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Technology and Operational Challenges for the High North

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Summary

The Petroleum Safety Authority Norway (PSA) has commissioned this project in order to obtain a picture of the HSE challenges related to petroleum activities in the Norwegian High Northern region.

The acquired overview will be used in the PSA's work with development of framework conditions and carrying out supervision of activities in this region.

It should, however, be noted that the opinions and recommendations expressed in this report reflect the view of the authors and are not necessarily the views of the PSA.

The report summarises information which has been collected and systemised with the view to map existing technologies and ongoing and needed technology developments which will contribute to safe exploitation of petroleum resources in Norwegian High North areas.

A questionnaire survey seeking information from industry, institutes and R&D environments has been undertaken as part of the study. This information, based on the industry's own views, represents an important background for the further evaluation of gaps and needs for research and technology development with a view to safe operations in the High North

A number of important research activities are ongoing - activities that will ensure safe developments in the Norwegian High North and activities that will be important for export of technology to projects in other countries in the Arctic. It is envisaged that such work be continued with enthusiasm and sufficient funding from private actors and from the government.

Technologies developed for exploration and process facilities are listed in Chapter 5 while technology for improved safety during operations is discussed in Chapter 6. Chapter 7, furthermore, discusses the challenges related to understanding of risk and the physical environment as well as listing status regarding international standards.

A series of recommendations has been given in the report. These include the needs to prepare personnel for activities in the High North, by educating graduates and continued education of experienced staff. The recommendations also include an encouragement for wide international participation by specialists from authorities and companies / contractors.

Finally the report recommends that particular attention should be paid to technologies needed for the far High North, for example the Svalbard Offshore Zone, and that increased attention should be paid to the mainly ice free zone of the Barents Sea where development activities might be undertaken in the near term. This applies both to the former disputed area between Norway and Russia where a delimitation agreement recently has been reached, and the area to the north where hydrocarbons recently have been identified (for example the so called "Skrugard" field, well 7220/8-1).

1 Project background

1.1 Introduction

This report is prepared by the University of Stavanger and IRIS for the Petroleum Safety Authority Norway (PSA).

The report summarises information which has been collected and systemised during a project carried out in 2009-2010 with the view to map existing technologies and ongoing and needed technology developments which will contribute to safe exploitation of petroleum resources in High North areas[1].

The project was aimed at aspects of importance for the Health, Safety and Environment (HSE) in the Norwegian High North and covered what is relevant to:

- employees' working environment, health and life
- prevention of major accidents and near-miss incidents that could lead to a major accident
- accident-fighting, rescue and evacuation in the event of a major accident
- better risk management, including better understanding of risk, better maintenance, better information about risk influencing factors (weather, reservoirs, etc.), better standards, etc

The effects of pollution on the physical environment fall outside the PSA's responsibility. Therefore the project does *not* include information on technology and knowledge that affect allowable emissions, what happens to oil and chemicals after reaching the sea and what can be done to reduce environmental damage that oil / chemicals can cause.

2 Study approach / methodology

2.1 Information gathering

The project has been based on three sources of information:

- Questionnaire survey seeking information from industry, institutes and R&D environments
- Information made available through open sources (conferences, publications, etc.)
- Knowledge acquired through direct involvement in industry and academic work

In order to establish a realistic picture of the petroleum industry's views on High North challenges and technology requirements, it was decided to undertake a survey amongst oil and gas operators, supply industry and research institutes. These sources were considered to be the most important for current knowledge, and a questionnaire was developed and presented to selected Norwegian and international companies. The respondents were asked to distinguish, where relevant, between topics related to the Norwegian High North and topics related to International Cold Climate regions.

The survey was conducted in the name of PSA who signed and distributed the questionnaires. Appendix I includes the questionnaire and list of respondents.

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1 In geographical terms The High North covers the sea and land stretching northwards from the southern boundary of Nordland County in Norway and eastwards from the Greenland Sea to the Barents Sea and the Pechora Sea. *The Norwegian Government's High North Strategy, 2006*

Through his active participation and involvement in a number of international conferences on arctic and High North issues, one member of the project team has acquired a solid overview and a view on useful sources of information. Further, Dr. Gudmestad has co-authored textbooks on petroleum developments in arctic regions and has been heavily involved in the development of the ISO 19906 "Arctic Offshore Structures" standard, where he since 2002 has represented Norway in the international working group. This broad insight in relevant topics has been a valuable asset for the study.

2.2 Information structuring

One study objective was to develop a framework for systematisation of challenges and technology contributing to the lowest risk and protection of life, environment and investments. The target area would be arctic conditions as those in the Barents Sea and around Svalbard.

The characteristics of the region were described and classified on the basis of physical conditions and challenges based on environment and safety related conditions.

Technological challenges and options were organised in the form of a "technology map", populated with the information gathered, providing an overview structured along the following functional / operational aspects:

Overall challenges
- Environment
- Geopolitical and socio economics
- Oil spills response
- Technical safety
- Ice management

Exploration and drilling
- Seismic
- Drilling challenges
- Drilling rigs and vessels

Field development
- Drilling and well completion
- Subsea and pipelines installation
- Offshore structures
- Mooring and risers
- Facilities engineering

Operations
- Transport and marine operations
- Rescue and evacuation
- Inspection and maintenance
- Environmental data and monitoring
- Communication

The overview is useful for a crude assessment of which aspects have received attention, both in terms of anticipated challenges and for technology development status, and which aspects are less focused by the industry and its suppliers. This information, based on the industry's own views, has been an important background for evaluation of gaps and needs for targeted research and technology developments with a view to safe operations in the High North.

2.3 Information repository

The project has, furthermore, established an overview of publications, conferences and web sites considered to represent qualified and up to date information related to petroleum activities in cold climate regions (cf. appendix IV). The intention was to identify a manageable amount of reliable sources to help keeping abreast of developments.

2.4 Need for research and technological development

Some emerging methods and technologies that address cold climate challenges are presented in Chapter 5 - 7 of this report. These do to some extent represent radical solutions and technology leaps, but also further development based on known components and solutions. While identifying such technologies and steps taken, there are some critical areas which appear to be less attended to. Considerations over such 'gaps' have been included in Chapter 8.

3 Characteristics of High North areas of relevance to Norway

3.1 The Arctic as opposed to the Norwegian High North

A common approach to marking the Arctic boundary is by the isotherm connecting a mean July temperature of 10° C. With this definition the Arctic covers about five per cent of the earth's surface of both onshore and offshore areas. These areas are associated with ice challenges as well as being ice-free with drifting ice challenges.

Figure 1 - Arctic areas, July temperature below -10° C (cf. Norwegian Polar Institute)

Another approach is to consider Cold regions, which would include oil producing provinces as Sakhalin, Northern Caspian Sea, Grand Banks of Newfoundland and Bohai Bay in China. Parameters used to define the overall situation in a specific area typically include:

- Ice conditions with severity throughout the season
- Temperature and wind chill; extreme lows
- Daylight hours by month
- Distance from shore
- Water depth

Other factors which have impact on design criteria are sea currents, permafrost, storm and waves. With such diverse conditions the technology requirements will therefore vary largely from area to area.

The DNV's Barents 2020 project suggests dividing the Barents Area into 8 sub-areas dependent on the areas' physical characteristics (cf. Lars Ingolf Eide, DNV) where the most significant criterion is the presence of sea ice. This division is considered appropriate with respect to the physical conditions in the Barents Sea:

i)	Spitsbergen	- *usually ice every winter*
ii)	Norwegian Sea	- *generally ice free*
iii)	Franz Josef Land	- *usually ice every winter*
iv)	North East Barents Sea	- *usually ice every winter*
v)	Novozemelsky	- *in between*
vi)	Kola	- *in between*
vii)	Pechora	- *usually ice every winter*
viii)	White Sea	- *usually ice every winter*

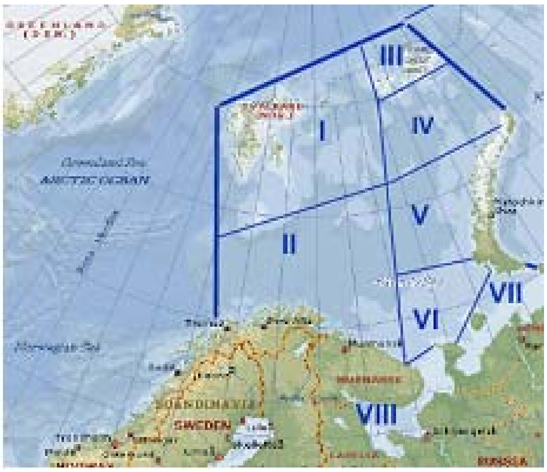

Figure 2 - Division of the Barents Area into sub-areas dependent on the physical characteristics (DNV's Barents 2020 project)

Sub-area ii (the coast off Norway and Murmansk), which at present is most relevant for the jurisdiction of the PSA, is generally/ normally ice free, whereas other sub-areas usually have ice every winter or are classified as 'in-betweens'.

3.2 Physical Conditions - some key aspects

Sea ice: Although not a predominant factor in the Norwegian waters, sea ice is the single most important environmental factor affecting operations in the Arctic. Ice affects all aspects of oil and gas activities, from the design and construction of facilities which can withstand ice conditions to planning for transportation or possible rescue operations. There is no simple description or set of design criteria related to sea ice. The characteristics and their potential impact on oil and gas field developments are subject to specific studies on ice properties, ice drift and ice forces actually encountered in the prospective area.

Temperature: The very low temperatures that can be experienced in the northern regions are hazardous both in their direct effects on human health and in their reduction of workers' efficiency and reaction time when they are exposed to cold. Further, the bulky protective clothing worn for warmth may interfere with tasks in ways that can cause increased risk for injury or accidents.

Polar lows: Polar lows are small, rather intense low pressure systems in the Arctic. They are formed at sea during cold air outbreaks during winter and are often characterised by their sudden and rapid development. Polar lows come with gale or storm force winds - seldom hurricane - and heavy snow showers, icing and changing wind direction. They can have a life span of 6 hours to 1-2 days and they typically cover an area of diameter 100-500 km.

Polar lows are a rare special case of strong troughs, and there is lack of meteorological models and data to predict these phenomena.

Spray ice: Icing on vessels is furthermore of concern in large areas of the Arctic during the ice free seasons.

Daylight: The most common method of tracking oil spills is by visual observation from aircraft. In many cases this will be difficult in the Arctic because of long periods with limited daylight conditions. Furthermore, fog is of concern parts of the year, limiting visibility severely. Fog appears particularly in the open water - ice covered seas transition region.

Distance: In addition to the severe environment, the primary consideration when planning for infrastructure and support services is the distance of the field from established bases onshore. In critical situations the remote location areas also make evacuation of personnel more time consuming and difficult, and delays start of medical treatment. Helicopter reach is of large concern.

4 Summary of information received from the industry

4.1 Corporate approaches – some trends

Some companies operating on the Norwegian continental shelf consider oil and gas exploitation in the Norwegian High North as a fairly uncomplicated extension of activities at Haltenbanken and out of Nordland South:

- Assume use of similar technology, however the technology needs to be qualified for the appropriate use
- General references are made to Norne
- The experience from the Snøhvit process plant development at Melkøya has usually been that some issues become amplified in the North:
    - appearances of polar lows and needs to “wait on the weather”, especially in autumn
    - winterisation of onshore facilities, in particular acknowledging icing and snowdrifts
    - instrumentation in cold climate

Other companies refer to their cold climate experience both offshore and on land, especially in Alaska and on Sakhalin.

Some oil companies also report that they actively develop technology for use in Norwegian North areas and others refer to general international technology developments for areas with cold climates.

Norwegian research institutes and universities are involved in a number of relevant technology developments funded by oil companies and major contractors:

- It is emphasised that several prospects in the Norwegian High North, especially south towards Vesterålen and Lofoten, are located near to shore and that technologies to prevent accidental discharges therefore must be improved.
- The cold weather and dark season of the year demand technology that reduces the likelihood of oil spills to an absolute minimum.
- It is also pointed out that working in a cold climate imposes special requirements to the working environment and needs to develop better safety gear.

Further one should take into account that there are extensive geographical distances, even from parts of the Barents Sea South to the coast. This may complicate the logistics, with the potential safety consequences this may entail.

4.2 Most referred topics

Figure 3 below summarises the number of survey respondents who referred the respective topics as an area associated with challenges. The most frequently mentioned concern was how to deal with oil spills. This topic falls outside the area of responsibility for the PSA, thus technology and solutions dealing with this have not been elaborated upon in this report.

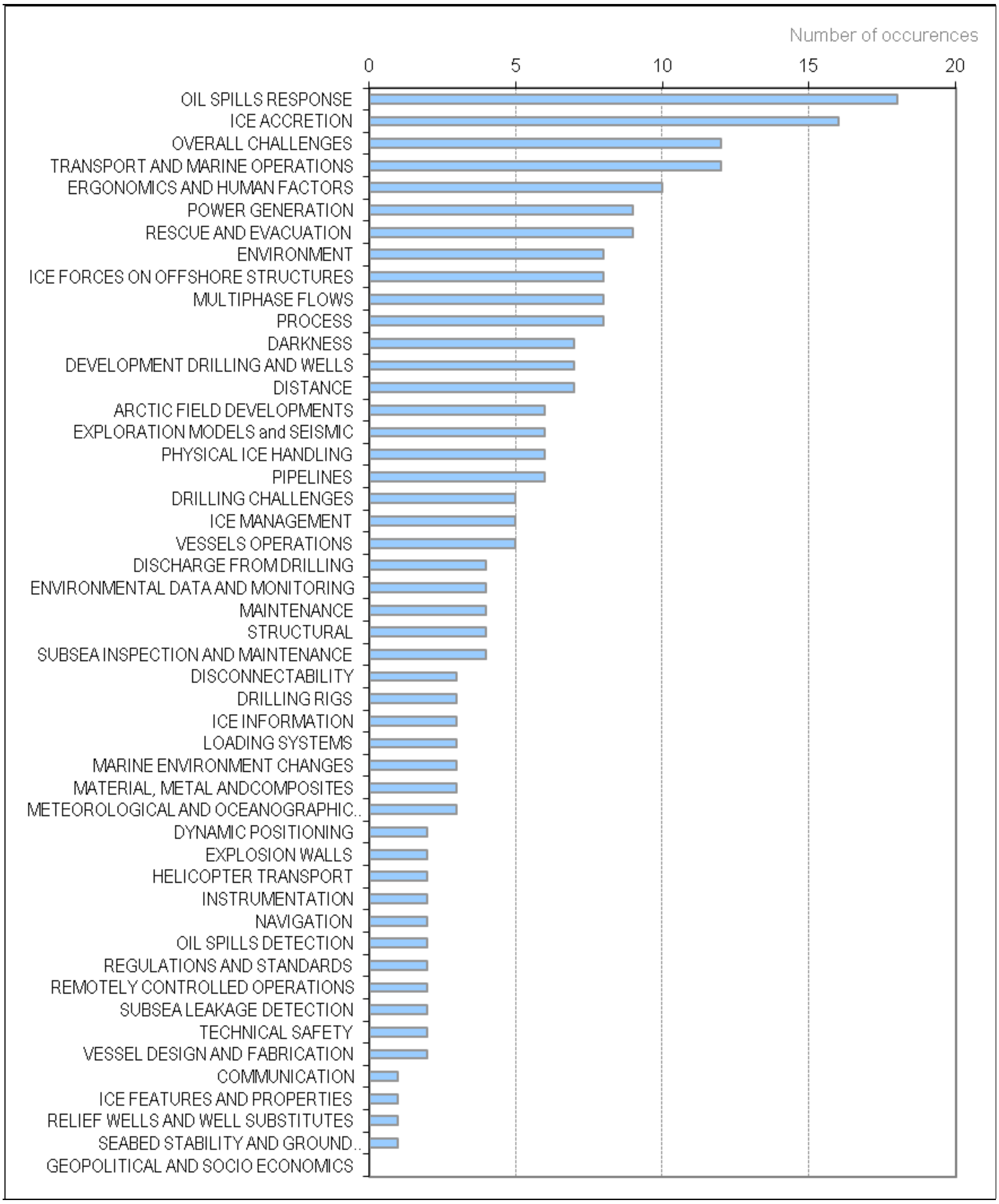

Figure 3 - Summary of the number of survey respondents who referred the respective topics as an area associated with challenges

Among the ten most listed areas are a number of generic challenges (ice, logistics, working environment, rescue situations) that are common to and may impact a wide range of operations. This is as was expected.

4.3 Industry views

The views that were put forward by the industry in the survey are summarised preceding the technology tables in Chapters 5-7. ”Ice heavy” subjects with peripheral relevance for the Norwegian Barents Sea have not been included.

Some overall challenges or key factors that would influence all activities were referred as:

- Harsh climate
- Darkness
- Understanding of cold climate issues
- Snowdrift and snow protection
- Operation of equipment and ships in rough, cold weather
- Design and performance with weather protection in place
- Low temperature design properties for equipment and materials
- Distance to supply base, helicopter base and medical facilities

There were also expressed challenges with regards to **Exploration models:**

New developments depend on increased probability / find rates. The challenge with geology different from other Norwegian areas requires improved exploration models. This means acquisition of more geo data, which implies more seismic and low cost exploration wells to establish more data points. In the most northern areas (e.g. around Svalbard) this means seismic over / under ice and on glaciers. Seismic reflections of salt diapirs also introduce challenges.

Some fundamental components of **economic Arctic field developments** were also put forward:

- Cost reduction will be required for drilling, infrastructure, product transportation, operation and logistics.
- Utilisation of gas will face a need for cost effective export solutions. Floating offshore LNG plants constitute one alternative, which also may enable cost effective solutions for small discoveries (”stranded gas”).
- New unmanned subsea process installations (compression, separation, pumping and injection) will deal with several Barents Sea challenges.
- Extended tunnelling (>10 km from shore) opens potential for land-based developments. “No offshore personnel” will reduce the risk potential normally associated with offshore petroleum exploitation.

4.4 Industry joint projects

A number of industry / institute collaboration projects were highlighted by the respondents. These projects address key issues and witness of high focus on safe developments and operations in the High North. The following provides a list of some of these projects (for most of the projects more details are readily available on the internet):

ArcticWeb (Making Arctic data accessible and searchable in one place)

AWKS (Alternative Well Kill System)

Badger Explorer (Potential to reduce the amount of conventional exploration drilling)

BiotaGuard (Real time monitoring of the marine environment)

CASP (Database of Arctic Tectonics and Stratigraphy)

C-CORE (Development of ice load model)

ColdTech (Sustainable Cold Climate Technology)

EER (Emergency Evacuation and Response in ice infested waters)

Eureka (Tunnel development for near shore fields)

FACE (Multiphase Flow Assurance Innovation Centre)

FlexShuttle (Export solution for advanced future offshore operations)

GANS (Gas Hydrates on the Norway - Barents Sea - Svalbard Margin)

HORIZON II (cost effective and safe operation of long distance gas-condensate and well-streams)

KARBIAC (Kara and Barents sea ice currents)

LedaFlow (complete wells - flowlines – risers – subsea-offshore-onshore – processing simulators)

NDP (Norwegian Deepwater Programme - safe and efficient drilling and field development)

Oil in Ice JIP (knowledge, tools and technologies for oil spill response in ice-covered waters)

P-cable (3D seismic with rapid deployment and retrieval from small vessel)

PetroArctic Project (Offshore and coastal technology for petroleum production and transport)

Reelwell (Drilling method for energy efficient drilling and reduced number of drilling locations)

RMR (Riserless Mud Recovery system)

SmartWear (Intelligent clothing with integrated technology)

Subsea Switchgear (Complete module with connection points for umbilicals and power)

5 Challenges, requirements and technologies related to installations for exploration and production

5.1 Industry views

5.1.1 Ice accretion

Arctic icing and ice accretion caused by atmospheric icing and sea spray can cause problems on outdoor facilities, installations and structures. Effects are both in terms of increased weight on the installation and access to and workability of critical facilities.

Precautions must be taken to prevent damage from dropping ice loads.

Marine operations, including logistics and rescue are exposed.

Amongst equipment that would suffer, were specifically mentioned sensors and optical instruments.

Two aspects need to be addressed:

- Prediction of arctic icing
- Preventing or limiting the potential for arctic icing

"We believe icing can be overcome, but better understanding of the issue and development of economical and practical solutions are needed."

5.1.2 Drilling and wells

Shallow reservoirs limit the number of production wells that can be drilled from one location. Thus, drainage of shallow and wide reservoirs will demand highly deviated wells and / or more well centres / satellites, i.e. higher development cost. Shallow reservoirs with low temperature and pressure will also need artificial lift and impose challenges for distance transport.

There may be technical challenges with well positioning and directional drilling in new areas with unstable formations and little knowledge of rock behaviour. Well positioning based on magnetic and gyroscopic directional technique in High North regions is associated with 4x the uncertainty at equator and 2x the uncertainty in the North Sea.

Weather window limitations mean shorter seasons and less time allowed for drilling, i.e. higher rig costs.

Environmental aspects:

- Emissions to air can be reduced by fuel saving dynamic positioning of rig
- Well testing without bringing hydrocarbons to surface

Some expressed technical requirements:

- Slimhole exploration drilling
- Robust wells for CO_2 injection / storage
- Better solutions for cuttings
- Smart subsea wells which extend the well's life and eliminates the need for interventions (choice of materials combined with instrumentation / remote control)
- Special vessels for light well intervention

Amongst research and development being undertaken is CO_2 injection and storage in sedimentary rock at Svalbard, drilling systems which shall ensure zero discharge to sea / relief well equivalency through alternative well kill systems.

More automated (and unmanned) drilling is seen coming, in combination with integrated systems for real time decision support to drilling operations.

5.1.3 Power generation

It is expected that electricity from shore will need to be evaluated for any development in South Barents Sea. This is a high cost solution, also due to long distances from shore, and an "environmental account" justification is likely to be a big challenge.

Power generation on site may be considered as a function of distance to shore; Low emissions on site vs. power from shore. *Energy efficient solutions* will be required on the installations.

New materials, components and systems for subsea power supply are likely to be developed.

5.1.4 Process

Challenges with hydrates formation in various types of equipment need to be dealt with:

- Subsea processing
- CO_2 capture and transport and injection / storage
- Compact heat exchangers for LNG production
- AGR - Acid gas separation / removal

Other needs foreseen are

- Further development of winterised chemicals
- Subsea processing and compression with produced water re-injection (PWRI) methods for arctic conditions
- Topsides protection of water carrying pipes, typically fire water systems
- Subsea monitoring and leak detection

5.1.5 Multiphase flows

Sea bottom temperatures close to 0°C challenge multiphase transport over long distance (>150 km).

Insulation and heating of pipelines is seen too costly. This calls for radically new solutions for flow assurance which inhibits hydrate formation with less use of chemicals.

Thermodynamics and CO_2-rich compositions at high pressure / low temperature will be required for pipeline design to avoid separation of water with corrosion as consequence.

Amongst research projects being undertaken are ”ColdFlow - Multiphase transport without heating” (Sintef) and ”Electrical heating of pipeline" (Sintef).

Proposed export concept: Use of large fixed installation to process well stream from surrounding independent fields that utilise conventional subsea technology. By use of specialised technology the joint production is then transported to shore from this processing hub. Such concepts will raise new challenges and technology requirements.

5.1.6 Pipelines

New pipeline solutions are needed due to long distances and demanding marine environment for subsea facilities (insulation, corrosion protection, etc.). Experience from Snøhvit and Goliat is useful.

For landfall or possible interaction with ice or icebergs, arctic pipelines require trenching to avoid effects of gouging. Improvements are also required for overtrawling and “minimum footprint" technology.

Pipeline stability is a challenge in areas with melting permafrost or erosion.

5.1.7 Structural

There will always be needs for enhanced design knowledge with respect to wave, wind and currents. This is connected to availability of sufficient and reliable data about the physical environment.

Challenges include ice induced vibrations of bottom founded structures anywhere in ice infested waters, both for structure integrity and for personnel comfort. Floating structures in ice will need ice management to be able to be directed against the ice drift.

Furthermore, a concern is ice floes that could be difficult to detect and which occasionally may drift into normally ice free regions.

Some civil challenges:

- Construction foundations on permafrost
- Waves and ice causing erosion close to quay structures
- Ice resistant constructions
- Extreme temperature differences on pipelines and structures

5.1.8 Material, metals and composites

Knowledge is required as to material's behaviour (fatigue, corrosion, brittle fracture, etc.) when used for extensive periods in varying cold climate.

There will be new requirements to fabrication work in rough climate, incl. needs for more robust materials and welding technology. Anti-icing coating for steel constructions may be a new requirement.

5.1.9 Explosion walls

The use of explosion walls in winterised enclosures can become a trade-off between satisfactory weather protection for personnel and facilities and the reduced risk from explosions / explosion pressure.

5.1.10 Instrumentation

There will be intelligent monitoring of water pollution around platforms, pipelines, etc. Early detection and monitoring of oil spill to sea will need to be integrated in subsea installations. Fast reacting technology, such as biological organisms used as sensors, becomes critical.

Optical instrumentation will suffer under snow and spray ice conditions on topsides installations.

5.1.11 Disconnectability

Methods and concepts for fast disconnect / connect of risers is being developed. Disconnectability is important in order to move from the location in the event of approaching ice bergs, especially in cases when there is limited capacity for manual handling of such objects.

5.1.12 Loading systems

Winterisation of tankers and systems for loading from installation to tanker in polar circum-stances will be required.

Offshore buoy loading at source combined with ship-to-ship operations is one viable solution for loading of oil / condensate or LNG between two large carriers. This can be a cost-effective transport system from arctic LNG plants, with use of icebreaking LNG tankers loading their cargo to conventional LNG carriers in ice-free waters further south.

5.1.13 Maintenance

Accessibility of equipment and facilities combined with logistics challenges are mentioned as areas of concern for maintenance of production facilities. In some parts of the year drift ice will limit the access to subsea systems for manual inspection.

The technology focus is less maintenance intensive technology, solutions and facilities in combination with remote operations support.

5.2 Associated new technologies

Table 1: Technologies for exploration

1.1	Badger
1.2	New type of BOP valve that both cuts and seals the well in one operation.
1.3	Seabed Rig
1.4	Drilling and production from subsea tunnels
1.5	Holding tank for oil spills
1.6	Drilling of exploration and production wells from land

Table 2: Technologies for production facilities

2.1	Improved technology for flow in pipelines
2.2	Safe transport of oil along the Norwegian coast
2.3	Condition monitoring and maintenance of facilities in cold climate
2.4	Biota Guard
2.5	Winterisation of equipment, vent panels
2.6	Reelwell Drilling Method (RDM)

Table 1: Technologies for exploration

1 Technology for exploration	Contribution to HSE incl. accident prevention, rescue and evacuation, better risk management, standards, etc.	Technology relevance	Time perspective of the technology
1.1 Badger *Being developed by Badger Explorer*	"Badger Explorer" is a tool to drill down and consolidate itself in the seabed, which facilitates drilling from the seabed without a surface drilling rig. This technology reduces the impact of weather conditions on drilling operations and aims to reduce the risk of adverse events that may lead to accidental discharges to the sea. www.bxpl.com/default.asp?id=895	The technology is intended for exploration drilling in all locations with petroleum prospects.	The technology should within 5 years be tested and assessed with regard to safety. It still needs development and will require relatively large invest-ments. The Norwegian Research Council appropriated 5 MNOK in December 2009.
1.2 New type of BOP valve that both cuts and seals the well in one operation. *Being developed by Cameron in cooperation with Chevron.*	This technique which allows wells that are not fully controlled, to be intercepted and sealed in one operation, will limit the amount of oil that may escape to a minimum as well as reduce the probability of a major blowout. The technology does not eliminate the risk that wells may come out of control and the need for relief wells however it facilitates faster recovery of well control and thus reduces the amount of oil coming into the sea.	The technology can be applied for all offshore drilling.	Chevron and Cameron develop the technology for their operations. It is realistic to believe that the technology can be taken in use within 5 years.
1.3 Seabed Rig *Being developed by Seabed Rig AS*	The Seabed Rig technology implies that drilling of wells is carried out automatically with equipment that is placed on the seabed. The technology requires control from the surface and reduces the impact of the physical environment on the drilling operation. There is uncertainty about how easily well control will be achieved by use of this technology. www.seabedrig.com	The technology can be used anywhere in deep water or under ice.	Large investments are still needed to realise the technology. It is anticipated that the technology will not be ready for the northern areas for at least 10 years.
1.4 Drilling and production from subsea tunnels *Being developed by North Energy in collaboration with Acona.*	Drilling from underground tunnels to prevent oil spills, i.e. this technology can reduce the likelihood of oil reaching the sea in the event of an accident. It is assumed that any accidental discharge from the drilling will not be of such magnitude that it "overflows" the tunnel entrance. An incident will be dealt with in the same manner as for drilling on land. Uncertainties related to personnel safety are being investigated.	The technology can be used for drilling and production in near shore areas, typically between 15 and 50 km from land.	It is possible that this technology can be taken in use within a 10-year perspective.
1.5 Holding tank for oil spills *Being developed by Odfjell Drilling and North Energy*	The concept implies a secure tank surrounding the drilling location such that an accidental discharge will be collected. Thus, in case of acute discharges, this technology will reduce the amount of oil that can spread beyond the drilling location.	The technology is relevant to all locations. Work is ongoing specifically for technology for water depths of 40 to 160 m.	With sufficient resources mobilised to qualify the technology, the technology can probably be taken in use within 10 years.

1.6 Drilling of exploration and production wells from land *Exxon and BP have experience, respectively, from Sakhalin and southern England.*	Drilling from land may ensure that oil spills are not going to sea. It is then assumed that any accidental discharge will not be so large that it "overflows" into the sea at the drilling location. An incident is dealt with and stopped in the same manner as for drilling on land.	The technology is applicable for drilling in coastal areas. Current drilling reach is 10 to 12 km from land, if rock quality permits.	The technology is available but must be developed further for weak rock formations. During a 5-year period, it is assumed that the method can be used to drill into reservoirs as far as 20 km from shore.

Table 2: Technologies for production

2 Technology for production	**Contribution to HSE incl. accident prevention, rescue and evacuation, better risk management, standards, etc.**	**Technology relevance**	**Time perspective of the technology**
2.1 Improved technology for flow in pipelines *The technology is developed by Statoil, Shell, IFE, Sintef, FMC and others*	Direct well flow to an onshore production facility can contribute to reduced chance of acute spills since there will be less surface equipment that is affected by the physical environment. It is assumed that the amount of energy spent to ensure the flow in the tube is limited.	The technology is used for water depths and under conditions where this is economical.	This technology is known and is being further developed with separation plants and subsea compressors so that the separated well flow can be exported to distant plants, often onshore.
2.2 Safe transport of oil along the Norwegian coast *The Coastal Administration is responsible for the actions taken*	Efforts to secure oil transport along the Norwegian coast represent a significant contribution to reducing the risk of shipping accidents and collisions between ships and installations, and thus a significant contribution to the reduction in probability of oil spills at sea. This is achieved through monitoring, setting requirements to the routes from the coast, and increased emergency preparedness of tug vessels. www.kystverket.no/?did=9140988	The technology can be implemented wherever there is oil transport at sea.	The technology is in use. Further improvement is possible through increased use of satellites for surveillance.
2.3 Condition monitoring and maintenance of facilities in cold climate *University of Stavanger and the University of Tromsø develop relevant technologies.*	Condition monitoring facilitates immediate notification of unwanted technical condition of equipment and structures. It is adapted for better maintenance and better precautions during operations. Condition monitoring and maintenance are key requirements to ensure technical integrity. Knowledge and technology contributing to condition monitoring and maintenance of plants in cold climate represent an important contribution for reducing the likelihood of acute spills to the sea. www.uis.no/nyheter/article14453-12.html	The technology can be used for production facilities in cold climate where the instruments can freeze solid and where equipment is exposed to extreme strain due to cold.	The technology is developed together with Swedish and Finnish industry, among others LKAB. They have extensive experience with facilities in cold climate. The technology could be available in a 5-year perspective, but lack of adequate funding can delay the work significantly.

2.4 Biota Guard *Developed by Biota Guard AS*	The Biota Guard alert system combines different sensor technologies (chemical, physical and biological) that can be integrated in the installation's control systems. Indication of leakage of hydrocarbons or chemicals would trigger an alarm to initiate manual or automated responses to address the situation, for example to implement shut off mechanisms. Through coordinated use of different sensors and associated algorithms, will Biota Guard in addition to notifying a leakage, also say something about the actual content and level (concentration, etc.), and thus be capable to indicate criticality. www.biotaguard.no	Critical points on subsea installations, e.g. flanges and valves with potential high impact / damage risk at acute discharges.	The technology is specified in close contact with subsea equipment suppliers and operators. Biota Guard aims for its first commercial supply contract in 2011.
2.5 Winterisation of equipment, vent panels *Statoil has patent applied for a method for winterisation of production areas.*	Winterisation ensures that safety critical equipment (detection, notification, isolation, shutdown, etc.) work as intended under all weather conditions. Winterisation may lead to increased risk of explosion in case of gas leaks. Further development is now done on equipment that will ensure immediate detection of collected gas that might cause explosions. Thus the improvement in winterisation measures that also seek to reduce the negative effect of explosion risk is an important measure to reduce the risk of serious incidents that may lead to acute spills to sea.	The technology can be applied wherever there is equipment that potentially could stop functioning due to freezing.	Gradually being taken in use. Provided financing, the solution could be fully developed within a 5-year perspective.
2.6 Reelwell Drilling Method (RDM) *Developed ny Reelwell with support from Statoil, Shell and the Research Council of Norway.*	RDM enables drilling of well sections with challenging pressure conditions and drilling to targets beyond conventional reach. This facilitates access to a substantially increased drainage area due to its extended reach capabilities. The use of clean drilling fluids and improved pressure control increases safety and reduces environmental impact in sensitive areas. www.reelwell.com	Increased horizontal reach from existing platforms lessens the need for additional platforms and subsea facilities.	Entered the operational phase through commercial wells with Shell Canada.

6 Challenges, requirements and technologies related to operations

6.1 Industry views

6.1.1 Ergonomics and human factors

There will be need for practical solutions for the working environment, related to darkness, cold climate and distances.

Work in low temperatures, which often are enhanced by the wind chill effect, implies new requirements to personal safety equipment and ergonomics.

Winterisation and weather protection of personnel and facilities contribute to sheltered areas.

Clothing must be warm and at the same time be flexible for execution of work tasks and be suitable for survival actions.

Technical solutions:

- Smart-wear for cold climate
- Higher degree of automation and "integrated operations"
- Field development from tunnels can dramatically improve the situation for working environment and HSE

The most effective measure to prevent unwanted incidents to happen is education and training in the proper use of available winterisation technology, and defensive behaviour with regard to possible falling loads, slippery work areas and access ways.

6.1.2 Rescue and evacuation

A new preparedness regime is required for EER (emergency, evacuation and rescue). The additional requirements need to be better defined for remote EER capability, i.e. preparedness must be in place relative to factors such as distance, existing infrastructure, time to mobilise and storage of equipment.

The combination of distance from permanent services and the at times challenging weather conditions, elevates both operational and safety risk.

New field development concepts must be accompanied with appropriate rescue methods, e.g. evacuation methods for tunnelled field development.

6.1.3 Transport and marine operations

Logistics functions for efficient development and operations in remote areas become challenging due to

- Darkness – nearly 24 hours / day during long periods
- Limited infrastructure
- Distance for oil and gas export to the markets
- Access to equipment and facilities
- Logistics planning and consequences of mistakes become more critical

There will be higher demands for surveillance of increased ship traffic in remote areas.

Also one foresees issues related to use of territory on Svalbard, Hopen and Bjørnøya for support purposes.

Expect higher focus on strategies for equipment which make operations more independent of regular and frequent logistics services.

6.1.4 Helicopter transport

With activities distant from land, far outside the reach of helicopters, there will be lack of options for shore bases and helicopter-landing sites. This is a logistics as well as a rescue preparedness challenge.

6.1.5 Vessel operations

Systems for oil and gas transport involve choice of logistics, vessel types and sailing routes, based on evaluation of capacity needs, economics, environmental and safety / risk perspectives, in accordance with large seasonal variations.

In some parts of the year drift ice will limit vessel operations. Monitoring of ice and better understanding of offshore ice conditions become important, as will technical facilities for optimisation of sailing routes with respect to sea ice.

One can foresee issues related to transfer of diesel, drilling fluids, cement and other material from supply vessel onto the installation. Although this may be controlled by requirements to equipment and procedures, it is still considered a challenge.

Dynamic positioning of stationary and mobile vessels will be more challenging since navigation tools like GPS, GLONASS etc. have limitations north of 75 degrees. Enhanced satellite services with orbits designed specifically for the high north are expected to improve this situation.

6.1.6 Vessel design and fabrication

Development of supply vessels and construction vessels for arctic conditions is addressed by the maritime sector. Hull design and maneuvrability resistance in ice are some criteria that are addressed.

Vessels must to a great extent be multi-purpose to act as both supplement and short notice back-up for the served installation, e.g.

- more storage capacity for a wide range of consumables and equipment
- systems for drilling fluids and mud mixing
- treatment and storage of drill cuttings
- stand-by vessel capabilities, including emergency handling
- spare accommodation capacity
- medical facilities, close to hospital capabilities
- long range helicopter landing capacity
- oil spill containment equipment

6.2 Associated new technologies

Table 3: **Technology for better safety (HSE)**

3.1 Winterisation as measure for better working environment
3.2 Winterisation, wind shielding
3.3 Clothing for better working environment
3.4 Lifeboat for the safe evacuation

Table 3: Technology for better safety (HSE)

A safe working environment is a fundamental prerequisite for safe operations and thus also to the prevention of adverse events that may lead to accidental discharges to the sea.

3	Technology for better safety	Contribution to HSE incl. accident prevention, rescue and evacuation, better risk management, standards, etc.	Technology relevance	Time perspective of the technology
3.1	**Winterisation as measure for better working environment** *Statoil has filed patent application for a method for winterisation of production areas.*	Winterisation not only ensures that safety-critical equipment works in all weather conditions; it is also an important work environment measure. Winterisation contributes both to safety and working environment, and thus to the prevention of adverse events that may lead to accidental discharges to sea.	The technology can be used wherever the climate conditions represent health and working environment risks.	Gradually being taken in use. Provided financing, the solution could be fully developed within a 5-year perspective.
3.2	**Winterisation, wind shielding** *Technology developed by Eni Norge for Goliat*.	Light wind protection prevents personnel from wind exposure and cooling effects, hence better prepared for monitoring of activities which require supervision, etc.	Can be implemented anywhere in cold climate where it is desirable that staff execute physical work.	Taken in use for new projects and will be implemented at Goliat.
3.3	**Clothing for better working environment** *Sintef project.*	For some operations it is required that personnel are exposed to cold weather. Comfortable and warm clothing is essential to ensure a working environment which lets staff perform their functions as expected in a safe manner. www.sintef.no/Projectweb/ColdWear	To be used anywhere in a cold climate where personnel is expected to work.	In use on new projects. Further development is ongoing and results are taken in use when available.
3.4	**Lifeboat for the safe evacuation** *Technology developed by Team Innovation*	A sound working environment is a prerequisite for safe operations. An important work environment factor is the individual employee's perceived safety. This assumes, among other things that staff feel confident that evacuation is possible. This technology can contribute to a sense of security and thereby make a positive contribution also on safety. www.nrk.no/nyheter/distrikt/nrk_trondelag/1.6748602	In areas with possible occurrence of ice.	The technology can be applied in a 5-year perspective provided financing for the development becomes available.

7 Challenges related to understanding of risk and the physical environment

7.1 Industry views

7.1.1 Meteorological and oceanographic data

Metocean, ice and environmental data bases are required for improved design criteria and for timely prediction or warning of ice, extreme waves and polar lows.

Reliable field specific data must be provided prior to development in order to meet technology challenges in a satisfactory way. It is seen as critical that existing data is made available and that newly gathered data related to the physical environment is shared.

Data collection and simulation projects are carried out by a number of operator/institute collaboration programmes.

7.1.2 Seabed stability and ground

Access to more and better (quality assured) data related to the physical environment and better understanding of seafloor conditions is required for understanding of shallow sediments and seafloor conditions, which will contribute to reduced safety risks associated with operations in the area.

Mapping of shallow gas and hydrates is especially important.

7.2 Work on standardisation

The ISO 19906 "Arctic Offshore Structures" standard was published in December 2010. The objective of ISO 19906:2010 is to ensure that offshore structures in arctic and cold regions provide an appropriate level of reliability with respect to personnel safety, environmental protection and asset value to the owner, to the industry and to society in general.

According to an agreement between ISO and CEN, an ISO standard becomes a European standard, thus a Norwegian standard.

7.3 Associated tables

Table 4: Technology for surveillance and knowledge of physical conditions, including weather

4.1 Alert of polar lows
4.2 Knowledge about ice accretion from sea spray and atmospheric icing
4.3 Models for snowdrifts

Table 5: Standardization

5.1 International standards for structures in cold climate
5.2 Barents 2020 - standardization of technical requirements for activities in the Barents Sea across the Norwegian and Russian continental shelf

Table 4: Technology for surveillance and knowledge of physical conditions, including weather

The Barents Sea weather conditions represent an important factor with potential risk impact. Development of knowledge and technology which target weather conditions and weather forces leads to a better understanding of risk and reduced uncertainty. This in turn facilitates development and use of technology and operational measures that are better adapted to the environment, thus safer operations.

4 Technology for surveillance and knowledge	Contribution to HSE incl. accident prevention, rescue and evacuation, better risk management, standards, etc.	Technology relevance	Time perspective of the technology
4.1 Alert of polar lows *DNMI has strong focus on this aspect*	With capability of forecasting polar lows in an efficient manner, we will have a better basis for planning operations in regions where polar lows occur. The probability that work will be carried out under conditions where the work should be halted and postponed is therefore reduced to a minimum. This technology is also relevant to provide reliable weather forecasts for the tankers that are associated with Norwegian petroleum activities or carry oil from Russian oil fields along the Norwegian coast. This can contribute to reduction of risk of oil spills through the reduction of the risk of shipping accidents and collisions between ships and facilities. http://met.no/?module=Articles;action=Article.publicShow;ID=778	The technology is applicable throughout the Norwegian High North. Polar lows occur in the period September to May. With changes in climate, the number of polar lows may increase in coming years	Technology is already in use, with continued focus on collecting relevant data about the weather so that modelling and alerts can be more reliable. This is a national responsibility. Model development requires funding, and special weather forecasting is associated with a significant cost aspect.
4.2 Knowledge about ice accretion from sea spray and atmospheric icing *DNV og Sintef project.*	Ice accretion can lead to malfunctioning or damage to production facilities, or cause vessels to become unstable. Better knowledge of ice accretion facilitates better technical solutions, better selection of equipment and more reliable operations. www.re-turn.no/pdf/MARICE%20Bulletin%202009-1_rev3.pdf	The technology is relevant in all areas of the Barents Sea where ice accretion can occur.	The technology is being gradually developed and taken in use.
4.3 Models for snowdrifts *Developed by Høyskolen i Narvik.*	Snowdrifts represent a significant challenge for instrumentation and can prevent access to some areas which are critical for safety, e.g. control centres for onshore facilities. Better snow drift models facilitate better design, better equipment selection and more reliable operations. www.hin.no/index.php?ID=2625	The technology is applicable wherever one can get snow-drifts, i.e. for all facilities in Norway and Northern Europe and in North America, on Sakhalin, etc.	The technology is being implemented.

Table 5: Standardization

It has recently been undertaken standardization work that has contributed to knowledge and capacity building in the petroleum industry. This has provided important information relevant to understanding and managing risk, among other events that may lead to accidental discharges.

5 Technology and Standardization	Contribution to HSE incl. accident prevention, rescue and evacuation, better risk management, standards, etc.	Technology relevance	Time perspective of the technology
5.1 International standards for structures in cold climate *Work done on international voluntary basis.*	The ISO 19906, "Arctic Offshore Structures", was published in 2010. The standard includes the experience gained for petroleum operations in cold climate, and the normative section gives a detailed overview of what needs to be taken into account in the design phase. In this way the standard represents a strengthening with regard to safety aspects that can lower the risk of undesired events leading to acute spills to the sea. www.pngis.net/standards/details.asp?StandardID=ISO+19906	The technology is applicable throughout all regions with cold climate.	Sections of the standard are implemented on Goliat and the standard is applied actively for the design of a solution for the Shtokman field.
5.2 Barents 2020 - standardization of technical requirements for activities in the Barents Sea across the Norwegian and Russian continental shelf *Financed by the Ministry of Foreign Affairs.* *DNV leads the project.*	Shared technical standards for use in petroleum activities in Norwegian and Russian continental shelf can lead to a technical standard that contributes positively to prevention of acute spills. The Barents2020-project has divided the Barents Sea in 8 areas with different climatic conditions, which may help to increase the precision of technology adaptation to weather conditions, which will vary widely in such a large area. http://viewer.zmags.com/publication/810da62a#/810da62a/1	The results can be used in the 8 areas as defined in the project report.	It has been reached agreement on which international standards and NORSOK standards are considered relevant for projects on both the Norwegian and the Russian continental shelf. Assuming continued funding, the project will proceed with drafting of common technical standards. It is assumed a good cooperation with the international, Norwegian and Russian authorities for standardization.

8 Discussion

With respect to technology development and preparation for operations in the High North, we have noted that ongoing efforts to a large degree relate to potential ***oil and gas developments in ice infested waters.*** This approach is logical when prioritising developments in waters with ice cover or where ice drift may occur, or in areas with potential for drifting icebergs. The designer will have to ensure that all aspects related to actions from drifting ice and iceberg are taken into account, and for operations one has to plan for all relevant ice conditions with potential for operational downtime. Disconnection is an option that might be considered.

The efforts to understand the challenges in regions with ice are highly relevant for several regions that are considered potential petroleum development provinces. Such are the Eastern and Northern Canadian waters, all the way from the Grand Banks towards the Baffin Island and through the North West Passage, Offshore Greenland (West and North East) and most regions of the Russian Arctic waters (e.g. the North Eastern Barents Sea, Pechora Sea, Kara Sea and Offshore Sakhalin). Furthermore, the actions from ice represent the design load for developments offshore North Western and Northern Alaska.

For Norway, it is for several reasons important to develop and keep competence related to technology and operations in waters with ice and actions from ice:

- Technology for activities in the Svalbard offshore zone should be known such that Norwegian authorities and companies can understand the potential and challenges in the case of activity in this zone. This relates not only to activities for oil and gas development but also for fisheries, transport, etc.
- The closeness to potential Russian oil and gas developments calls for close cooperation with Russia, whether it is the authorities, the oil companies or the contractors. Such cooperation could help to ensure the quality and sustainability of operations and new projects, and there exists potential for a link with projects in Norwegian waters.
- Norwegian based oil companies and contractors could be involved on commercial basis in the development of the High North worldwide, depending on their competence and ability to understand the requirements of the regions in question.

At present the mapping of technology needs for the new Norwegian province in the Barents Sea, the formerly Disputed Area ("Grey Zone") between Norway and Russia, receives less attention. However, consideration of challenges related to meteorological and oceanographic conditions and the technology needs in the ***mainly ice free region of the Barents Sea*** should be made. Of particular interest are operational challenges related to polar low pressures and icing, as well as winterisation of equipment and the human work place. Evacuation and escape are important issues that have to be resolved prior to start up of any production from these areas.

One should be aware that for offshore projects in this region there may be operational limitations that cause downtime, both during the exploration, the installation phase and the operations phase.

9 Recommendations

In view of the discussion in Chapter 8, it is recommended[2] that all the good work carried out at research institutions, contractors and oil companies in relations to the High North, should be followed with interest and be supported by the authorities.

The specifics of the High North should be highlighted in relation to personnel health and safety, the environment and to the specific requirements to ensure “winterization” of all facilities for operations in the region. The necessity to take the actual weather conditions into account during all activities must always be kept in mind.

The Research Council of Norway has an important function in supporting relevant activities. It is envisaged that the newly established Centre for Research Based Innovation at NTNU (cf. appendix II) will play a major role, also for the education of specialists that are needed for the safe development of the High North. In this respect the availability to use facilities at UNIS, Longyearbyen for research should be further encouraged.

Further, it is recommended that contractors and oil companies continue to prepare themselves for activities in the High North. For involvement in the region there *are* specific challenges that require relevant competence. The training course offered by the University of Stavanger, UiS (cf. appendix III) and the newly established education program between UiS and Gubkin University in Moscow may serve as basis or models for competence building.

It is also envisaged that the educational institutions located in the High North get heavily involved in education of the personnel that will operate the onshore as well as the offshore facilities in this region.

In order to follow international technology developments suitable for the High North it is, furthermore, recommended that international contacts be nourished. This also implies support to the potential for Norwegian authorities and specialists to contribute nationally and internationally to the safe and sustainable development of the petroleum reserves of the High North. Funds should in this respect be made available by the authorities so not only the larger oil companies and institutions can keep updated on ongoing developments. The Barents 2020 project has been an excellent program with wide national involvement.

It is recommended that keeping abreast with technology for ice covered waters is important in view of potential resources on the Norwegian Shelf in the far High North, for example in the Svalbard Offshore Zone. The potential for export of technology and technical solutions to projects in other Arctic countries is in this respect also important for oil companies and contractors.

Finally it is recommended that the technology and operational needs of the normally ice free region of the Barents Sea receive an increased attention in the near future. This will be particularly important in view of the activities that can be expected relatively soon in relation to the newly identified petroleum resources in the High North and to potential activities in the former disputed zone between Norway and Russia. One may assume that large joint development projects will take place with Norwegian and Russian companies working closely together in all project phases. Where reservoirs are identified across the boundary, such joint projects might even be shared on the national level.

2 Opinions and recommendations expressed in this report reflect the view of the authors and are not necessarily the views of the client (PSA).

Appendices

I. Questionnaire and Respondents

QUESTIONNAIRE

The questionnaire was submitted to selected Norwegian and international companies. The respondents were asked to distinguish, where relevant, between topics related to the Norwegian High North and topics related to International Cold Climate regions.

> The Petroleum Safety Authority Norway (PSA) is conducting an assessment of technologies and technology development needs for petroleum activities in the High North. Our focus is development of technology which may enhance technical and operational integrity as well as the working environment in cold climate operations, both offshore and on land plants. The scope includes, but is not limited to, advances in materials, components, equipment, systems, field development concepts, etc.

1. TECHNOLOGICAL CHALLENGES

What do you consider to be the most critical technological challenges for exploitation of petroleum in the Norwegian High North areas?

a) South Barents Sea b) North Barents Sea, including the Spitsbergen shelf

2. TECHNICAL SOLUTIONS

Do you work on technical solutions with specific relevance to the areas highlighted in question no. 1 above? If 'Yes', please indicate topics or challenges being addressed.

3. TECHNOLOGY PROJECTS

If you undertake technology projects, has information about this activity or your concepts been announced or published at conferences, in technical publications or press journals? If 'Yes', please refer to relevant sources.

4. NEED FOR ADDITIONAL TECHNOLOGY DEVELOPMENT

Do you perceive needs or technology challenges which are not being dealt with in ongoing technology developments? If 'Yes', please indicate prioritised areas.

5. IMPACT ON HSE

Will the technical solution(s) you work on have direct or indirect effects related to health, safety and/or environment, also with respect to impact on probability of unwanted incidents occurring and/or the consequences of an incident taking place? If 'Yes', please indicate the effects you foresee.

6. ENVIRONMENTAL AND METOCEAN DATA

Do you carry out activities related to collection and/or registration of relevant data for the geographical areas described in question no. 1? If 'Yes', we would appreciate information regarding the availability of the data.

7. TECHNOLOGY DEVELOPMENT PARTNERS

If you are in position to provide us with names, we would appreciate a list of cooperating companies in your High North projects.

RESPONDENTS

Companies that provided information through the survey questionnaire:

Ausenco Sandwell
Chevron Norge
ConocoPhillips Norge
Dana Petroleum Norway
Det norske oljeselskap
Eni Norge
E.ON Ruhrgas Norge
ExxonMobil Exploration and Production Norway
GDF SUEZ E&P Norge
Gubkin Russian State University
HSVA – Hamburgische Schiffbau-Versuchsanstalt
Idemitsu Petroleum Norge
IRIS
LOTOS Exploration & Production Norge
Lundin Norway
Maersk Oil Norway
Marathon Petroleum Company (Norway)
National Research Council Canada - Canadian Hydraulics Centre
National University of Singapore
NILU Norsk institutt for luftforskning
Noreco
NorLense
Norske Shell
North Energy
NTNU
OMV (Norge)
RWE Dea Norge
SINTEF Petroleumsforskning
Statoil
Talisman Energy Norge
Total E&P Norge
Universitetet i Stavanger

II. Recent events

Report from Arctic Technology Conference, Houston, Feb. 2011

The first Arctic Technology Conference (an Offshore Technology Conference event) was held in Houston, Texas during the period from 7th to 9th February 2011.
See: www.arctictechnologyconference.org/documents/ATCpreviewLowResJan06.pdf

The conference was advertised by the wording "The burgeoning Arctic arena offers a host of opportunities for companies that can solve the complex environmental, physical and regulatory challenges it presents". The key topical areas focused were therefore selected as follows:

- Resources;
- Exploration Drilling;
- Production Drilling;
- Facilities and Export;
- Physical Environment;
- Logistics and Marine Transport;
- Regulatory;
- Environment.

Regulatory aspects were particularly discussed with emphasis on

- the newly issued ISO 19906 "Arctic Offshore Structures" standard, which was praised as representing a great improvement as compared to previous arctic standards
- the Barents 2020 initiative by Norway and Russia to review all standards needed for safe development of the Barents Region, which was received without negative comments
- the regulatory regime in USA and Canada, where no drilling in the Arctic offshore has been allowed this year. Shell lacked one permit (of a total of 34) to start drilling during summer 2011. Frustration was expressed with respect to the uncertainties of obtaining permits. It was, however, generally accepted that the regulatory regime might change after the Mercado well blow out in 2010. Due to regulatory uncertainties, investments were now on hold.
- the opening of the Greenland shelf with licenses along the West coast of Greenland and in the Baffin Bay (Greenland was well represented at the exhibition that was held in parallel with the conference)
- the role of the "People of the Arctic", where the message was involvement and use of traditional knowledge, in particular with respect to description of severe (design) ice events

The discussion of the ISO 19906 standard was weak and suggestions to improve the standard or correct errors were only fragmentary. As this standard will be basis for all work in the Arctic and Cold Climate regions, including the Barents Sea, it will be necessary to openly discuss findings in areas where the standard gives insufficient answers.

Emphasis was placed on the potential **resources** in the Arctic with presentations from Russian scientists and a number of references to the USGS report on the resource potential of the Arctic: energy.usgs.gov/arctic

The Arctic Marine Shipping Assessment (AMSA) of the Arctic Council was conducted between 2005 and 2009. Canada, Finland and the United States led the effort under the Council's Working Group on Protection of the Arctic **Marine Environment**. The report can be found at www.pame.is/amsa/amsa-2009-report

The description of the physical arctic environment was, as expected, given much attention with reports from new data collection programs with main emphasis on Alaska offshore.

With respect to **technical solutions**, emphasis was placed on:

- The Shtokman Development Project, where a vessel designed with icebreaking capabilities and disconnection options is planned for the offshore spread.
- Barlindhaug Consult of Tromsø's presentation of results from use of a new computer program to calculate ice loads on vessels with high accuracy
- Ice detection, where different types of upward looking sonars are considered in combination with satellite and flight surveillance and the use of Autonomous Underwater Vehicles (AUVs, like the Hugin equipment developed by Kongsberg Maritime, www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/B3F87A63D8E419E5C1256A68004E946C)
- Technology for Escape, Evacuation and Rescue (EER), where the "Arktos" concept used in the Caspian Sea, is being developed for the Shear Zone
- Pipeline design for arctic conditions with emphasis on trenching depth and trenching technology as well as different solutions to enhance flow in pipelines
- Loading from ice and the needs for and effects of ice management to reduce the loading in operational state as well as in the design conditions

"Sustainable Arctic Coastal and Marine Technology", Centre for Research-based Innovation at NTNU

The research Council of Norway from 2007 to 2010 partly financed the PetroArctic project "Off-shore and coastal technology for petroleum production and transport from arctic water" at NTNU.

The objective of the project was to increase the knowledge of arctic / cold climate technology for safe and sound petroleum production and transport from the Arctic region. The project in particular aimed towards sustainable development and exploitation of petroleum resources in arctic waters and has enhanced the competitiveness of Norwegian oil industry with activity in such areas.

The project comprised nine topics which were all relevant for the oil industry and especially applicable for offshore petroleum production and transport in the ice-infested part of the Barents and Pechora Seas. The research which also is relevant for the petroleum development in the Kara Sea, the Caspian Sea and off Sakhalin comprised the tasks:

Task 1: Ice ridges
Task 2: Dynamic ice actions on structures
Task 3: Marine units in ice
Task 4: Ice gouging and protection of sub-sea installations
Task 5: Berm breakwaters and ice barriers in cold waters
Task 6: Ice actions on jack-ups
Task 7: Thermal stresses in ice and inhomogeneity
Task 8: Collection of ice pilot experiences from sealers
Task 9: Miscellaneous (workshops, printing of books)

The PetroArctic project is being followed up with a new centre for research-based innovation at NTNU: **SACME** - "**Sustainable Arctic Coastal and Marine Technology**". The Centre has been granted funding for 5 years with possible extension for another 3 years.

The centre's primary objective is to develop the technology needed for activities in arctic areas, both for offshore operations and for land-based activities. The centre's focus is on climate related challenges and safety as related to damage and wear from ice and weather conditions at offshore installations and on inshore infrastructure where climate change could lead to erosion and reduced permafrost. The centre's broad geographic range will include North Western Russia.

The PetroArctic project and the SACME centre both build on research carried out at UNIS, Longyearbyen.

III. Industry upgrading - training courses (examples)

Arctic technology (University of Stavanger)

The University of Stavanger has developed and delivered industry courses focusing on arctic engineering. The most comprehensive package was developed for the marine contractor Acergy in 2009 / 2010 involving the following series of courses that together represented one year's work:

- Arctic Technology I
- Operations and maintenance
- Arctic Environmental Technology
- Offshore industry and External Environment
- Marine technology and design
- Reliability Analysis
- Arctic Technology II
- Pipelines and risers in cold climate regions
- Ecotoxicology
- Project Management 1

Other companies might want to replace some of these courses with topics like:

- Subsea Engineering
- Introduction to Petroleum Engineering / Offshore Field Development in Arctic conditions
- Marine operations in the Arctic

A short version of the Arctic technology courses, Operations in cold climate, has been organised for the marine contractor Subsea 7 and for Russian oil companies (in Moscow).

Further to this, the University of Stavanger (UiS) and Gubkin State University of Oil and Gas in Moscow have initiated a double degree Master program in Arctic offshore Field Development. The attending students will during the two years spend time in Stavanger and Moscow and will gain two diplomas, one from each of the universities. It is believed that the students attending this program will be particularly qualified to participate in joint Norwegian Russian projects in the High North.

For references see: www.tu.no/jobb/article290214.ece and www.barentsobserver.com/kick-off-for-norwegian-russian-double-degree-in-oil-technology.4951833-116320.html.

IV. Sources for arctic technology updates

CONFERENCES

Annual events

ARCTIC ENGINEERING - OMAE CONFERENCE - www.ooae.org
- Specialises in all aspects of ocean, offshore and arctic engineering, and in the recovery of resources in hazardous, offshore and arctic environments
- Organised by the Ocean, Offshore and Arctic Engineering (OOAE) division of the American Society of Mechanical Engineers (ASME International)

INTERNATIONAL OFFSHORE AND POLAR ENGINEERING CONFERENCE, ISOPE - www.isope.org
- Specialises in polar engineering aspects which relate to theoretical problems the engineers encounter when working in the polar environment
- Organised by The International Society of Offshore and Polar Engineers (ISOPE)

CONFERENCE ON ARCTIC FRONTIERS, TROMSØ - www.arctic-frontiers.com
- Specialises in discussing the sustainability of work in the Arctic
- Attended by company officials and those in government. In the past, the Norwegian official politics on the Arctic have been presented at this conference

Biennial events

CONFERENCE ON PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS - www.poac.com
- Scientific conference dealing with a wide range of port and ocean engineering aspects under arctic conditions

IAHR INTERNATIONAL SYMPOSIUM IN ICE - www.iahr.net
- Specialist scientific conference, mainly dealing with ice engineering
- Organised by the International Association of Hydraulic Engineering and Research (IAHR)

CONFERENCE ON PERFORMANCE OF SHIPS AND STRUCTURES IN ICE - www.sname.org
- Specialises in all aspects related to the performance of ships and structures in ice
- Attended by practical engineers and representatives from the authorities
- Organised by the Society of Naval Architects and Marine Engineers (SNAME)

CONFERENCE ON RUSSIAN ARCTIC OFFSHORE - www.rao-offshore.ru
- International conference and exhibition for oil and gas resources
- A “must” for oil companies that want to do business in Russia
- Development of the Russian Arctic and CIS, mixes technology and politics
- Organised by the official Russia

ARCTIC OFFSHORE TECHNOLOGY CONFERENCE - www.arctictechnologyconference.org
- Conference organised by Offshore Technology Conference (OTC)
- Emphasis on projects and lobby for sustainable Arctic offshore oil and gas activities

PUBLICATIONS

COLD REGIONS SCIENCE AND TECHNOLOGY

The most important journal for presentation of key papers on technology for cold climate.
ISSN: 0165-232X Imprint: ELSEVIER
www.elsevier.com/wps/find/journaldescription.cws_home/503326/description

JOURNAL OF OFFSHORE MECHANICS AND ARCTIC ENGINEERING (OMAE)

The journal presents key papers from the OMAE conference as well as other papers related to offshore mechanics and arctic engineering.
www.omae.org/jomae/jomaedatabase/jomaedatabase.htm

ISOPE JOURNAL (IJOPE) - JOURNAL OF THE INTERNATIONAL SOCIETY OF OFFSHORE AND POLAR ENGINEERS (ISOPE)
The journal presents key papers from the ISOPE conference as well as other papers related to offshore and polar engineering
www.isope.org/publications/publicationsjournal.htm

WEB SITES

BARENTS OBSERVER
Watching the events in the Barents region: www.barentsobserver.com

INSTITUTE OF THE NORTH
Emphasis on Arctic events in the Northern America: www.institutenorth.org
Weekly information updates (*Top of the World Telegraph*) can be subscribed to.

PETRO NORD
Petro Media's updates on the Northern Region (in Norwegian): www.petro.no/nord

V. Literature

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