Technological innovation as an ecological risk reduction instrument in the development of Hydrocarbon Resources in the Russian Arctic

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Abstract. There are many challenges on the development of oil and gas in the Russian Arctic, most risks facing the oil and gas industry are magnified in such an ecologically vulnerable region. Modern technology can help manage some of those challenges, by coordinating different sources of information in order to minimize risks that could end up in very costly tragedies in terms of losses of ecosystem services and human life, robotics reduce these risks. This paper concludes that Russian companies need to learn from the example of Norway and invest more in technological innovation.

1. Challenges on the development of the Russian Arctic

The Russian Arctic shelf contains more than 80% of all hydrocarbon resources found in the Arctic. As early as 1930 Russia started prospecting the Arctic for oil and gas before any other nation attempted exploration for hydrocarbons in the area. After the discovery in 1930 of the Chibyuskoe field new areas of concentration of hydrocarbons were found in the Yamal area and started production in 1935 [4].

The Arctic region has very extreme weather conditions, average temperatures most months might be -35°C, with high winds and waves during the summer months. Additionally, the Arctic everywhere has limited access to supporting infrastructure for human activity. While there are more than 1000 different tribes of people who live in the Arctic as a whole, these communities subsist with limited infrastructure and little access to sewage, water, hospitals and vocational and educational facilities. Most of these communities subsist on traditional methods, like hunting and gathering or the herding on animals indigenous to the Arctic. They heavily depend on seasonal hunts of wildlife and fishing [3].

The Russian arctic has areas where there was a high amount of industrial development, however, development has slowed down during the crisis of the 1990 and has been stalled after because of low investment and high costs of production. Many Russian companies, such as Rosneft, have completed projects creating infrastructure thanks to beneficial tax regimes in the region and to subsidies from the government. These projects still might not be sufficient for the needs of the region.

As oil fields reach maturity and pass into declining production, there is renewed interest in unconventional and challenging resources. Hydrocarbon resources in the Arctic do not only require more significant investments in the exploration and on the exploitation phases, they also require more significant investments during maintenance. Additionally, the costs of maintaining personnel in Arctic conditions are larger and logistics are challenging in average conditions, much more when there are difficulties [1].
Ecosystems in the Arctic rely on fewer natural species that can thrive in Arctic conditions, these species depend on a very narrow margin of temperatures for important processes like reproduction. The keystone species, on which most of the Arctic food web, including humans, are already under significant pressures because of global warming. Disruption of life cycles due to oil and gas activity in the Arctic can have significant consequences because of the narrow windows of open ice or of temperature gradients where some species carry on with their activities [4], [6].

Furthermore, the behavior of oil in ice and snow conditions has not been sufficiently explored. Oil absorbs differently in frozen conditions. Oil spills in Arctic conditions offer several challenges. First, reaching the areas where spills occur because of ice conditions. Second, the behavior of oil under Arctic conditions and the seeping into terrestrial and marine soils, permafrost adds another difficulty on the predictability of oil penetration in the soils.

Even during safest operations of oil and gas there might be leaks of oil. Oil is a complex mix of hydrocarbons. While lighter hydrocarbons evaporate in warm conditions, heavier components are more persistent and some, like aromatic compounds, have proven to be heavily toxic to fish particularly on their reproductive stages of birds in physical and chemical means, whether by coating or by ingestion. Toxicity of oil to krill, one of the centerpiece species of the Arctic, is the highest dangers of oil and gas exploration.

Countries like Norway have been at the leading edge of development for resources in the Arctic circle. Norway has developed many areas of the Arctic thanks to steep investment on technology. This table shows the averages of R&D of Equinor, formerly Statsoil, and leading Norwegians Service companies operating in the Arctic in comparison of other companies. Equinor has a deep leverage because of the large investments that it undertakes in Arctic and offshore projects. Overall these investments have translated into higher profits and into higher levels of production with few losses and a great record on safety.

The example of Norway shows that oil and gas companies can manage the challenges of the Arctic through the use of technology, not only to achieve profitability, but also reduce environmental damages and achieve higher safety. The technology used by Norway has not only opened many areas for exploration, it has been the basis of further improvements and innovation in oil and gas exploration.

Russia could achieve such levels if access of capital is similar. One of the reasons why Norway has achieved such results is the availability of service companies that have incentive to innovate because of competitive pressures. Russian oil companies are vertically integrated and are exposed to less competitive pressures. Access of capital problems in Russia do not favor smaller service companies or encourage an environment where they can thrive. This, in turn, may stall innovation which is one of the most important factors on managing the challenges of the Russian Arctic [4].

2. Technology in the Russian Arctic

The Arctic, in spite of all of its promise, has been explored less than any other region and because of this there is comparable low amounts of geological, chemical and ecological research that can be used to guide development. In spite of increasing amounts of investment on research by the US, Canada, Norway, the EU and Russia, there is less research than is needed specially in one of the most important areas of the Arctic, ecology and methods to assess the consequences of exposure of Arctic ecosystems to oil and gas development.

While development of Oil and Gas in challenging Arctic conditions is more difficult, it is not impossible. We have many modern technologies that can aid in managing these challenges, and already have shown to be reliable in fields operated by Equinor, Gazprom and Rosneft.

Oil and Gas companies produce lots of data, and this data is a resource that can help manage the challenges of oil and gas exploration in the Arctic. One of the goals for modern companies is the capture of meaningful data that can be translated into knowledge to be used as input for relevant decisions. Oil and gas companies are data rich because of the many sensors that are needed for operations, however those sensors can’t always be coordinated with modern technology to enrich the process of evaluation of operations and decision making [1]. There are companies that have attempted and are currently
attempting to bridge that gap but many of them have been limited on participating with Russian companies in Arctic projects because of the recent international sanctions directed particularly to the oil and gas industry. A significant part of the Russian infrastructure is mature or aged and is more difficult to adapt to a digital framework. However, Gazprom, Rosneft and Novatek have been investing heavily on the construction of new and modern, digital-ready wells, fields and treatment plants.

Russian companies like Gazprom have been routinely criticized for big capital investment, but modernization is the key of better connectivity. Even if such investments might look like a loss over the short term, they will turn into gains in the future. The long business cycles are not always perceived by investors or reflected by share prices [5].

The most promising technology in the Russian arctic is the use of remotely operated vehicles that can perform functions of supervision, installation of equipment and regular monitoring. The latest models with intelligent control and machine learning can assess a situation and locate a menu of solutions. Machine learning can connect these robots with data of other wells that can bring alerts and focus on what could be the problem. The robot can then choose the option on that menu that better fits the problem. There are also possibilities that these robots can run Monte Carlo simulations and, if approved, can choose a solution at a speed that no human could. The most dramatics accidents on history of the oil and gas industry, for example the Exxon Valdez, the Proudhomme Bay spill, and the Deep Water horizon, have occurred because of human error. The use of big data, connectivity, cloud and machine learning, digital twins, even gamification and wider simulations can provide us with tools that can significantly reduce human error. The risk is that some of this technology has not been deployed for enough time to adequately evaluate their effectiveness and their long-term consequences [6].

Robots even in their simpler functions of supervising and reporting conditions can work for longer times than humans. Offshore robots operating supervising conditions of pipes on offshore Norwegian installations have batteries that can work throughout the whole year, these robots not only reduce the cost of human deployments, but they have no down time in an industry of constant production demands. Offshore and Arctic conditions are challenging for humans and, as we have already discussed, raise the cost due to the logistic demand. The use of robotics, especially on underwater construction and pipes, both reduce costs after the initial investment and provide more reliability to oil and gas development. Reliability is particularly important under the unpredictability of Arctic conditions. Robots like ANYmal have been performing offshore since 2018, in functions of supervision and leak detection [2]. Other robots like Argonaut perform functions in pairs for verification purposes while on deployment [16].

Many tests point at the possibilities of using drones to assess oil spills and gas leaks. Drones can be armed with sensors that can detect even minute amounts of chemicals. The drone then can send information to a center that can assess risk against already existing data of accidents. If this data seems out of the normal it will send an alert that will compare it to a larger pool of statistical data. If a risk is observed over the tolerance programmed the intelligent engine deploys further resources such as repairing robotics or alert the emergency management plan. Time is of the essence when an emergency occurs in the Arctic, the longer than an oil spill or leak continues the larger volumes of hydrocarbons that are thrown into the ecosystem. Rapid response is essential on Arctic development [6].

Optic exploration of oil and gas resources can reduce the needs for sonar technologies that might damage the delicate hearing systems of whales or might deter fisheries movement. Sonar systems have before impaired the movements of fisheries, and sound disturbance might affect communication in cetaceans and might translate like predatory movements for prey species. Sound Disturbances can occur both during exploration and exploitation of oil and gas hydrocarbons but are less dramatic during transport.

Smart wells and smart fields have some of these capabilities written in their DNA and, in this sense, they are quick to adapt to the challenges of the Arctic. Yet to be used efficiently they must coordinate with many different sets of data. This is one of the most important elements of successful operations in the Arctic that respect the integrity of ecosystem services and retain safety standards. Smart wells must connect to sources of ecological data. For example, sensors of the positions of migrating animals that might impact the construction of pipelines or sensors of wildlife or plankton that might be affected by
run off. Production can be delayed or accelerated so production does not disturb natural functions. Fully automated wells at Osberg have been operated without any significant incidents [15].

Unfortunately, to prioritize ecological processes, we need to qualify and quantify them in terms of economic losses and costs considering regulation. Ecological regulation in Russia is not always as straightforward as in other nations with stricter legal systems. Russia has penalties for pollution but also taxes and fees for the intake of water. Some of these penalties and fees are overall lower than in other nations, but they are higher than those in developing nation. Russia has had some of the most remarkable ecologists, particularly in the 60s and 70s, but there has been little coordination of ecology with the economic sciences in order to value the ecosystem services or their damage by the extractive industries. There have not been major oil spills like the ones of Exxon Valdez that have affected Russia, and because of this the legal systems to assess and resolve oil issues is untested. We have to remember that most US regulation about oil spills were crafted out of need and many after dramatic accidents showed the width of their consequences. Russia lacks experience in this issue, even though there has been reports of pipe leaks in Siberia, these incidents have not been so dramatic as to require a legal reform.

One of the latest technologies that could affect repairs is robots that include 3D printers that can produce themselves parts in critical areas for maintenance. 3D printers and robots capable of using machine learning and interpret data to take resolutions in simple tasks and obtain reinforcement for their decisions and finally big data and digital connectivity are already in development and deployed in some testing sites. This technology could potentially save millions of dollars because repairs could be done on-site, cutting downtime. There are already digital pigs that can clean pipes, in the future it might be possible for a robotic pig to receive information from a sensor, then assess the weakness in the pipe, explore the area, 3D-print the necessary materials make repairs, and test the strength of the repairs.

![Figure 1. Operator expenditures and Operator Intensity in Service companies Source Dolittle](image)

Although this article intends to consider the relation between the use of robotic and digital technologies and profitability, profitability in the oil and gas industry is affected by some factors more than others. One of the strongest elements on profitability in oil and gas is price. Oil prices are such an important factor in the industry that can turn a company that was highly profitable at one price into near bankruptcy after a correction. The oil and gas industry has OPEC, which attempts to stabilize prices for oil producer nations, however, not all produced countries are subject to OPEC control. The shale
revolution in the US threw a large supply of gas and oil that took oil and gas prices into a dive. This affected the profits of other oil and gas companies like Rosneft and Gazprom. The oil and gas industry is also sensitive to changes in regulation, Norway’s carbon taxes for example have already shown a negative effect on profits of Equinor in the year 2018-2019. Companies that are more profitable might indulge on higher capital expenditures, but at the same time, companies that maintain higher profits by lowering costs could be endangering their future in the industry by neglecting to make improvements, repairs or by failing to incorporate technology that will constitute a competitive advantage.

In the attempts to form a model that can show the advantages of investing in high technology on oil and gas development in the Arctic, we have encountered the fact that many large international oil companies have outsourced innovation to service companies. Norway’s Statsoil, one of the leading national companies, makes widespread use of service companies to support its technological needs. Because of this, counting the investment in technology in Equinor alone would give an incomplete picture of the relation between Equinor’s profitability and its investment on R&D, while national companies investment on R&D would have a more direct relation to its profitability. The difficulties of accounting for this disparity are the reasons why such calculations are not essential to this analysis. A means to approach this issue is to adjudicate a factor of the profitability of the service company to the large oil company as a percentage. For example, Equinor would be given a percentage of the R&D of Aker solutions corresponding to the number of contracts it was awarded by Equinor. This skewing on the investments in research and development for oil and gas companies that make extensive use of service companies might inaccurately reflect the percentages of the services company invested on one technology. Because of that, the more accurate models for investment on Research and development are the ones in the National companies.

3. Developing a model to explain the benefits of technology in the Russian Arctic
Because of the absences of statistically significant data in oil and gas development in the Arctic and the impossibility of presenting complete data on technology that has not been revealed by individual companies, is difficult to present an accurate model on the effects of R&D in profitability of enterprises on oil and gas in the Arctic, however we can present individual cases of technologies that have increased profitability. We can also present some of the links between profits and research and development data, but we do not claim that this is a perfect correlation as it is affected by previously explained factors. We can reduce these by using years in which the prices of oil and gas fluctuated the least. We can formulate this statement: The results we obtained only considering 4 companies, Gazprom, Rosneft, Lukoil and Equinor are shown in figure 2. Multiple R = 0.96574397 R Square = 0.93266141. Correlations with larger western companies with limited Arctic operations show a lower correlation and are not included.

2017 Market Cap to R&D for Companies operating in Arctic

![Figure 2. Correlation between Market cap. and R&D in companies Operating in the Arctic](image)

Benefit of Innovation Technology in the Arctic BAT = reduction of waste of resources $R_{w}$ + reduction on damages to the environment $R_{env}$ + reduction on the costs of penalties and clean up and restoration $R_{e,ren}$ + reduction on the cost of personnel and operation $R_{pen}$, + reduction insurance costs
Re_{ins} and might increase attractiveness of investment+ reduction on time or down time Re_{dt} + residual benefit for further innovation Inc_{inv} as patents developed out of original patent Pt_{ad} + licensing of the technology Inc_{lic}.-Cost of Technological Investment on Technology in the Arctic C_{tech} = cost of training to use such technology through risk of technology C_{train}, divided by Risk R. Unfortunately, some of the required information was missing to fit on the model but running regressions with the limited variables available [11], [12], [13], [14].

$$BAT = \left( \frac{(Re_{env} + Re_{pen} + Re_{clean} + Re_{pers} + Re_{ins} + Re_{dt} + Pt_{ad} + Inc_{inv} + Inc_{lic}) - (C_{tech} + C_{train})}{R} \right)$$

3.1. Limitations of Model

Unfortunately some of the required information was missing to fit on the model, but running regressions with the limited variables to correlate the amount of Research and Development on Profits for all major companies involved in the Arctic showed a moderate to weak relation that shows that in itself this does not show the creation of value and that the proposed model might be a more accurate description. In the course of this year we hope to find the information to complete our estimations.

3.2. Collaboration

The Arctic is a very challenging environment due to all of the logistical, geological, hydrological, ecological, and biological factors that affect operations of oil and gas which in themselves are very complex and augment the risks of operations in any environment. These factors mean that there is a need for collaboration in many areas, and this collaboration is essential to the environmental safety, security and safety in the Arctic.

If there is an accident in the Arctic, for example an oil spill, it is likely that the damage will not be localized to a single country. Legislation on damage and on assessment of toxicity is often different depending on the country. This variation and lack of standards makes it very challenging to assess liability. As we observed, liability of a service company might not cover all the damages of a catastrophic incident. In Russia the state is liable to respond to emergencies and damages, not only the oil and gas companies. Insurance requirements in Russia are different than in other countries often less and not as clearly demarked. The Russian government does not hold bonds or funds, as in the case of the US superfunds, large bonds that are held by the government in the case of large pollution events to ensure that there is accountability. The US government also demands that oil companies that use vital ecosystems like wetlands and might damage them not only restore those ecosystems but also protect other wetlands that might be more resilient,. Some ecosystems can’t be fully returned to their previous state and therefore their services might be permanently compromised. The US in the cases of such large risks, for example in Louisiana, demands that another area that is far more valuable will be protected for every hectare of wetland that is used. Russia at this time does not have such legislation. Canada also has failed to assess the value of her wetlands and there is already significant damage that has been underestimated by current indicators. Many argue that this has been intentional in order to develop more of the tar sands at a lower cost [9].

Collaborative networks can help verify the damage to ecosystems and assess the risks of the technologies without bias. These networks can also better coordinate the capabilities that exist around the world. These collaborative networks are impeded by security concerns and by political and geopolitical problems. However, Russia has understood the need for collaboration among all stakeholders to avoid ecological catastrophes, and to distribute necessary knowledge and has participated in numerous initiatives, despite sanctions. Yet what is urgently needed is the ability to translate this collaboration into technological solutions and networks that can properly deploy those solutions [7].

Investment in technology can turn into an evolutionary instrument that increasingly creates profits for a company and develops the capabilities of a region and therefore of national potential, as it can be observed in Silicon Valley. Digital technology is poised to grow exponentially, and therefore any
investment on modern technology of oil and gas can become a mine for the future [8]. Some of the most advanced technology of oil and gas was developed in military settings and is kept secret. Some of the technology used in offshore and arctic settings also originates in space technology, as in many of the components of robotics. Security does not allow Russia or any other country to share its military secrets, however already deployed technology that might have already been reverse engineered might be able to be shared in certain contexts if it can offset the risk of the loss of income, or exposes patterns or open weaknesses in security or military networks.

Russia abides by the guidelines of agreements in fisheries and in cooperation with emergency response in the case of accidents in the Arctic and regularly takes its place in the Arctic council hosts activities and organizes and cooperates with research institutes in issues on social, economic and ecological issues [6], [10].

3.3. Change Management
Oil and gas development in the Arctic requires change in the way management addresses technology and the function of oil and gas as a part of society and environment. Although we are aware of some of the consequences and costs of the extraction of non-renewable resources in communities and in the ecosystem, in the Arctic these consequences can be more dramatic. This forces oil and gas companies to reconsider the technology and processes they have used and their possible costs for society in the perspective of the future of the planet. Although there are many ways to quantify the impacts of oil and gas, there have not been one standard across countries. In the Arctic these effects are likely to be shared by many different stakeholders, including fisheries, indigenous communities, natural ecosystems, and rare animals or plants. Development of Arctic resources requires technology that largely has not been consistently tested or is still in development. National companies that previously operated with secrecy and with the protection of governments can now be examined by international observers even without direct access to resources. NGO’s accused Rosneft of spilling large amounts of oil in Siberian forest and provided proof of that by the use of drones and GPS, for example.

Oil and gas executives need to integrate many elements in their decision-making including ecology, biology, chemistry, and geology through the use of very important data science that integrates the information through tools like machine learning in order to filter irrelevant information from relevant. These integrated elements can turn into outputs such as patents or new discoveries that might aid further research. According to the Innovation Index of 2018. Russia lags behind on conversion of inputs to outputs in Innovation, even when it ranks high on middle income nations on this index.

Figure 3. Russian Federation Scores by Areas. Global Innovation Institute 2018
Decision makers in oil and gas in the Arctic are facing different challenges and many stakeholders that might have been neglected in the past. However, the availability of new technology shows that these challenges can be undertaken by developing the capabilities needed through innovation. These capabilities require a new understanding that is adaptive, flexible and holistic in nature. Long cycles in the hydrocarbon industry coincide with long cycles of ecological processes, while this would have normally meant that there had to be a long wait before the development of some processes and tools, the technology of simulations and digital twins allow us to forecast with more certainty the possible changes that can occur if a variable is changed. Since oil extraction is such an environmentally invasive process, these simulations become even more valuable tools. More than ever, there are alternatives to oil and gas as energy sources. Oil and gas companies have to be concerned more with the needs of consumers, including the need to protect renewable resources in vulnerable areas like the Arctic Shelf.

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