

Evaluation of gas transport alternatives in the Barents Sea South



Introduction

This report contains an evaluation of future solutions for gas transport from the Barents Sea South. The evaluation is based on analyses and include observations and recommendations for the way forward.

BACKGROUND AND SCOPE

Gassco as the system operator is responsible for the further development of upstream gas pipeline network and associated processing plants with the objective to achieve holistic transport and processing solutions for the petroleum operations, according to the Petroleum Act (Petroleumsforskriften) 66A. The start-up of projects is mainly driven by the need for new solutions from users.

Gassco perform various work processes to handle the system responsibility, also known as the architect mandate. One example is carrying out area studies for transport needs for gas from several fields and discoveries in an area. The purpose of area studies is, among other things, to identify and map long-term capacity needs together with the potential for developing integrated gas transport and -processing solutions within defined areas on the Norwegian shelf.

In 2013 – 2014 Gassco, together with the petroleum industry, performed extensive work to evaluate the need for gas transport in the Barents Sea. The work evaluated needs for gas infrastructure and the profitability of different transport solutions with a basis in expected future gas resources in the Barents Sea.

During 2018, the need for an updated fact base and new evaluations of gas infrastructure solutions in the Barents Sea was gradually identified both for fields in operation and fields under development and for discoveries that are being evaluated. The area study conducted in 2018 – 2019 has been carried out in close cooperation with operators and licensees in the Barents Sea, the Norwegian Petroleum Directorate and other relevant stakeholders associated with petroleum operations in the north.

To ensure effective resource management and further development of the Barents Sea, updated information about gas transport needs will be important. The geographic area for the study does not include the resource potential from unopened areas, like the Barents Sea North. When we in this report refer to the Barents Sea, it is synonymous to the Barents Sea South.

SUMMARY

Gassco has performed an area study, based on resource data from operators in the Barents Sea and from the Petroleum Directorate, to assess how to further develop the gas infrastructure from the area. Since the previous work was done five years ago, the gas resources in the Barents Sea have matured. In particular, many field development projects have matured further, investment decisions have been made for one field, and it is clearer which gas transport needs these will have. These are fields with both oil and gas (associated gas).

Based on the analyses in this area study, we can envision three possible development scenarios for gas transport in the Barents Sea towards 2030:

- Today's LNG capacity at Melkøya is maintained and fields with a need for a gas export solution enter into capacity agreements with licensees in Snøhvit Unit and the production period is extended.
- The LNG capacity at Melkøya is increased somewhat to meet the need for gas export from today's fields and discoveries. Opportunities for inclusion of unproven resources will be limited.
- Investments in new gas treatment capacity for processing and export beyond the existing LNG plant at Melkøya to accommodate for proven and unproven gas resources. Alternatives for new gas transport capacity from the Barents Sea South can be different pipeline alternatives or new LNG capacity.

The results of the work are summarized below in a set of observations related to the development of the gas resources in the Barents Sea and the need for gas transport and -handling capacity in the Barents Sea South:

1. The Barents Sea is expected to have significant remaining petroleum resources. Several fields are in operation and under development and new discoveries are being matured towards investment decisions.
2. The capacity at the Melkøya LNG plant is planned to be fully utilized over the next 20 years with the gas resources from the Snøhvit field alone.
3. There is a need for gas transport capacity for fields in operation and fields under development before capacity is available at the Melkøya LNG plant.
4. Associated gas in oil fields have historically been an important driver for the development of the gas infrastructure on the Norwegian shelf, and the same seems to apply for the Barents Sea.
5. Several alternatives for gas transport have been evaluated: LNG and pipelines appears the most relevant.
6. Increased capacity enables increased value creation. Accommodating gas capacity at new fields beyond the field's need and potential accelerated gas production from existing field will further increase value creation.
7. Early increase in capacity will enable faster development of proven gas resources, and at the same time accommodate for more optimal production of oil with associated gas.
8. Larger increase in capacity requires more than gas resources in fields and discoveries to be profitable. At the same time, such a solution provides an option value that must be taken into account for additional resources from fields in operation, fields under development and from new discoveries.

9. Simpler solutions for gas transport and technology development will contribute to reducing costs of development and operations.
10. Coordination across production licenses is necessary to accommodate for an holistic development of the gas infrastructure in the Barents Sea.

In the coming years, more decisions will be made both for fields in operation and for discoveries under development which will shape the future development of the Barents Sea as a petroleum province. To ensure good decisions related to these projects, and for the general development of the Barents Sea, the recommendation is to continue this work as follows:

- Further studies to mature projects for increased gas transport capacity, both LNG and pipeline solutions.
- Current and future field development projects should include solutions accommodating for holistic and future processing and transport needs for gas.

The Barents Sea as a petroleum province

INTRODUCTION

The Barents Sea is a growing petroleum province on the Norwegian shelf, where fields like Snøhvit, Goliat and Johan Castberg provide a foundation for significant production and value creation the coming decades. The production in the Barents Sea has gradually increased since the start of the Snøhvit field. The Snøhvit field started in 2007 and consists of subsea installations and an onshore facility for processing of the gas to Liquefied Natural Gas (LNG) at Melkøya. The Goliat field started in 2016 and is mainly an oil field with associated gas. A future export solution for the gas in this field is not yet clear, but a gas export solution is necessary to better utilize the resources in the field. Historic production per year is shown in Figure 1.

Historical production in the Barents Sea
MSm³ oil equivalents per year

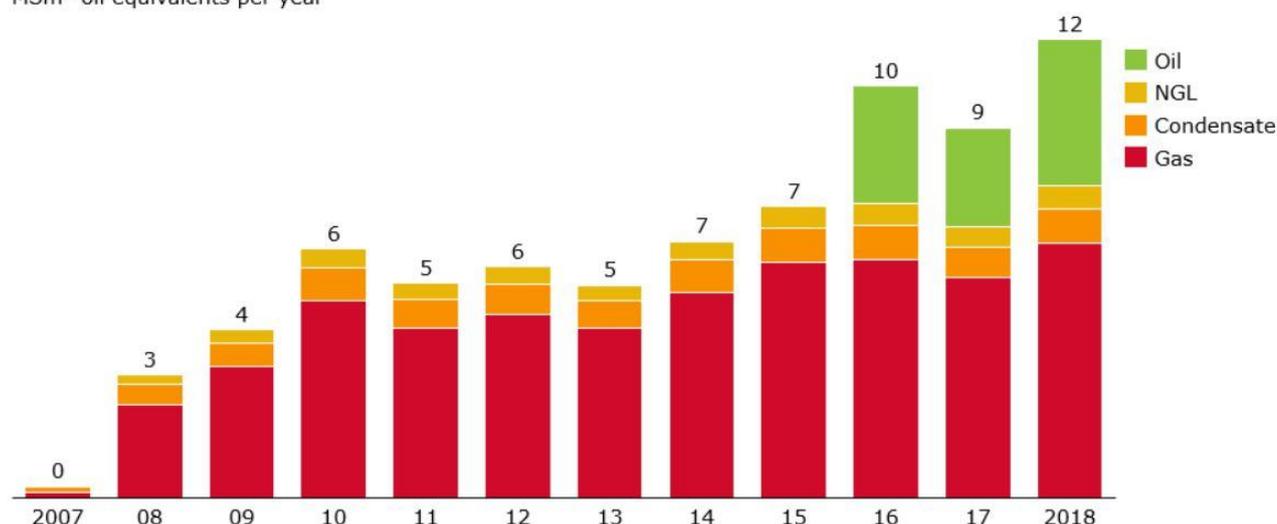


Figure 1

The Norwegian Petroleum Directorate has estimated that there are significant gas resources in the Barents Sea. According to the Petroleum Directorate's resource report from 2018, ~37% of the total unproven gas resources are expected to be in the Barents Sea South, while ~29% of the total unproven gas resources are expected to be in the Barents Sea North. To realize the full value creation potential from oil and gas in the Barents Sea, it is therefore important to find good gas infrastructure solutions within and out of the area.

In 2013, Gassco established the Barents Sea Gas Infrastructure (BSGI) forum, where stakeholders jointly evaluated the opportunities for cost efficient gas infrastructure in the Barents Sea. The work gathered 26 oil and gas companies, authorities, research centers and special interest organizations. They concluded that new discoveries would be required to lift new gas infrastructure, that the resource base indicated that such discoveries was expected, and that a coordination between production licenses would be critical to realize the resource base. The results of this work were presented in 2014. The task at the time was to assess whether Snøhvit together with the exploration prospects could form the basis for new gas infrastructure.

In the five coming years, several field development projects have been matured in the Barents Sea South and it is more clear which gas transport needs these have. Examples of such projects are Goliat, Johan Castberg, Alke, Wisting, Alta and Gohta.

In 2018, Gassco established a cooperation with the operators of production licenses in the Barents Sea, authorities and special interest organizations to conduct an area study. In the study, the above-mentioned fields and discoveries form the basis for possible gas transport alternatives, together with the resource potential in unproven gas resources. The geographic area for the study is limited to the Barents Sea South. Awarded licenses in the Barents Sea together with field and discoveries under development are shown in Figure 2.

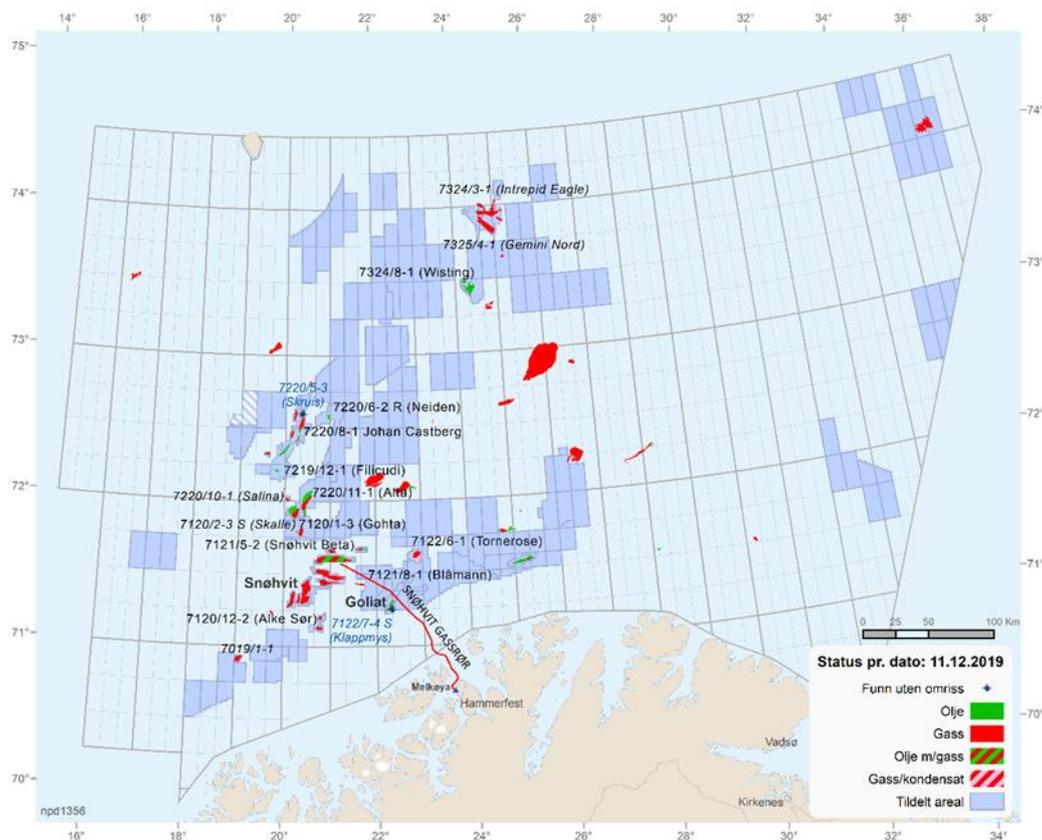


Figure 2

All parties have contributed constructively to the work to create the best possible basis for making good decisions about the development of the Barents Sea:

- Operators have shared their estimates of proven recoverable gas resources.
- The Petroleum Directorate have updated their resource estimates for unproven gas resources that form the basis for the resource scenarios Gassco have based their work on.
- Gassco collaborated with stakeholders to identify different gas transport alternatives for proven gas resources and bigger solutions which also include capacity for unproven gas resources.

CURRENT SITUATION

The petroleum production in the Barents Sea has in the first six months of 2019 been at around 26.700 Sm³ oil equivalents (OE) per day, with Snøhvit and Goliat as the two fields in operation. Snøhvit is currently the only gas exporting field in the Barents Sea with around 20 MSm³ gas production per day and about 200 bn. Sm³ in remaining gas reserves. The gas produced from Goliat is currently reinjected into the reservoir.

Several ongoing field development projects will contribute to further develop the Barents Sea as a petroleum province and will require gas transport solutions:

- Snøhvit: Further development of the field (drilling new wells, onshore and offshore compression) to enable plateau production towards 2040. Decision to Concretize (BOK) has been made and work is now done to develop the basis for Decision to Continue (BOV). Evaluation of different CO₂ reducing measures is taking place in parallel.
- Goliat: Work is in progress to present an updated plan in Q1 2020 for gas offtake according to the terms for approval of the plan for development and operation (PDO) in 2009.
- Johan Castberg: The field is under development with planned production start in 2022. The licensees will, based on updated source data, evaluate the chosen production strategy and prepare a plan for further development of the resource potential according to the terms of the PDO.
- Alke: Assessment of different development solutions is in progress. After Decision to Concretize (BOK), the solution was a joint development of Alke and gas at Goliat, and development of a new LNG facility close to Melkøya
- Wisting: Evaluation of alternative development concepts and solutions for production and offtake of gas is in progress. Decision to Concretize (BOK) has been made and work is currently carried out to develop the basis for Decision to Continue (BOV).
- Alta/Gohta: Work with development solutions is in progress. Decision to Concretize (BOK) has not been made yet.

The below figure shows the timeline for when PDO is planned for the different projects.

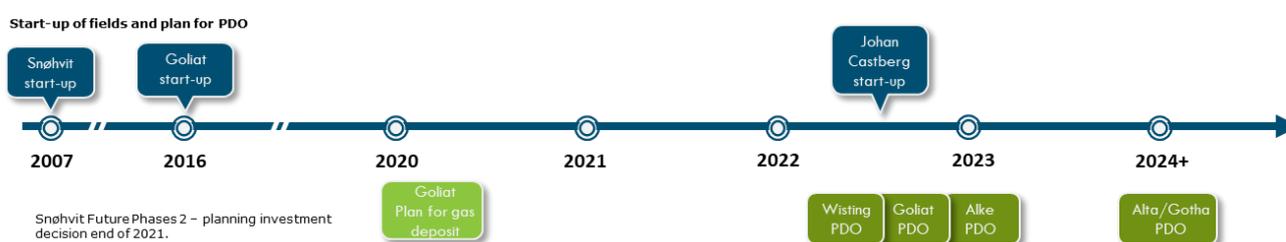


Figure 3

Oil production is the main business driver for several of these projects. That is not the case for Alke, which is a gas discovery under development, and Snøhvit which is a gas field under further development. A gas transport solution can often be necessary to ensure optimal production of petroleum resources as a whole from oil fields, both to maximize the value of the oil resources and to realize the additional value of the gas. Historically, coordinated development of fields and gas infrastructure has contributed to increased value creation on the Norwegian continental shelf (NCS).

With this portfolio of projects, it is possible to build a good basis for the long-term development of the gas resources in the Barents Sea. Good resource management should be based on holistic assessments of solutions and production strategies for the individual projects. Holistic assessments imply that area assessments and resource and value potential in discoveries and unproven resources must be included in analyses and seen in relation to decisions on individual fields.

Existing gas infrastructure in the Barents Sea is the gas pipelines from the Snøhvit field to shore with associated processing and export capacity at the LNG facility on Melkøya. The capacity at Melkøya will be fully utilized the coming 20 years based on expected Snøhvit production.

In the Barents Sea there is a large variety of stakeholders with a total of 23 companies as licensees. To ensure good decisions for the development of petroleum resources in the area, cooperation and sufficient coordination is necessary to get consistent and holistic decisions for the different value chains from field to market.

PROVEN RESOURCES

The license operators in the Barents Sea have reported a resource estimate for gas in fields (RC1-5), discoveries (RC4-7) and prospects (RC8). The reported gas resources are mainly located in the south-western part of the Barents Sea. The definition of the different resource categories is shown in Figure 4.

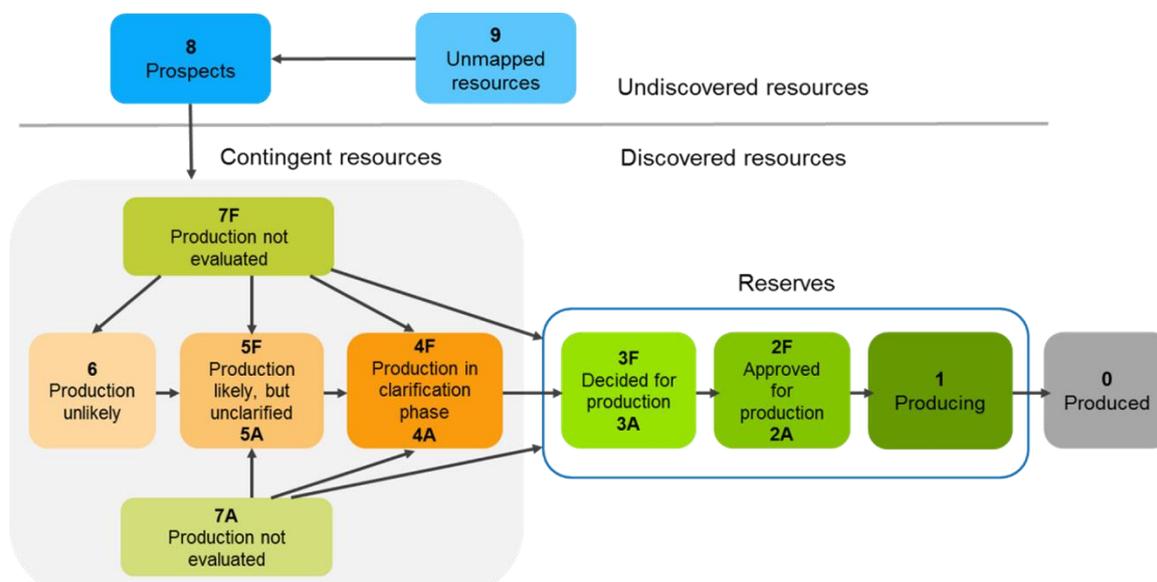


Figure 4

Table 1 shows fields and discoveries reported to Gassco by the license operators.

	Field/find	Resource category
Goliat area	Goliat (gas)	RC 4
	7120/12-2 Alke	RC 5
	7019/1-1	RC 6
Johan Castberg area	Johan Castberg (gas)	RC 7
	7220/7-2 S Skavl	RC 5
	7219/9-2 Kayak	RC 7
	7220/5-3 Skruis	RC 7
	7220/4-1 Kramsnø	RC 5
	7219/8-2 IskrySTALL	RC 5
Alta/Gohta area	7220/11-1 Alta	RC 5
	7120/1-3 Gohta	RC 5
	7220/6-2 R Neiden	RC 7
	7120/2-3 S Skalle	RC 6

	7219/12-1 Filicudi	RC 7
	7220/10-1 Salina	RC 6
Wisting area	7324/8-1 Wisting	RC 5
	7324/3-1 Intrepid Eagle	RC 6
	7325/4-1 Gemini Nord	RC 6
Snøhvit area	7122/61 Tornerose	RC 4
	7121/5-2 Snøhvit Beta	RC 5

Table 1

Reported gas resources beyond the Snøhvit field are approximately 104 bn. Sm³, illustrated in Figure 5. The reported resources contain gas from fields in operation, fields under development and discoveries being assessed. In addition, gas resources from discoveries the license operator has currently classified as RC6, e.g., due to lack of gas infrastructure, have also been reported. The resources of Snøhvit are not included in the figure.

Reported gas resources from license operators

Bn. Sm³

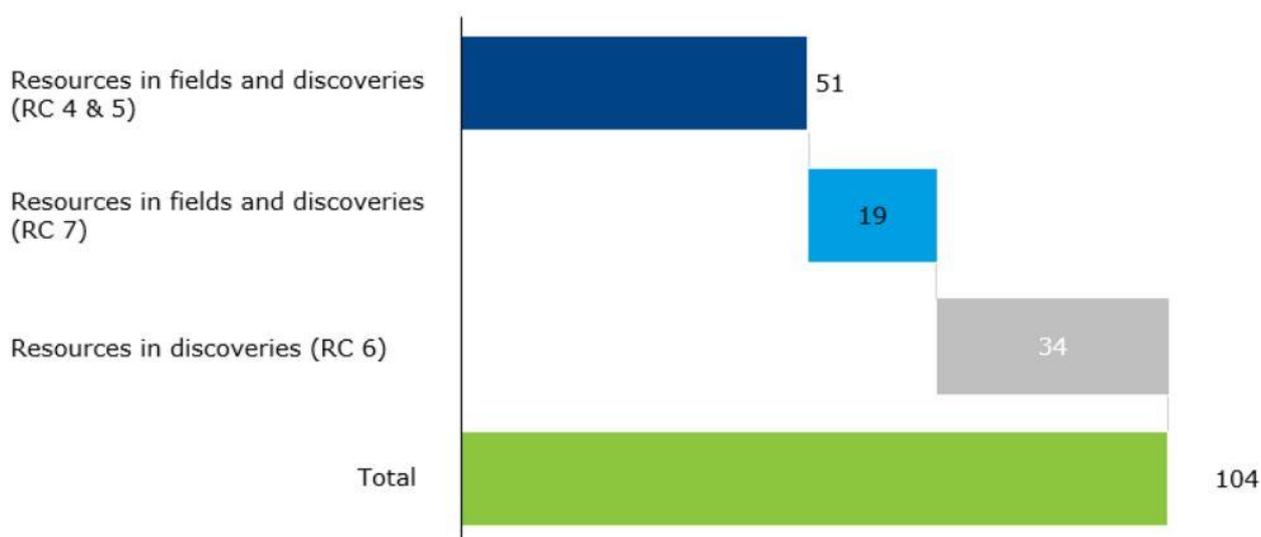


Figure 5

In addition to the reported resources, several gas discoveries in the Barents Sea have been relinquished, e.g. due to lack of nearby infrastructure and export capacity. Further development of the infrastructure in the Barents Sea will contribute to making some of these discoveries financially profitable. In addition, the incentives to explore for gas in these areas will be strengthened.

EXISTING GAS TRANSPORT CAPACITY AND NEED FOR NEW CAPACITY

Figure 6 shows reported gas profiles from fields in operation and discoveries under development. The capacity level in the figure shows the rich gas capacity at the Melkøya LNG facility, which is 7.4 bn. Sm³/year (4,3 MTPA) before processing.

Capacity and profiles, years 2026 - 2050

Bn. Sm³ per year



Figure 6

The capacity at the Melkøya LNG facility is currently not sufficient to cover the registered gas transport need from the operators. This implies that if the gas export capacity does not increase, fields and discoveries need to delay start-up, delay gas export, reinject the gas permanently or make capacity agreements with licensees at the Snøhvit Unit about using some of the capacity of the Melkøya LNG facility. The gas production at the Snøhvit field would in such cases be somewhat delayed.

In addition to the gas transport need that has been reported, there will be additional production from future discoveries.

UNPROVEN RESOURCES

The Petroleum Directorate expects the unproven resources on the Norwegian shelf to be about 4 bn. Sm³ OE, where the largest share is in the Barents Sea South and North. According to the Oil Directorate's resource report from 2018, 37% of unproven gas resources on the Norwegian shelf is expected to be found in the Barents Sea South.

Figure 7 shows the potential of different areas with an uncertainty span (per 12.31.2018). The numbers highlighted on the graphs state the expected value in the individual area and the range shown in the pillars are from P95 to P05, according to estimate. The uncertainty and the potential are larger in the Barents Sea than in the North Sea and the Norwegian Sea, among other things because the number of wells is still considerably lower, and consequently the knowledge about the area is more limited.

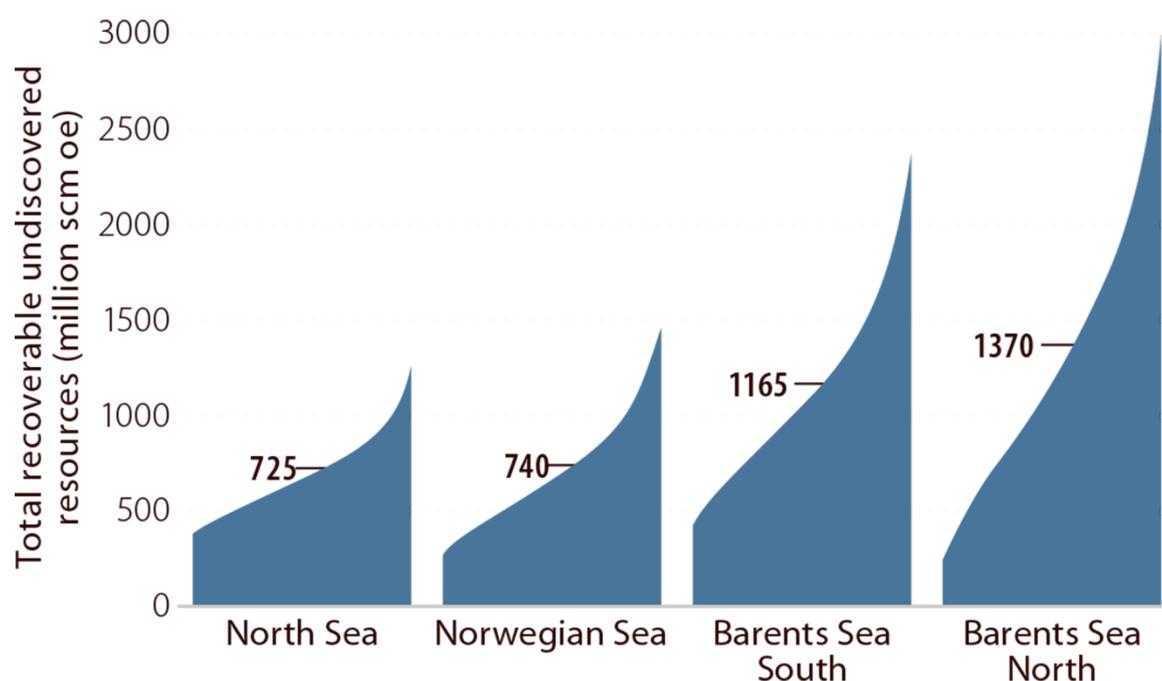


Figure 7

The opportunity to make significant discoveries is higher in less explored areas. Figure 8 shows the number of exploration wells and resource growth in the three areas from 2011 until the end of 2018. In this period, 60 wells were drilled in the Barents Sea with added volumes of a little more than 300 MSm³ OE. As a comparison, the more than 160 wells in the North Sea in the same period have added 240 MSm³ OE. The figure shows that discoveries are made in all areas and that the likelihood of discovery is high. At the same time, it shows that the largest recent discoveries have been made in the Barents Sea, with the highest average discovery size and with 7324/8-1 Wisting as the largest discovery in the period (70 MSm³ oil equivalents). Based on experience, similar explorations activity across the different areas is expected to provide comparable future development.

Resource increase curves per sea area, years 2011 - 2018

Cumulative latency curves, MSm³ OE

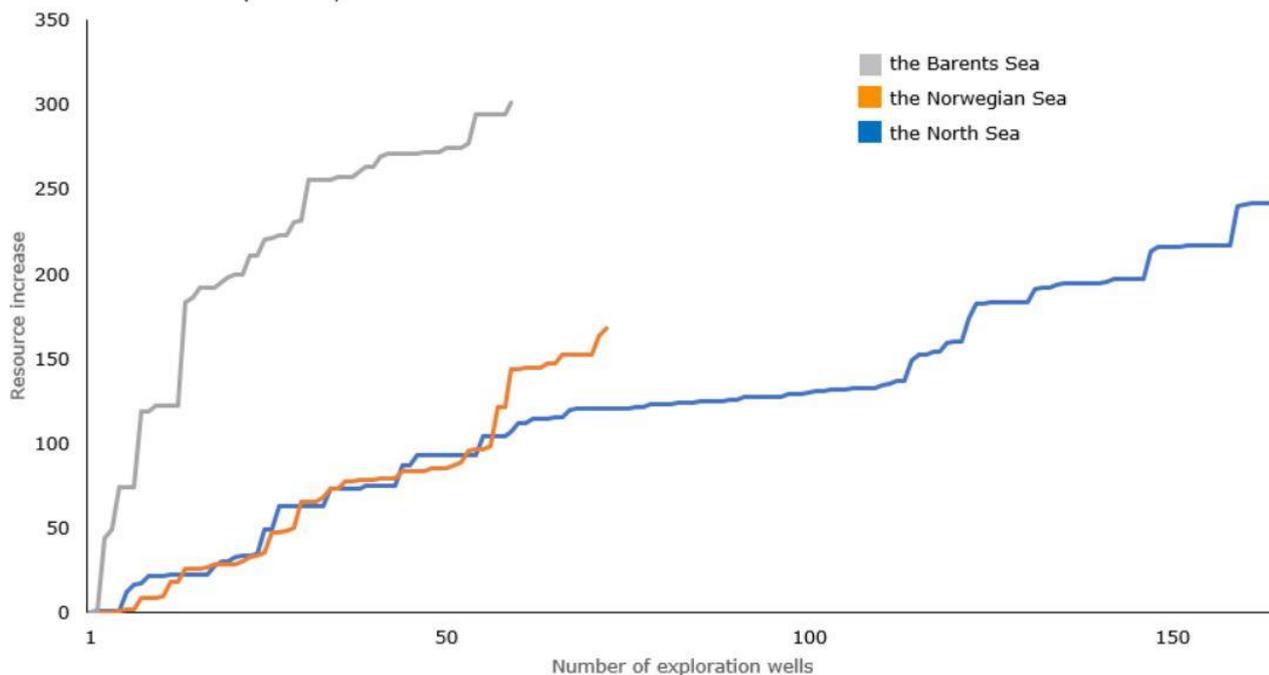


Figure 8

The Barents Sea South and North constitutes more than 60% of the total unproven resources on the Norwegian shelf. Figure 9 shows expected share of liquid, gas and total unproven resources in the different areas where the Barents Sea contributes with 37% of the total share of gas. This constitutes approximately 685 bn. Sm³ of gas.

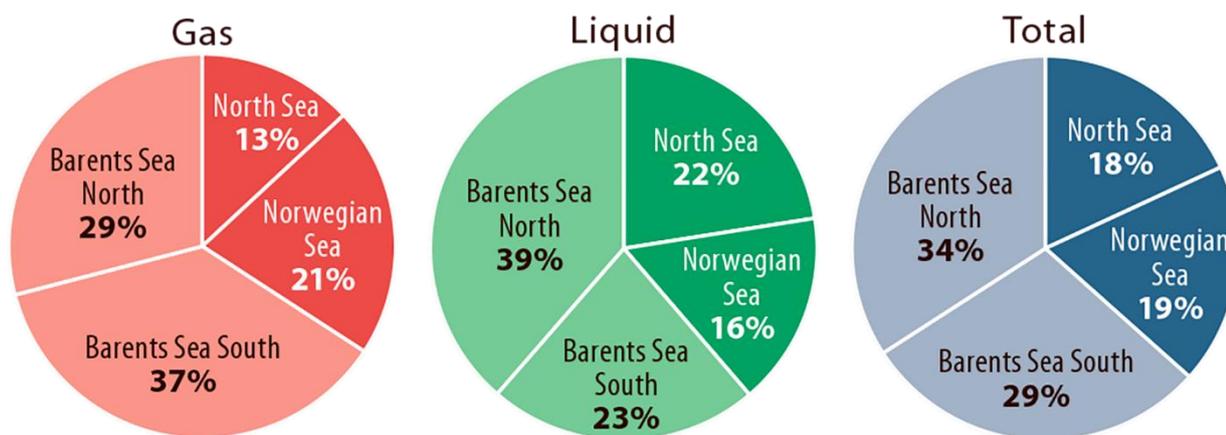


Figure 9

Overall, we now have a situation in the Barents Sea where already the ongoing field development projects create a gas transport need exceeding existing capacity, and in addition, we expect significant gas resources in the area beyond what has been proven. In the next chapters, we look at the opportunities for further developing the gas infrastructure in the Barents Sea and the assessment of gas transport alternatives.

Gas transport alternatives

Gassco conducted a separate study of gas transport options from the Barents Sea in 2018-2019 on the basis of a request from a group of licensees with interests in the Barents Sea. Several of these gas transport options are included in this area study.

Alternatives for using and / or exporting natural gas from the Barents Sea have been identified and assessed. This chapter provides an overall description of some of the alternatives.

MAIN ALTERNATIVES FOR GAS TRANSPORT

Several options for gas transport have been considered from the Barents Sea. The most relevant are:

- Increased capacity at the Melkøya LNG plant (HICU)
- Developing a new LNG plant
- Developing a traditional processing plant (DPCU) at Melkøya with transport via a new gas pipeline to the existing transport system in the Norwegian Sea
- Developing a simpler processing plant and transport via a new gas pipeline (single phase / multiphase) to existing transport system in the Norwegian Sea

Below is a brief description of the alternatives, with opportunities and challenges associated with each of them.

Increased capacity at the Melkøya LNG plant (HICU)

As part of the Snøhvit Future Phase 2 (SFP2) project, the operator Equinor in 2018 conducted a study in which they considered increasing the capacity of Melkøya LNG (Hammerfest Increased Capacity Unit - HICU). The purpose of the increased capacity was to accelerate production of the gas resources in Snøhvit.

HICU consist of a small LNG-train which runs in parallel with the existing train at the Melkøya LNG plant. Two alternative production capacities for HICU, 7.5 MSm³ / d (1.5 MTPA) and 4.5 MSm³ / d (0.9 MTPA), have been assessed.

The HICU plant on which the economic analyzes are based on, covers the LNG train including the entry arrangement and CO₂ removal and deposition systems. It is assumed that existing utility systems and power supplies have sufficient capacity. This gives clear limitations to the capacity increase, where the relevant limits must be considered in further work.

Two alternative locations for HICU have been considered: On the inside of the fence of the existing plant and on the outside of the fence on existing plant to the east.

Developing a new LNG plant

As part of the Alke field development project, the operator Vår Energi has conducted a feasibility study for an independent LNG plant in the Hammerfest area. The concept consists of an independent plant with a capacity of 3 MSm³ / d (0.7 MTPA) or 5 MSm³ / d (1.2 MTPA). The purpose of the plant is to receive and process gas from the Alke and Goliat fields for which Vår Energi is the operator.

The design of the LNG plant includes the removal of CO₂ and maximum injection of LPG into the LNG to avoid the need for a separate storage system for LPG. The plant also includes export facilities for LNG and condensate to vessels. No technology qualification is required in the design and construction of this LNG plant.

Developing a traditional processing plant on Melkøya

Equinor has performed a study of a traditional processing plant (Dew Point Control Unit - DPCU) located at Melkøya and integrated with the existing LNG plant. The study is based on a previous study conducted by Equinor in 2012 on a separate plant with a capacity of 20 MSm³/d. Three capacity levels have been assessed; 10 MSm³/d, 20 MSm³/d and 10 MSm³/d pre-invested to facilitate an increase to 20 MSm³/d if needed. The capacity of the latter option can be even further increased.

The purpose of the DPCU plant is to treat rich gas in order to meet the transport specification for pipelines and receiving facilities. A more detailed description of the pipeline is included in the chapter "Transport via new gas pipeline to the existing transport system in the Norwegian Sea".

Removed CO₂ will be re-injected via the existing CO₂ storage solution. As for HICU, the DPCU plant will partly use existing utility systems at the Melkøya LNG plant. This particularly applies for the condensate handling system. The power supply is assumed in this study, as for HICU, to be taken from the existing power grids. Most utility systems for a DPCU plant must be installed independently, but there are some possibilities for integration with existing utility systems where these must then be upgraded.

Planned location of the DPCU plant is outside the fence on the east side of the LNG plant at Melkøya.

Developing a simpler processing plant

Gassco has also conducted a study to assess the possibilities and costs associated with building a simpler processing / drying plant (including compression) that is not integrated with the existing Melkøya LNG plant. The purpose of the study is to identify the minimum required processing in order to transport the gas via pipeline to existing infrastructure. For example, if the gas is exported via Åsgard Transport with further processing at Kårstø, the need for processing in a new processing plant will be limited.

In the study, a set of gas qualities were assessed based on reports from fields and discoveries in the Barents Sea. In the assessments, the need for processing is mapped to meet

specifications in existing infrastructure. Different capacities have been used, such as 10 MSm³/d, 20 MSm³/d and larger capacities.

The need varies between the different gas qualities. On the one extreme, there is a need for full fractionation and export of the liquid products, while on the other extreme it is sufficient to dry the gas, remove CO₂ and then compress.

The alternative included in the economical assessments is designed with a capacity of 10 MSm³/d and with no need for export of liquid components from the process. Further work will be required to verify this solution.

A more detailed description of the pipeline is included in the chapter below.

Transport via new gas pipeline to the existing transport system in the Norwegian Sea

Gassco has carried out a study of a new pipeline (32") for transporting rich gas (single phase) from Melkøya to the existing transport system in the Norwegian Sea. This will be a necessary part of the value chain for both a traditional processing plant (DPCU) and a simpler processing plant. The pipeline is assumed to be connected to an existing gas pipeline in the Norwegian Sea. Technical assessments and cost estimates are covered in the study.

The study assessed connection to both Åsgard Transport with processing at Kårstø and connection to Polarled with processing at Nyhamna. The starting point for the cost estimate below is the connection to Åsgard Transport. Estimated length of pipeline from Melkøya to Åsgard Transport is ~1000 km and to Polarled ~830 km. Both receiving terminals (Kårstø and Nyhamna) are assumed to have available capacity, and no technical limitations have been identified. The main difference between the plants is the degree of liquid recovery.

The different fields and discoveries may have different needs for gas processing before further pipeline transport. Gas processing can be developed over time and can be done at the individual field installation or in a common solution onshore. Technology development or increased field processing may be required for the solution to be robust for the relevant fields and discoveries in the Barents Sea.

The capacity of a pipeline depends on both inlet and outlet pressure. In a 32" pipeline from the Hammerfest area with a capacity of 10 MSm³/d connected to Åsgard Transport, an inlet pressure of about 180 barg is required. Similarly, about 220 barg would be required for a capacity of 20 MSm³/d. Alternatively, the diameter of the pipeline can be increased to allow for lower pressure early and higher capacity in the future.

The basic assumption for a rich gas pipeline from the Barents Sea is that the gas is processed to meet the specifications of existing gas infrastructure. Another alternative could be to process the gas to a lesser extent and transport the gas as rich gas / multiphase in a pipeline from the Barents Sea. In such a case, the gas can come from a simpler onshore processing plant or directly from the platforms. This may require technology qualification, as one currently has no operational experience with multi-phase transport over such long distances. However, such a solution will potentially imply significant cost reductions and the possibility should be explored further. Furthermore, this type of gas transport may require more liquid processing capacity on existing processing plants.

OTHER TRANSPORT ALTERNATIVES

A number of other gas transport solutions in and from the Barents Sea have been considered in addition to the main alternatives described above. These are:

- Floating LNG (FLNG)
- Compressed natural gas (CNG)
- Offshore facility as a hub
- Subsea facility as a hub

The main challenges of these alternatives for gas transport from the Barents Sea are high cost and immature concepts.

COSTS OF GAS TRANSPORT ALTERNATIVES

The HICU and DPCU alternatives are based on studies conducted by Equinor, a new LNG facility is based on studies conducted by Vår Energi, while the alternative with simpler processing and a new gas pipeline to the existing transport system has been studied by Gassco. The costs are based on unclassified estimates and are summarized in Table 2.

Capacities and costs of various transportation alternatives

Gas transportation alternatives	Capacity	CAPEX	OPEX
	M ³ /day	MNOK ₁₉	MNOK ₁₉ /year
Capacity increase at Melkøya LNG plant (HICU)	4.5	5 900	245
	7.5	9 050	395
New LNG plant	3	6 365	196
	5	8 800	273
Traditional processing plant (DPCU) at Melkøya	10	15 400	254
	20	23 000	462
New gas pipeline	10-20	12 500	125
Simpler processing plant	10	4 219	254
	20	7 594	440

Table 2

CHARACTERISTICS OF THE GAS TRANSPORTATION ALTERNATIVES

Gas transport alternatives have different characteristics in terms of market access and facilitation of further development of petroleum resources in the Barents Sea South.

For the LNG and pipeline alternatives, the differences are partly about which real options each alternative provides:

- LNG offers greater geographical flexibility in the shipment of gas to the market and thus a potential market flexibility premium. In addition, LNG can facilitate deliveries to the market for small-scale LNG that is developing in Europe as use of LNG is increasing.
- Pipeline alternatives have a lower marginal cost for increased capacity and can thus be more easily arranged so that the upside volumes can be phased in earlier than for the LNG alternatives. In addition, it is possible to invest in stepwise increased capacity in gas drying and compression. Pipeline solutions with increased capacity can thus contribute to increased incentive for exploration for new gas, as well as being a solution for future discoveries and / or being an alternative transport option for fields in operation. The gas will also enter existing infrastructure at a time when capacity will become available and existing transport and processing capacity can be used efficiently.

All the alternatives will contribute to significant ripple effects from the petroleum industry for the northern areas, both in the development and operations phases. The alternatives will primarily be driven by field development projects and when fields come into production. Access to free gas transport capacity helps develop economically viable petroleum resources at the right pace.

Analyses of transport alternatives

This chapter analyzes the main gas transport alternatives. First, we look at the dimensioning of possible new gas infrastructure based on proven resources, then the respective gas transport alternatives are evaluated based on unproven resource scenarios and finally we do financial assessments.

CURRENT GAS TRANSPORT ALTERNATIVES FOR PROVEN RESOURCES

Seven fields and discoveries have been used as a basis for the analyses of the gas transport need. These have been selected based on assessments made with operators and the Norwegian Petroleum Directorate and are based on the maturity of resources.

The status for these fields and discoveries is:

- Snøhvit is a gas field discovered in 1984. The field is operated by Equinor and located approximately 140 km northwest of Hammerfest. The Snøhvit field that started production in 2007 was the first field to be developed in the Barents Sea. The field is an underwater development and the wellstream from the field goes into the Melkøya LNG plant for processing. LNG is transported from Melkøya by ship to the market. It is believed that the Snøhvit Beta and Tornerose discoveries will be developed via Snøhvit.
- Goliat is a Vår Energi-operated oil and gas field that was developed and put into production in 2016. Goliat is located about 50 km southeast of Snøhvit. Today, the oil is transported to the market with shuttle tankers. A future gas export solution is pending, but a gas export solution is needed to get a more optimal utilization of the field. In the analyses, it is assumed that the gas in Goliat is exported via a pipe to a location in the Snøhvit area.
- Johan Castberg is an Equinor operated oil field, with a gas cap, located about 100 km northwest of Snøhvit. Johan Castberg consists of the three structures Skrugard, Havis and Drivis, which were discovered between 2011 and 2013. The field is under development and is planned to start-up in 2022. Export of the gas is planned at the end of the field's lifetime. The analyses assume that nearby discoveries are linked to Johan Castberg and that gas is exported via pipelines to a location in the Snøhvit area.
- Wisting is an oil discovery that was discovered in 2013 by OMV. It is located about 230 km northeast of the Snøhvit field. Wisting needs the export of associated gas in order to achieve optimal oil recovery. In the analyses it is assumed that the gas is transported via a pipeline to a location in the Snøhvit area, which is in accordance with the operator's recommended solution.
- Alke is a Vår Energy operated gas discovery that was discovered in 1981. The discovery is located approximately 60 km southwest of Goliat. In the analyses, it is assumed that Alke gas is exported via a pipeline to a location in the Snøhvit area.
- Alta is a Lundin operated oil and gas discovery discovered in 2014. The discovery is located approximately 35 km northwest of the Snøhvit field. In the analyses, it is assumed that Alta is exported via a pipeline to a location in the Snøhvit area.

- Gohta is a Lundin-operated oil and gas field discovered in 2013. The discovery is located about 35 km northwest of the Snøhvit field. The analyses assume that Gohta is exported via a pipeline to a location in the Snøhvit area.

Sizing of gas transport alternatives

Resources in these fields and discoveries, excluding Snøhvit, are approx. 50 billion Sm³. In the analyses of the gas transport needs and the design of the gas transport alternatives, the following assumptions are used:

- The rich gas capacity at the Melkøya LNG plant is assumed to be 7.4 billion Sm³ / year.
- In the capacity assessments, annual volumes are assessed against the annual capacity.
- Gas processing and associated capacities in fields and discoveries are based on input from the respective operators.
- In some of the transport options, acceleration of gas production from fields in operation has been assumed to utilize increased capacity.
- In the analyses of proven resources, planned start-up of discoveries and start of gas export from fields is based on information from the operator.

Different transport options with different capacities have been considered. These are summarized in Figure 10.

Capacity of different gas transportation alternatives and reported profiles

Bn. Sm³ per year

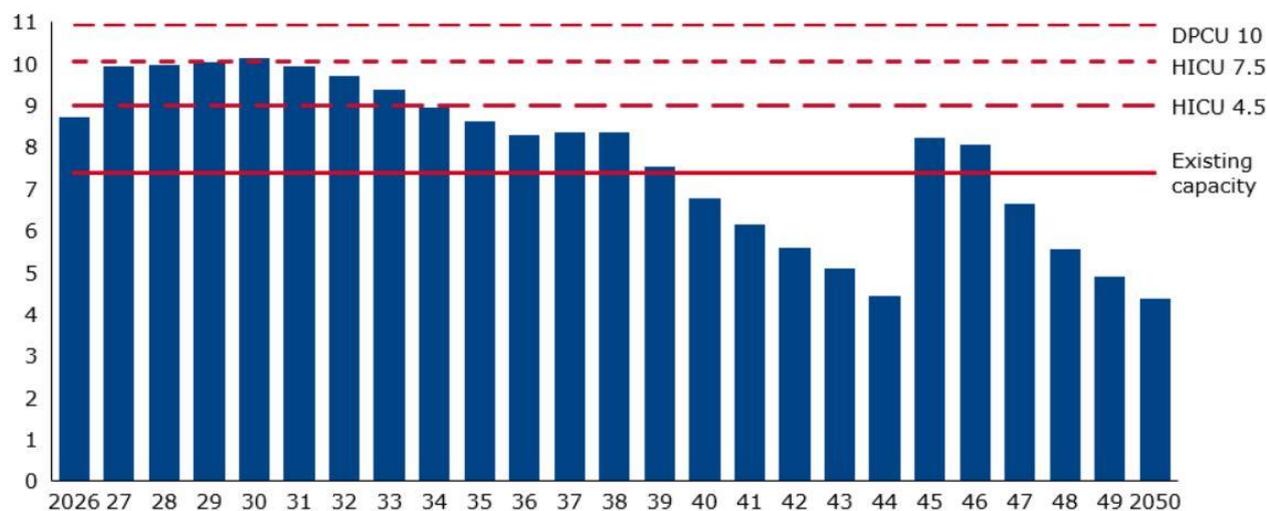


Figure 10

Existing capacity at the Melkøya LNG plant is expected to be fully utilized by Snøhvit over the next 20 years. Resources in fields and discoveries in the area therefore drive a capacity requirement beyond today's capacity. The acceleration of producing fields will further increase the need. Current gas transport alternatives to meet the need may be increased capacity at Melkøya LNG plant, a standalone LNG plant or a new gas pipeline (with or without traditional DPCU). The capacity requirement for proven gas resources is up to 7.5 MSm³ / d.

GAS TRANSPORT ALTERNATIVES FOR UNPROVEN RESOURCES

On the basis of the total resource base in the Barents Sea South, the Norwegian Petroleum Directorate has made an additional assessment to identify unproven gas resources that are assumed to be socio-economically profitable.

Since there are uncertainties associated with unproven resources and the location of resources to be proven through future exploration, three scenarios have been developed (high, medium and low) for these resources.

The phasing in of future discoveries (unproven resources) is driven by the exploration history, average lead time from discovery to production in near-infrastructure and frontier areas, as well as available capacity at the field centers. Coordination between oil and gas and between fields and discoveries (proven and future discoveries) are important requirements.

The inclusion of unproven resources indicates a need for a higher-capacity gas transport alternative than an increase of the capacity at the Melkøya LNG plant of 7.5 MSm³/d (HICU). Solutions with higher capacity may have a positive effect on the incentives for exploration and thus affect the companies' exploration strategies. Access to shared processing and transport capacity reduces the cost threshold for developing new discoveries and realizing future resources compared to a situation where the cost of such infrastructure must be covered by a discovery alone. In addition, profitability of future field development projects may be dependent on investments in extra gas capacity at the field centers.

Various gas transport alternatives have been used in the development of the resource scenarios. In scenarios that include unproven resources, flexibility at the field centers (weight, degree of gas processing etc.) are important premises. Available capacity will also affect exploration activity and lead time from discovery to production.

Proven gas resources in fields and discoveries beyond Snøhvit do not get capacity in the existing LNG plant at Melkøya before after 2040 as shown in Figure 11. Associated gas in these fields therefore needs to be reinjected, contributing to maximizing oil production. The gas is assumed to be partially phased into the tail of the production at Snøhvit from 2040. This requires that the fields have profitable production long enough for the gas to be produced and exported through the Melkøya LNG plant. There will be no free capacity for unproven gas resources until after 2050.

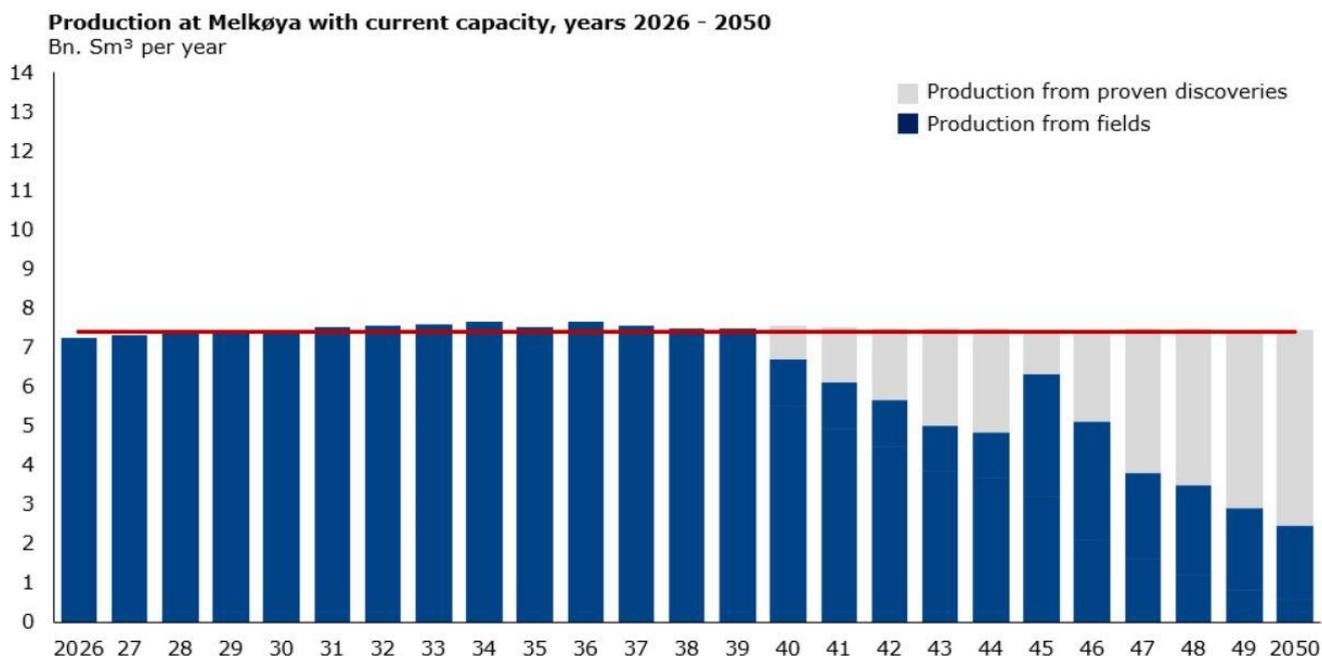


Figure 11

One way to phase in unproven resources before 2050 is to increase the capacity of the Melkøya LNG plant (HICU). In this alternative, fields and discoveries share the increased LNG capacity with Snøhvit, and a limited acceleration of production from the Snøhvit field is assumed. If unproven resource scenarios are included, there will be full utilization of the increased capacity for the whole period until 2050.

A larger capacity increase, for example a gas pipeline, could facilitate additional unproven gas resources. Such alternatives provide incentives for development of the gas resources in the area but may also result in higher investments than in the other alternatives. A resource scenario which includes some unproven resources in the area around Wisting, Goliat, Johan Castberg, and Alta/Gohta is illustrated in Figure 12. Production from the different areas is here limited by the expected gas capacity of existing and future fields.

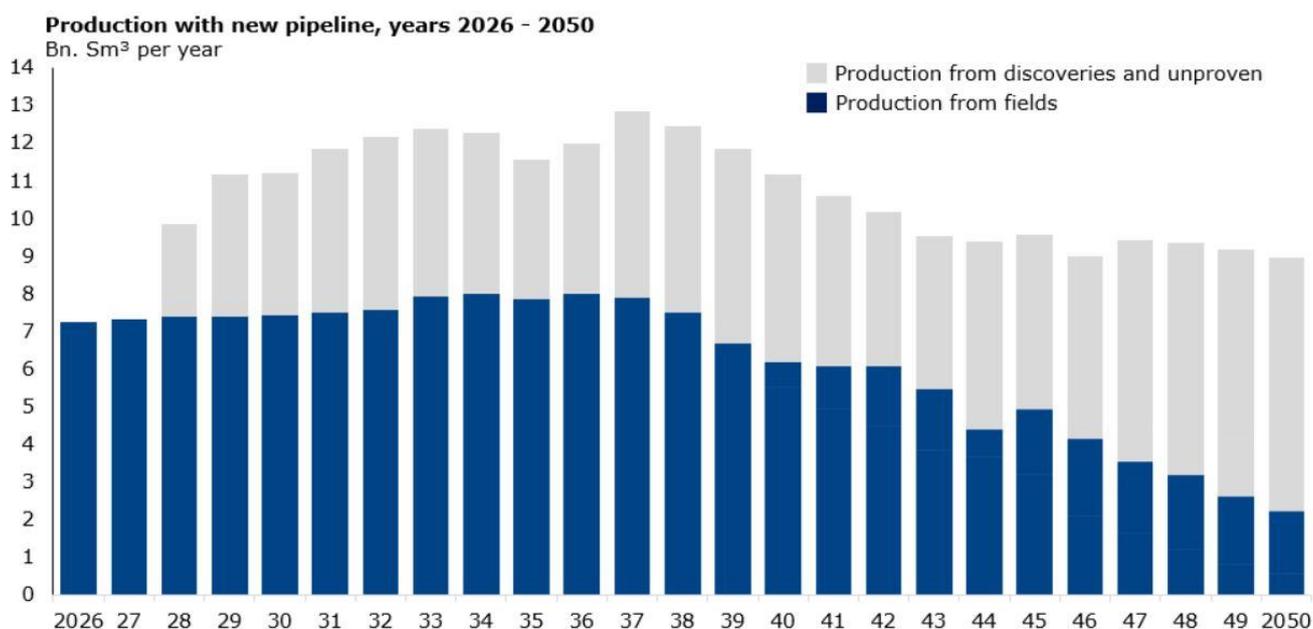


Figure 12

ECONOMIC ASSESSMENTS

All economic assessments are based on socio-economic considerations and show a change in present value before tax with a 7% real discount rate based on the value of gas production in addition to changed costs (investments and operating costs) as a result of an earlier start when capacity is increased. This assessment may give different results than a project financial assessment.

The starting point for the analysis (base alternative) is that fields in need of gas export solutions enter into capacity agreements with the licensees in the Snøhvit Unit and the production period is then extended. The analysis includes effects until 2050 and the total volume is the same for all the alternatives. Gas resources used in the financial analyses¹ for proven resources, excluding Snøhvit, is approx. 50 bn. Sm³ until 2050.

The impact of developing new gas transport capacity is increased value for oilfields with associated gas. This effect is not included in the financial assessments in accordance with the above assumptions that capacity agreements for associated gas has been established. The impact of delayed production at Snøhvit is included in the assessment.

Figure 13 shows an overview of net present value of different gas transport alternatives based on a selection of proven resources (50 bn. Sm³) as well as a scenario for some unproven

¹ The following assumptions are used for the analyses:

Start of increased capacity in 2026. Gas price based on revised national budget (RNB) 2019 (1,94 NOK₁₉/Sm³), LNG is assumed to have an added value of 3 øre₁₉/Sm³ compared to gas price. Transport/re-gasification of LNG is included with a cost of 31 øre₁₉/Sm³. Changed operating and life cycle costs in downstream transport system is included based on increased capacity utilization.

resources compared to the base alternative where gas volumes are added to the tail of Snøhvit production. Independent LNG facilities are not included as this is considered a field specific solution. The following results should be highlighted:

- A HICU alternative with a capacity of 4.5 MSm³/d based on proven resources can provide increased value creation.
- There may be added value from increasing the capacity to 7.5 MSm³/d to accelerate the gas production.
- The investment in a traditional processing plant with associated pipelines connected with the existing transport systems will give negative value creation based on proven resources, due to high costs. This alternative will require an additional 25 bn. Sm³ of unproven gas resources to be profitable.
- A simpler processing plant with associated compression can increase value creation based on proven resources.
- All alternatives give positive present value including unproven gas resources.

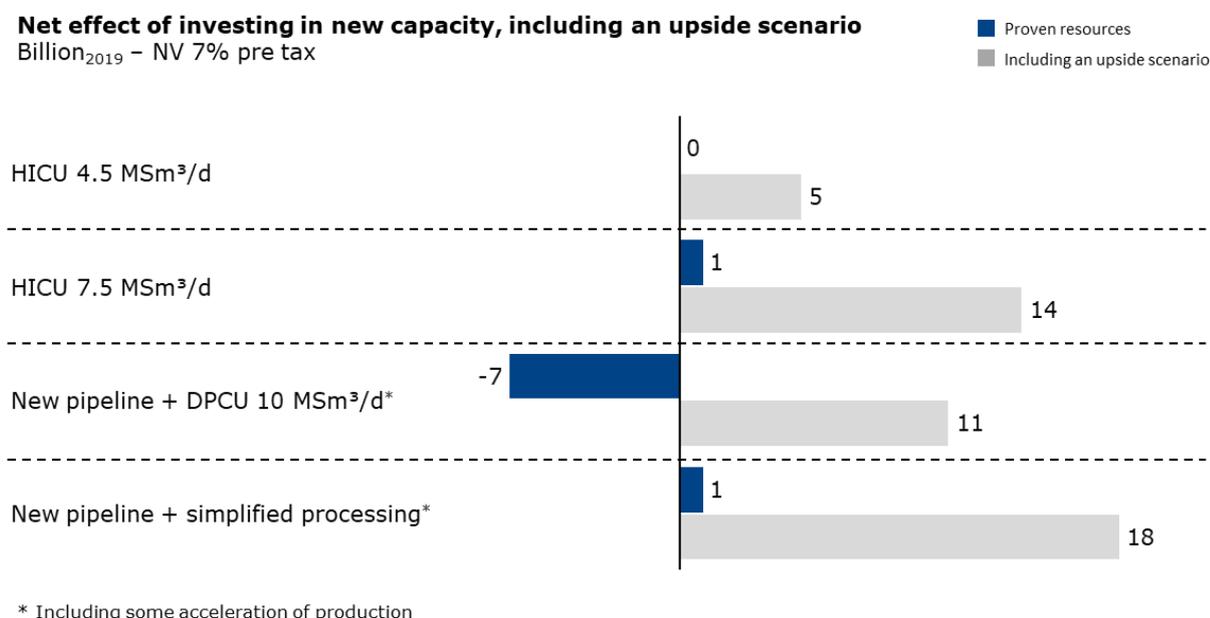


Figure 13

Economic sensitivities have been carried out, including uncertainties in both gas prices and costs. The gas price in the current period is somewhat lower than what can be expected long-term in the revised national budget 2019. However, the industry expects the gas prices to increase in the 2020s and to reach the previously expected level. This is also reflected in the forward prices.

In addition to the financial effects of investing in new capacity shown above, increased capacity for future volume will have additional effects on oilfields with associated gas which is not reflected in the present value number above.

Figure 13 illustrates how much proven gas resources will be necessary to get a positive present value of different gas transport alternatives and how much additional capacity there will be beyond this necessary minimum volume. With additional volumes from unproven gas resources as illustrated in Figure 12, the volumes will exceed the capacity in both HICU

alternatives, while there in the other alternatives will be capacity for additional unproven resources.

Resources required and available capacity for different gas transport options

Total available capacity in the period 2026 to 2050, Bn. Sm³

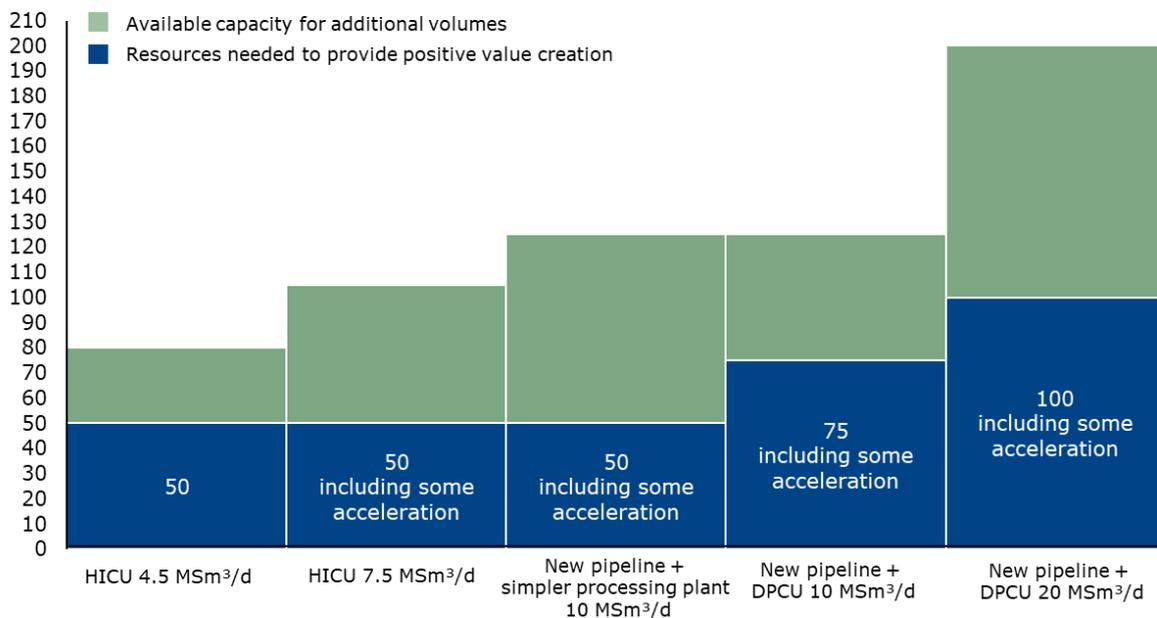


Figure 14

ORGANIZATION OF GAS INFRASTRUCTURE INVESTMENTS

Infrastructure investments for the gas operations is a part of a larger value chain from field to market and the drivers will be closely connected to upstream fields' need for new transport capacity.

On the Norwegian shelf, infrastructure has been developed gradually in connection with the development of new fields. This has typically been fields with large amounts of gas, and which justified large investments in own transport solutions. The costs of building pipelines and process facilities for gas are high but the investments have proven to give significant scale economics.

New gas infrastructure and export solution from the Barents Sea can provide increased value creation from production of resources in fields and discoveries. If proven resources classified as RC 6-7 and unproven resources are also used as a basis, the value creation will increase significantly.

The Barents Sea is characterized by a need for substantial infrastructure investments and a large number of players with 23 companies with participation interest in production licenses throughout the Barents Sea South. The need for substantial investments in shared gas infrastructure, in addition to field development costs, will reduce the return level for license owners. At the same time, the large number of companies can lead to demanding decision-making, partly because field owners of existing fields and discoveries may have to finance infrastructure covering their own identified capacity need and capacity for other upside volumes that may be owned by other companies.

Rate of return for license owners can potentially be improved by third-parties investing fully or partially in gas infrastructure. Third-party investors could typically be financial investors with a need for long-term secure investments such as pension funds etc., infrastructure companies/funds or other actors with a business strategy of investing in and developing infrastructure, both in the oil and gas industry and other industries. Third-party investors may have lower return requirements than traditional upstream companies. If the cash flow risk is small, the return requirement would often be lower than the field owner's general return requirements where the cash flow risk is significantly higher.

Investment models where the gas infrastructure owner is willing to invest at lower expected capital return than the 7% real (used as a basis for the calculations), will result in a higher socio-economic profitability than what is assumed for the calculations in Figure 14. Financial investors, however, will seek to reduce the downside through transport commitments or other payment obligations.

SUMMARY

In the near future, several existing fields and field development projects will make decisions that will contribute to shaping the way forward for the Barents Sea as a petroleum province. The decisions will have consequences for the profitability of these projects themselves and also contribute to shaping the incentives for further exploration for and production of oil and gas resources in the area.

Based on the analyses in this work, we can see three possible development scenarios for gas transport in the Barents Sea South towards 2030:

1. Today's capacity at Melkøya is maintained and fields with a need for gas export enter into capacity agreements with the licensees in the Snøhvit Unit, re-injects produced gas or waits for available capacity. This alternative will not strengthen the incentives for exploration in the Barents Sea. Gas resources in the fields may remain unexploited if the fields are closed down before the gas is fully produced.
2. The LNG capacity at Melkøya is somewhat increased to meet the need for gas export from today's fields and discoveries. A limited share of the unproven resources can be phased into this alternative.
3. Investments are made in new gas handling capacity for processing and export beyond the existing LNG plant at Melkøya. Alternatives for new gas transport capacity from the Barents Sea South can be various pipeline alternatives or new LNG plant alternatives. The pipeline alternatives offer a larger potential for increased gas export capacity and to a larger degree stimulate development of the gas resources in the area, but they may also imply somewhat higher investments than the other alternatives.

The analyses show that both scenario 2 and 3 can have positive socio-economic profitability even based on proven resources only. In addition, scenario 3 creates the best flexibility for production from future discoveries. Based on information from the companies, no individual field/discovery can support new infrastructure, so coordination is necessary to carry out investments in socio-economically profitable gas infrastructure in the Barents Sea. In that respect it is crucial that also the socio-economic option value of flexibility are emphasized.

In analyses that don't consider option value, the tailored solution will always have the highest present value, as flexibility has a high cost for the individual projects. Flexibility has cost implications, either through pre-investments (e.g., more deck space on a platform, a larger diameter pipeline) or by choosing flexible concepts.

In summary, the proven oil and gas resources in fields and discoveries beyond Snøhvit can provide a basis for increased gas export. Cooperation across production licenses (producing fields / discoveries and oil / gas) is necessary to accommodate for an holistic development of gas infrastructure within and from the Barents Sea.

Alternative investment models in gas infrastructure, where investors in such infrastructure require lower returns on capital than other private investors, can help increase the likelihood of realizing socio-economically profitable gas infrastructure projects in the Barents Sea.

Observations

The following observations have been made based on data about proven and unproven gas resources, evaluation of gas transport alternatives and analyses with different sensitivities related to the opened part of the Barents Sea South:

1. The Barents Sea is expected to have significant remaining petroleum resources. Several fields are in operation and under development and new discoveries are being matured towards investment decisions.

Total unproven resources on the Norwegian shelf are expected to be around 4 billion Sm³ OE with a share of over 60 % in the Barents Sea South and North. Close to half of the total unproven resources are expected to be gas where the Barents Sea South alone, contributes with 37%. The largest growth in resource is therefore expected to be in the Barents Sea.

There are several fields in operation, one under development and several discoveries are being matured towards investment decisions. For an optimal further development of the area, decisions related to gas infrastructure are important in order to facilitate development of gas discoveries and oil discoveries with associated gas.

2. The capacity at the Melkøya LNG plant is planned to be fully utilized over the next 20 years with gas resources from the Snøhvit field alone.

Production of gas from the Snøhvit field has gradually increased. In addition, Snøhvit has ongoing projects for further development of the field (drilling new wells, onshore compression and compression at the field) to enable plateau production until 2040.

In the unproven resource scenarios, there will be no capacity for future discoveries until beyond 2050 and incentives for exploration will consequently be low.

3. There is a need for gas transport capacity for fields in operation and fields under development before capacity is available at the Melkøya LNG plant.

Ongoing new field projects with gas transport needs are planned with a start-up between 2025 and 2027. In the various projects both new gas transport solutions and use of the existing Melkøya LNG plant are being evaluated.

4. Associated gas in oil fields have historically been an important driver for the development of gas infrastructure on the Norwegian shelf, and the same seems to apply to the Barents Sea.

Fields in operation and discoveries under development are evaluating gas transport solutions for associated gas to facilitate for optimal oil production.

Analyses show that increased gas transport capacity could lead to increased value for gas resources in fields and discoveries and at the same time optimize oil production.

Gas transport alternatives will primarily be driven by field development projects and planned commissioning date for these.

5. Several alternatives for gas transport have been evaluated; LNG and pipelines appear to be the most relevant.

Several alternatives have been evaluated for gas transport. A selection of these have been analyzed and LNG- and pipeline alternatives seem to be the most relevant.

For LNG alternatives, increased capacity at the Melkøya LNG plant and a new LNG plant have been analyzed. For pipeline transport, rich gas pipelines with associated traditional processing plant (DPCU) at Melkøya and rich gas pipelines with an associated simpler processing facility have been analyzed. In addition, the possibility of transport of gas as multiphase in pipelines have been mapped.

6. Increased capacity enables increased value creation. Accommodation gas capacity at new fields beyond the field's own needs, and potential accelerated gas production from existing fields will further increase value creation.

Based on analyses of gas resources in fields and discoveries under development, expanding the gas transport capacity within and from the Barents Sea will offer increased value creation compared to utilizing the capacity at the Melkøya LNG plant.

The increased value will be different for LNG and pipeline solutions. This is mainly due to differences in initial investment costs and the value of available capacity for production from future discoveries. Increased gas capacity on fields for potential additional resources further increases the value.

7. Early capacity increases will enable faster development of proven gas resources, and at the same time accommodate for more optimal production of oil with associated gas.

Ongoing new field projects is planned to start between 2025 and 2027. These projects need gas transport, and a delay of the projects will destroy value. At the same time, commissioning the fields without an optimal transport solution for the gas will also provide lower value of the oil production.

If planned field development projects are tailored to the existing capacity at the Melkøya LNG plant, there will be a higher threshold for realizing a new large gas infrastructure solution.

8. Larger increase in capacity requires more than gas resources in fields and discoveries to be profitable. At the same time, such a solution provides an option value that must be taken into account for additional resources from fields in operation, fields under development and from new discoveries.

The expectations for unproven resources are as mentioned in observation 1 largest in the Barents Sea. Lack of available capacity at the Melkøya LNG plant makes it less attractive to develop gas discoveries and can affect the companies' exploration strategy. A long-term solution for gas infrastructure with increased capacity can contribute to realizing future resources and will consequently contribute to incentives for increased exploration.

Including unproven resources in the analyses implies a need for a larger solution.

9. Simpler solutions for gas transport and technology development will contribute to reducing costs of development and operations.

Gas transport from the Barents Sea would require large investments. A simpler processing plant with associated compression could provide increased value creation based on proven resources. The same would apply to transport of gas as multiphase over longer distances.

10. Coordination across production licenses is necessary to accommodate for a holistic development of the gas infrastructure in the Barents Sea.

To ensure good decisions for the development of the petroleum resources, cooperation and sufficient coordination between the licensees in the area is valuable. This will contribute to decisions which are consistent for the various value chains from field to market.

There is currently no single license able to cover the large investments needed to get a new value chain for gas in addition to the Melkøya LNG plant. To achieve long-term solutions for gas transport, coordination across production licenses will be necessary.

In the coming years, several decisions are being made on fields in production and discoveries under development that will affect the longer-term gas infrastructure. This will provide increased value and enable possible synergies between fields and discoveries, and between oil and gas both for field projects and long-term solutions for gas transport.

The way forward

The area study of the gas infrastructure in the Barents Sea is based on a collaboration between a large number of actors. The results of the work points to natural next steps to take this collaboration forward. Further work is recommended in particular for the areas mentioned below:

- **Further studies to mature projects for increased gas transport capacity, both LNG and pipeline solutions.**

Field development projects that are developing documentation for Decision on Continuation (BOV) need concrete gas export solutions. Both PL 489 Alke and PL 229 Goliat have requested the capacity from the Snøhvit Unit. Analyses of proven gas volumes confirm this need and that it will be socio-economically profitable to increase the gas transport capacity from the Barents Sea compared to using existing gas transport capacity.

Furthermore, analyses show cost saving opportunities by challenging traditional gas transport solutions with full processing. Limited processing of gas from fields would realize a larger potential in unproven gas resources and could in addition provide increased profitability in discoveries that are currently demanding to develop.

Analyses with sensitivities and measures to increase robustness, where unproven resources and acceleration of existing gas resources are included, clearly show that it is too early to exclude larger gas transport alternatives. The potential from realization of the unproven resources will be significantly higher in large-scale gas transport solutions.

Onshore facilities are part of the value chain in the various gas transport alternatives. The technical solutions for gas transport in the further studies will be based on low emission technology. Making a good, long-term assessment of the different alternatives also requires a better understanding of the cost to maintain current capacity.

- **Current and future field development projects should include solutions accommodating for holistic and future processing and transport needs for gas.**

PL537 Wisting has requested capacity for gas processing to Johan Castberg and Snøhvit. The choice of solution at Wisting could be important for the realization of resources in the area and could have implications for the establishment of increased gas capacity in the Barents Sea.

The type and magnitude of gas processing capacity established for new fields is an important part in realizing the gas resource potential in areas where there currently is little or no infrastructure.

Gas handling capacity at new fields and gas pipelines should be dimensioned to provide flexibility for receiving new discoveries in adjacent areas.



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