has been used to analyze the potential for commercial production of oil and gas in the Danish North Sea, and for coordinating the renewal and renovation of existing infrastructure for production, processing and transport of oil and gas.

The economic model has been developed by consultants Strategic Decision Group (SDG). The model is designed to deliver a strategic analysis of the size of the potential in the Danish North Sea. The different strategic scenarios of the model include the interaction between infrastructure, cost and the potential from exploration, technological resources and ongoing production.

The analysis has focused on three different strategic scenarios. The three scenarios represent three different activity levels regarding, among other things, investments and exploration.

1. **Baseline scenario**
   This scenario represents the minimum level of activity and includes production of volumes producible based on decisions, which have already been made. No further major investments in infrastructure will be made.

2. **Projected activities scenario**
   This scenario reflects the activity level displayed by the industry for 2010-2014, and includes adding volumes from the completion of expected commercially viable developments.

3. **Growth scenario**
   In this scenario, a higher level of investments and higher exploration activity is assumed. The scenario includes increased investments for renewal of facilities and the added

For each of the scenarios, the model has attached a collective level of investment for the companies.

**Conditions and model input**
The calculations are, among other things, based on data from the account of geological and technological potential, see focus area 1 and 2. Furthermore, information on reserves and production profiles from known fields and identified discoveries have been included. Estimates for discoveries yet to be made have also been included. The total input for the analysis has been made in 2014/15.

The modeling has been carried out in first half 2015. The modeling has been made probabilistically, which means it is based on probability distributions, thereby mitigating uncertainties on a number of parameters such as oil price, gas price, geological uncertainties and cost. The modelling has not taken into account the possible starting point fiscal situation of the companies, like deficit and depreciation balance as of 1 January 2015. For each parameter sample spaces of low, medium and high values have been used. The results are therefore not to be interpreted as absolute values, but they indicate scales and expected statistical values. Because of this, the results should primarily be used to compare different scenarios and evaluate trends. Figure 12 shows the correlation between the basis for and results of the modeling.

![Figure 12: The model structure](Source: Data from the strategy process)
Sensitivity analyses have been modeled, including cost, the number of processing facilities etc. Limits to capacity on processing facilities have not been fully taken into account, which may be significant in the realization of actual projects.

The calculations have been based on a number of conditions regarding oil price, gas price, discount factor, inflation rate and cost. The model uses three different price time series for oil and gas, and assumes a continued exchange rate of 6.50 DKK/USD, see figure 13.

It is noted that the price and cost assumptions are based on primo 2015 levels, which are somewhat higher than current price levels. It should also be noted, that investment decisions in the North Sea are typically based on expectations for long term oil and gas prices at the individual investors.

The development of the oil and gas price is the most significant single parameter when assessing the scale of expected future production and the value generated from it. The model automatically adjusts capital cost in relation to the applied oil price in order to reflect the expected development in the market at high and low prices respectively.

In the model, the oil price in 2020 is assumed to be between 45 and 86 USD per barrel (2015 prices) which has been used as low and basis price scenario, respectively, see figure 13. This is based on projections from early 2015. The state assumes the oil price (May 2017) to be at about 72 USD in 2020. The state’s estimate for the oil price (May 2017) is a weighting of the forward prices and The International Energy Agency’s (IEA) long-term prognosis, World Energy Outlook, as per Denmark’s Convergence Programme 2015.

![Figure 13: Applied price scenarios (in 2015 prices) for oil and gas in the modeling](source: Wood Mackenzie Q2 2015)

In practice projects are sanctioned by companies on the basis of a number of criteria such as a positive present value, exposure, cash flow and economy. These criteria vary from company to company and are dependent on the global context they operate in.

The model is based on standard assumptions for tariffs for processing of production by third parties at production facilities, and the model assumes that projects with the highest present value will have the earliest possible start. No distinction has been made between the starting time for third party projects and projects with a uniform ownership structure.

**Results of the modeling**

The modeling has provided results for the potential for production of oil and gas in the three analyzed scenarios.

Sensitivity scenarios have been carried out for different oil prices, including a continued low price. The trends described between the basis scenario, the projected activities scenario and the growth scenario are also applicable at a continued low oil price. Estimated at an oil price of 45 USD per barrel the commercially viable potential in the projected activities and growth scenarios will be approximately 30 percent lower.

Of the total potential of 3.0 billion boe in figure 14 the modeling shows that about 0.9 billion boe will be produced in the basis scenario. In the projected activities scenario, where investments are made in the production of commercial volumes, production is increased to 1.4 billion boe. If the investments in renewal of infrastructure and development of marginal projects which are assumed in the growth scenario are carried out, production will increase by a further 0.3 billion boe up to 1.7 billion boe, see figure 14.

It should be noted that the modeling indicates that referring to the above, a potential of 10% may be present as a result of optimized use of the processing facilities, involving increased cooperation on the use of existing and new infrastructure.

![Figure 14: Estimated production potential in different scenarios](source: Data from the strategy process)
It is noted that some uncertainties are attached to the calculations. They are statistically expected values based on a number of modeling assumptions. The values should therefore primarily indicate scales and should be interpreted with caution.

The model can also be used for calculation of how changes in operation cost affect the production level. The calculations show, among other things, that a reduction of operating cost of about 10 percent only increases the total production by 3 percent. The reduction is primarily due to cheaper cost for maintaining infrastructure, which thereby has a longer lifetime. This means that a larger production not only requires a reduction of operating cost, but probably combined reductions in both investment and operating cost.

This conclusion should be seen in the light of the modeling not having identified economic benefits in reducing the number of processing facilities, for example as a result of the remaining production becoming more profitable due to falling maintenance cost.

Investments in infrastructure

The modeling of scenarios for the production potential and investments indicates that an assessment of the need for renovation and renewal of the individual facilities should be made with focus on the central parts of the infrastructure. This should create the best possible foundation for the continued optimization of the recovery of the remaining quantities of oil and gas in the subsoil.

Especially the Tyra field in the southern North Sea and the Siri field in the northern North Sea will require significant investments in renovation within a few years.

The Tyra field has been in production since 1984, and several of the facilities have exceeded their original design life. The seabed is sinking as a result of production of gas from the subsoil and the distance between the surface of the sea and the facilities have thus decreased. Besides, new knowledge of wave heights and effect has been collected via an extensive study cooperation with leading research institutions within the area. To be able to handle the safety risk which otherwise will increase year by year, renovation is required, if production from the field shall continue. Without renovation, the production from Tyra and affiliated fields will cease within a few years, and production of the remaining reserves will not be possible.

With an agreement between the Government and the license holders (on behalf of the DUC partners) of 23 March 2017, the foundation has been laid for a full reconstruction of the Tyra field’s facilities.

This investment will also involve a large increase of the recoverable quantities as this facility is the hub, primarily for gas processing.

Use of infrastructure - Third party access

Access to the existing infrastructure for third party is crucial for an optimum use and development of the Danish area. This is among other things due to the potential of new discoveries being estimated at 0.7 billion boe, see figure 10. The majority of these discoveries is characterized by being relatively small discoveries, with more than half being economically unviable to produce in the current conditions. However, 90 percent of the potential volume is found within 25 km from existing infrastructure. This is one of the reasons an optimum use of the processing facilities will increase the possibilities of commercial production.

The model analysis, initially assigned discoveries to the closest processing facility. In doing so, the model failed to take into account that significant resources could be lost due to sub-optimal utilization of the processing facilities.

As a result, an individual assessment of the assignment of discoveries to processing facilities was made to optimize the utilization of the infrastructure. This assessment has to some extent been based on confidential information.

The assessment has primarily been based on the following criteria:

- Physical distance
- The suitability of the processing facilities for the expected production (oil/gas)
- Expected economic lifetime of the facilities
- Other technical conditions such as properties of the prospects.

This individual assignment of discoveries indicates that production may be increased by about 10 percent.

The modeling thus indicates a need for flexibility in the infrastructure, in terms of capacity, exploitation and access. The sensitivity analysis show that the tariff-level has limited significance for the total production and value creation. Conversely, a faster maturing of prospects (that means shortening of the time from granted authorization to start of production), will mean that the value of the total production will be increased.

At the same time, it indicates that it might be prudent to focus on the natural areas that the Danish North Sea is divided into around the existing clusters of processing facilities. This might lead to a better utilization of production capacities and a longer lifetime for processing facilities. At the same time, there may be a reduction of investment cost for producing new discoveries. This indicates that increased cooperation on using existing and new infrastructure will be worthwhile.

This corresponds to the conclusions in the Wood report⁶ regarding Great Britain, where it is stated, among other things, that it is necessary to move away from singular optimization of individual facilities and instead focus on collective optimization of the infrastructure. This is also seen in Norway where the shelf is partitioned into areas, and in Great Britain, which aims to facilitate an

overall optimization of the infrastructure by looking at areas. This has been implemented by the Oil & Gas Authority in an effort\(^2\) to establish regional development schemes.

**Other circumstances regarding infrastructure**

A series of topics and circumstances have been raised during the strategy process which may influence how the optimal infrastructure and optimal framework conditions should be structured. A number of these are briefly described in the following sections.

**Energy efficiency, including electricity from ashore**

For several years the industry has made agreements with the minister for energy on action plans covering energy efficiency for offshore facilities for producing oil and gas, the latest from 2012-2014. The plans have covered temporarily limited periods. The purpose of the plans has been to conduct analyses of possible initiatives to promote energy efficiency and to carry out the chosen initiatives. From 2006-2014 the energy consumption, including flaring, has been reduced by 24 percent. The utilization of energy management principles in the daily operation as well as in new projects has been the main factor in developing more efficient solutions and a new way of thinking about energy consumption. It should be noted that the consumption of energy is not directly proportional to the size of production.

Based on data on energy consumption etc. for the individual facilities, an analysis of energy consumption in the different scenarios has been carried out. The analysis shows that, since the larger production in the growth scenario makes it economically viable to operate processing facilities for a longer period of time, it results in a higher total energy consumption than for both the basic scenario and the projected activities scenario, where the production of oil and gas from the North Sea is smaller.

During the lifetime, the consumption of fuel and flaring will account for about 5.5 percent, 4.5 percent and 5.7 percent of the expected potential for production in the basic scenario, the projected activities scenario and the growth scenario respectively. In the growth scenario gas volumes make up a relatively larger part of the total production potential in relation to the basic scenario and the projected activities scenario. The production of more gas will lead to relatively larger total energy consumption, as the bulk of the energy consumption on processing facilities is related to the processing of gas.

Energinet.dk has in 2015 made a preliminary analysis of the possibilities for electrifying a part of the processing facilities, so they can be supplied with electricity from ashore. The conclusion is that the consumption from renovating the Tyra facilities is in itself not large enough to make the project profitable. A total marketing of electricity to the North Sea of about twice the size is required before the project may be viable. If new information should arise, which might make electrification beneficial to society, the possibilities for doing so can be analyzed again in cooperation with the industry.

**Onshore-offshore processing**

In larger reconstructions of offshore facilities and installations it should be considered if it might be economically beneficial to place facilities onshore. Normally the costs of establishing and operating facilities are significantly higher offshore than onshore. It might, however, be necessary to install some parts of processing facilities offshore, even though the main facility is placed onshore.

In coming years, significant reconstructions will be carried out offshore. In these cases, the possibility for placing facilities onshore should be individually assessed.

**The oil pipeline to shore, upstream gas pipelines and tariffs etc.**

The infrastructure for transporting oil and natural gas to shore includes upstream gas pipelines and an oil pipeline. It is crucial that the operation of these pipelines is reliable and cost efficient.

In possible changes of ownership etc. these considerations must continue to be upheld. A closer clarification of the future framework for this is still unresolved, but it is pivotal to ensure clarity and predictability regarding the commercial terms and conditions for the users of the pipelines.

**ASSESSMENT**

There is a significant potential for further production from the Danish part of the North Sea, from further production from existing fields as well as from production of new discoveries. For this, an accessible infrastructure is a prerequisite. The existing infrastructure provides at the same time the possibility that smaller discoveries may also be commercially produced by using available capacity on existing facilities.

The most significant challenges are related to the extension of lifetime and to ensuring flexibility in capacity in expected changes of processing and transport facilities. It should be ensured that capacities to the widest possible extent are prepared for, or dimensioned under consideration for, the potential in the area. Therefore considerations in connection with changes should include the estimated total production from the area as well as existing or planned other capacity, whilst taking into account the economy and risk of the companies.

This will lead to a better utilization of production capacities on processing facilities, and thereby to a reduction of investment costs for producing new discoveries. Furthermore, a longer lifetime for processing facilities could lead to a longer production of reserves on fields in production, leading to a higher utilization of resources.

There is a need for increased cooperation on the use of existing and new infrastructure, and to ensure completion of new projects as well as producing the largest possible commercially viable potential. This should happen, among other things, by securing cooperation between different stakeholders, and by ensuring that agreements can be made on third party access on reasonable and predictable terms. This cooperation can be focused within some natural areas in the North Sea.

A more effective use of the oil and gas resources should be based on the area’s processing facilities, wherever possible to be used for production from all discoveries in the area. This is regardless of whether the license holders for individual discoveries are the owners of the facilities or not. Because

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\(^2\) Oil & Gas Authority Call to Action: Six months on, September 2015 point 2.2
of this, reconstrucțion or removal of producțion facilities should be coordinated, so that future production from the area is not lost. There is a need for close cooperation between the operators of the facilities and the licensees of the discoveries to ensure such an optimization.

RECOMMENDATION

Recommendation D: optimized shaping and utilization of the infrastructure

To design and utilize the infrastructure optimally in order to maximize the commercial production of oil and gas from the North Sea, it is recommended that when altering facilities, developing and starting new projects, considerations are made for the following principles and processes:

D.1 Within areas in the North Sea, the design and utilization of the infrastructure must be optimized to maximize the commercial production of oil and gas from the area by optimizing the assignment of discoveries to relevant infrastructure.

D.2 A forum for coordination will be established within Oil Gas Denmark with participation from all licensees with permits for exploration and production of hydrocarbon in an area, in order to ensure further area cooperation. Through regular dialogue the forum for coordination will support an increased degree of transparency on plans for future production from the area and opportunities for available capacity or possible needs for further capacity or prioritizing the use of existing capacity. The Danish Energy Authority will participate as an observer at the meetings.

D.3 The Danish Energy Agency will produce a clear framework for third party access, including, in cooperation with the industry, also guidance documents, possibly based on experiences from other countries.

A lower level of cost related to the production of oil and gas will support increased production from the North Sea. A reduction of cost may among other things contribute to increasing the exploration effort and increase the recovery rate from existing fields. It will be worthwhile to produce more of the remaining smaller deposits and the lifetime of existing fields may be extended, so that the oil and gas resources in the North Sea can be utilized in the best way possible to the benefit of society.

ASSESSMENT

The companies share a series of challenges in optimizing the production of oil and gas from the Danish part of the North Sea. As the area matures it becomes increasingly important that new installations, apart from meeting regulations on safety and the environment, are as cost-efficient as possible. This is true in particular for platforms designed to produce smaller discoveries, but also pipelaying and methods for decommissioning.

The companies in the sector are already engaged in bringing down the level of cost. The strategy process has, however, uncovered a demand for increased industry cooperation. There is a potential for lowering cost further through closer cooperation and standardization across companies.

By cooperating on developing joint solutions to common challenges through standardization and simplification, competencies from all companies can contribute, and through joint dialogue with the authorities, concepts and solutions can be adapted to Danish conditions and applicable regulation.

The effort to lower cost should especially be focused on the heaviest expenditure items, including drilling cost, cost for expansion, cost for removal of facilities (abandonment) and the running cost of operation and maintenance.

Decommissioning of facilities is yet to be carried out in the Danish area. The Danish Energy Authority has estimated the cost of decommissioning at about 41 billion DKK. Because of this, it would be wise to exchange experiences between companies on decommissioning activities with the purpose of lowering cost.

Such partnerships must take place within the boundaries set by competition law.

Cost could also be reduced by completing operations in sequence (campaigns) instead of separately. This is true for drilling of wells, the use of hotel platforms, for installation and decommissioning of facilities and for well maintenance. What these operations have in common, is that the startup-cost are high in relation to, e.g., lifting, transport and commissioning of drilling- and accommodation units. There may also be economies of scale and synergies to be gained by coordinating maintenance and transport further.

Today an extensive regulation of security and health in offshore oil and gas activities is in place. The activities in the North Sea are performed within the boundaries set by the subsoil act and the
offshore safety act. The offshore safety act contains both national regulation and implementation of European Union regulation.

In order to uncover the potential for removing especially cost increasing Danish special regulation for mobile and fixed offshore facilities, an analysis of the current regulation of mobile and fixed offshore facilities should be carried out. The purpose is to identify potential for simplification of regulation which is not compromising safety. The analysis should be based on a mandate agreed by a working group within the Offshore Safety Council, which consists of the parties and the Work Environment Authority.

RECOMMENDATION
Recommendation F: A common approach to the coming decommissioning of marginal projects

A partnership on the development of joint solutions to challenges through standardization and simplification should be established between companies in the Danish part of the North Sea. The development of concepts and solutions must be adapted to applicable regulation and should be based on close dialogue with the authorities.

To support a common development of standardized solutions, it is recommended that:

E.1 the industry cooperates on investigating the possibilities for developing specific solutions aimed at secure, flexible cost-efficient development of marginal projects in the form of increased standardization and simplification of, e.g., platform solutions, pipelaying and drilling concepts.

E.2 the operators establish a forum for sharing knowledge – possibly within Oil Gas Denmark – to increase the effort against common challenges and to share experiences on selected technical and safety related areas such as wells, marginal field developments and decommissioning.

Recommendation G: Joint conduct of activities

Cost may possibly be reduced by carrying out more activities and operations in sequence in so-called campaigns, instead of conducting them individually. This applies to, among other things, drilling of wells, the use of hotel platforms, installation and decommissioning of facilities and well maintenance.

To support joint execution of activities it is recommended that:

G.1 an operator forum is established in Oil Gas Denmark in which participating operators can discuss operational conditions and coordinate the need for in campaigns, to the extent it is appropriate, to cooperate on evaluating new time and resource saving well technologies for, e.g., well completion, well stimulation, multilateral wells etc.

G.2 the operators and the supplier industry in close dialogue with the authorities, possibly within Oil Gas Denmark, cooperate to reduce cost, and in doing so examine the possibility for more cost-efficient disposal and landfill of waste, including drill cuttings – with the least possible impact on the environment.

Recommendation H: Regulation of offshore facilities

The operators experience that the regulation of offshore oil and gas facilities in some areas is stricter than in other countries around the North Sea, including in relation to Danish implementation of the EU-regulation.

It is recommended that:

H.1 an analysis of substantial parts of the current requirements of fixed and mobile offshore facilities is carried out in order to identify simplification potential without compromising safety. The mapping is conducted in cooperation with the industry stakeholders.

H.2 the most basic regulation is translated into English and guidance to the regulation is developed in both Danish and English. This will help current and future operators and rig-owners in the Danish part of the North Sea meet the requirements of the offshore safety act.
The Danish oil and gas industry is high tech and employs highly trained specialists, engineers, specialized offshore skilled workers and unskilled workers. The requirements for technical abilities are usually high in the industry and the workforce is mobile across borders.

The industry has occasionally experienced that recruiting for the Danish oil and gas industry has been a challenge over recent years. This has resulted in wages going up and in some cases the cancellation of activities. The years of historically high oil prices and activity in the oil and gas industry in Denmark as well as globally have created an increasing demand for labor in all parts of the industry. Since the summer of 2014 oil prices have dropped significantly which has shifted the focus to the development in cost, and has, among other things, lead to layoffs and fewer new employment in the Danish part of the North Sea and globally. It is expected that the demand for qualified labor will increase immediately if oil prices go up and stabilize and/or the activity level rises.

In 2015 the industry has conducted a mapping of the workers in the industry and their educational background, positions and other characteristics relevant to recruiting. The survey included more or less 8,400 employees, equivalent to more than 50 percent of the estimated number of employees in the industry. Furthermore, a survey of the industry's image has been conducted, and the international experiences in recruitment initiatives in the other countries surrounding the North Sea have been examined.

The mapping has shown that the workforce in the oil and gas industry is characterized especially by its high level of education and the degree of foreigners among the employees. The work has also shown that occasionally, recruitment challenges have been experienced in all parts of the industry, including geology/geotechnics, engineering skills in construction, drilling and production as well as support. This is evident in the difficulties the companies have in recruiting staff for these positions and in the large share of foreigners. This indicates that occasionally it can be difficult to recruit within our national borders.

The challenges in recruiting often relate to the highly educated technical or scientific staff in the aforementioned disciplines and to skilled workers primarily employed in production.

This points to a structural problem with a scarcity of supply of relevant technical and scientific competencies.

The demand for labor in the future has been examined qualitatively in to different scenarios: A projected activities scenario, meaning a scenario where only decisions already made on investments are included, and a growth scenario, where activity increases as a result of increased investments. In the projected activities scenario, a brief significantly increasing demand related to the removal of infrastructure from 2025 will be replaced by a significant drop in demand as activity will become very low. In the growth scenario demand will increase by about 1,500 jobs moving towards 2030, and will remain constant hereafter as a result of retaining jobs in the industry. The analysis was made in 2015.

**ASSESSMENT**

The analysis identifies that occasionally there is a series of challenges in recruiting for the oil and gas industry. Such challenges may become a barrier to the utilization of the potential from increased activity. As a result, retaining and attracting the necessary competencies should remain a priority.

There is a need for increasing the supply of technical and scientific Masters of Science at all levels in Denmark, as the competition for these is increasing among industries. This is to secure the right competencies in the long term and must be seen in relation to the need for Danish companies to be competitive internationally on global talents.

Recruitment initiatives must in the short term support that Danish oil and gas companies are able to attract relevant competencies from abroad, and to make domestic workforce aware of the employment opportunities in the industry.

Recruitment initiatives with a longer perspective are intended to attract more young people to technical and scientific educations in order to increase the supply of potentially relevant workforce. For the industry, this can also include a series of activities to widen the knowledge of the industry and for its employment opportunities.

In addition to the recommended recruitment initiatives a number of other possibilities exist, which might result in better recruitment conditions for the oil and gas industry, but which are not included in the recommendations. This is because they are related to many different types of industry, making them very general in nature. For example, this is this case in the tax scheme for foreign researchers and highly paid employees. The researcher tax scheme is a framework condition relating to a number of industries dependent on highly specialized workforce in global competition, such as finance, the pharmaceutical industry and the oil and gas industry. The oil and gas industry has, among other things, highlighted the abrupt taxation transition when the scheme ends as inconvenient in projects stretching for longer periods of time. Furthermore, it has been discussed that the industry perceives the scheme as inflexible.
Recommendation I: increased cooperation between the oil and gas industry and relevant educational institutions

There is a need to direct attention to educations relevant for the offshore industry (oil/gas), and to involve the industry further in the organization of teaching at vocational educations and higher educations. On that background, it is recommended that:

I.1 vocational education institutions and offshore companies in relevant cities are encouraged to strengthen their cooperation. This could help in strengthening the image of the schools, creating a more offshore-directed specialization, while at the same time boosting the intake at offshore relevant educations. It could be considered to have the leading companies in the regions, within the specific subject areas, supply employees with the necessary technical knowledge to the schools, to guest-lecture the students.

I.2 a forum for dialogue is established between the oil and gas industry and the institutions for higher educations, which educate for the industry. This will ensure that students attain the relevant skills and competencies within oil and gas production. It is also recommended that the oil and gas industry apply for membership of relevant boards and committees at the relevant institutions.

Recommendation J: More focus on technical and scientific educations

There is a need to ensure a sufficient supply of young people with technical and scientific skills at all levels, not just in the oil and gas industry, but also in a series of research and production industries in Denmark. On that basis, it is recommended that:

J.1 A partnership is established focusing on facilitating the interest for technical and scientific educations among children and young people in primary school and secondary education institutions. The partnership will provide an overview of the relevant initiatives in this area, it will promote the sharing of knowledge on how to increase the number of applicants for technical and scientific educations, and it will provide inspiration for new initiatives contributing to solving the challenge of the shortage of technical and scientific labor. Representatives from public as well as private organizations can participate in the partnership, which will be anchored in a ministry and build on the government’s educational policy. How to provide e.g. STEM competencies (Science, Technology, Engineering & Math) may among other things be looked at in a future Technology Pact.

Recommendation K: Better knowledge of the oil and gas industry

One of the major challenges for the oil and gas industry is the students’ lack of knowledge of the industry and their lack of desire to work in it. On that background, it is recommended that:

K.1 the oil and gas industry is encouraged to examine the possibilities for students for obtaining voluntary internships in the industry. The internships can be short, aimed at students wanting an introduction to the industry, but also longer, for students attending higher educations. To follow up on this, the industry can improve the possibilities and conditions for internships, thereby securing greater knowledge of the industry and supporting a better practical education aimed at production in the Danish industry.

K.2 the oil and gas industry is encouraged to work diligently on an array of branding and communication activities aimed directly at relevant target audiences. Examples of this are campaigns, bilateral partnerships between the industry and schools/educational institutions, development of training materials for primary schools and secondary education institutions etc.

Recommendation L: Continued focus on attracting international workforce

The oil and gas industry is to a large degree dependent on recruiting from the international workforce to launch new initiatives. On that background, it is recommended that:

L.1 it remains in focus that Denmark has good framework conditions in the international recruitment of international workforce.
### Explanation of words and terms

<table>
<thead>
<tr>
<th>Words and terms</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantities present</td>
<td>Expressed in HCIIP/STOIIP/GIIP (HydroCarbons/Stock Tank Oil/Gas - Initially In Place) and is a term for the quantity of oil and gas originally present in the reservoir before production.</td>
</tr>
<tr>
<td>Oil equivalents (oe)</td>
<td>Gas can be converted to oe, thereby creating a comparable number for oil and gas. Boe = barrels of oil equivalents</td>
</tr>
<tr>
<td>Research potential</td>
<td>The research potential consists of the share of quantities present of hydrocarbon yet to be discovered. This quantity can be increased further by increasing exploration activities, which contribute increased knowledge.</td>
</tr>
<tr>
<td>Technological potential</td>
<td>The technological potential includes the additional quantities of hydrocarbon estimated to be producible through the development of new and improved technologies.</td>
</tr>
<tr>
<td>Potential from known fields</td>
<td>The potential consists of the quantity of oil and gas potentially producible from known oil and gas deposits using new technologies.</td>
</tr>
<tr>
<td>Risk-weighted quantities</td>
<td>The quantities present times the chance of discoveries results in a measure for the risk-weighted quantities.</td>
</tr>
<tr>
<td>Recovery rate</td>
<td>The rate indicates the share of quantities present expected to be producible.</td>
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<tr>
<td>Third party access</td>
<td>Third party access provides the owners of a discovery or field with access to processing or transport via an infrastructure owned by a different license holder.</td>
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<tr>
<td>Marginal projects</td>
<td>An investment in developing a new field or expanding an already producing field can be economically marginal at a given point in time. This means that the economy of the project is close to the investors demand for return on investment. The oil companies’ demands for return on investments vary from company to company.</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Includes facilities for production and transport of oil and gas, including production platforms, processing facilities, wells, pipelines etc.</td>
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<tr>
<td>Prospect</td>
<td>A prospect is a potential hydrocarbon accumulation, sufficiently well defined (possessing sufficient data) to be a target for drilling. The well may prove a hydrocarbon discovery.</td>
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<tr>
<td>Lead</td>
<td>A lead is a potential accumulation of hydrocarbon lacking data/evaluation to be well enough defined to be classified as a prospect.</td>
</tr>
<tr>
<td>“White areas”</td>
<td>The white areas are made up of areas where insufficient data coverage and no prospects or leads have been mapped, but where statistical analysis indicates that hydrocarbon could still be discovered.</td>
</tr>
<tr>
<td>Seismic analysis</td>
<td>Seismic is a geophysical methodology mapping the subsoil using sound waves.</td>
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</tbody>
</table>