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Implications of Arctic Energy Supply for European Policy Goals

by Sebastian Petrick (Kiel Institute for the World Economy, IfW) and Katrin Rehdanz (Kiel Institute for the World Economy, IfW, and University of Kiel, CAU).

1 Introduction

Climate change has made the Arctic Ocean and its resources more and more accessible for economic activities. Over the last 25 years the extent of Arctic summer sea ice shrunk from 7.2 million square kilometers in 1979 to only 5.3 million square kilometers in 2014 (Fetterer et al., 2002). The retreat was considerably faster than scientific models had been predicting (Stroeve et al., 2007). At the same time, the remaining sea ice is younger and, thus, usually thinner (Maslanik et al., 2011). Especially the hydrocarbon resources below the seafloor have attracted interest of the littoral states (Canada, the US, Russia, Norway and Denmark/Greenland) and beyond. This has led to considerations on the geopolitical and economic implications of Arctic energy development. This interest has increased even more after the US Geological Survey (USGS) confirmed the rich resources under the Arctic seafloor (Gautier et al. 2009). USGS estimates that about 30 % of the world's undiscovered natural gas and 13 % of the world's undiscovered oil may be found beneath the Arctic seafloor, with especially promising areas in the European Barents Sea and off the coast of Greenland (Gautier et al., 2009). Even so, the special conditions in the Arctic, namely low temperatures, long periods of darkness, presence of winter ice and icebergs, lack of infrastructure and environmental risks, aggravate the extraction of resources, make it more expensive and risky.

This report highlights the economy-wide implications of potential resource extraction in the Arctic, comparing different future development pathways. We evaluate economic consequences, both for Arctic countries and beyond. Our analysis is based on a larger study on the implications of Arctic offshore oil and gas production for Europe (Calzadilla et al., 2014). In our analysis we focus on a number of EU policy goals including economic prosperity (Section 3), energy security (Section 4), price stability (Section 4), and climate protection (Section 6). We add to Calzadilla et al. (2014) by discussing the implications of Arctic energy development for European security of energy supply. The next section (Section 2) provides information on the methodology applied and the scenarios used.

2 Scenarios and Methodology

For our analysis on the policy implications of Arctic hydrocarbon production we use the scenarios and methodology employed by Calzadilla et al. (2014). As future development of Arctic energy production is unknown at present, Calzadilla et al. (2014) use a number of scenarios on potential developments of offshore Arctic energy production that differ regarding location, produced quantities, and technology. For a specific location, with given technology and costs, they assess the economic viability of production and, should production be viable, the economic impact of production.

For the assessment of economic implications of Arctic offshore gas production Calzadilla et al. (2014) link two models; a partial and a general-equilibrium model. Partial-equilibrium models focus on one particular sector; general-equilibrium models consider other sectors as well to determine economy-wide effects but tend to be more comprehensive, both spatially and in terms of economic sectors. To assess the viability of natural gas production as well as the direct effects on world gas markets, they use the partial-equilibrium gas market model COLUMBUS, developed by the Institute of Energy Economics at the University of Cologne (see Growitsch et al., 2013, for more details of the model). COLUMBUS models natural gas production and trade in great detail, including location-specific production and mode-specific trade, i.e. differentiating between pipeline and LNG trade. For the macroeconomic assessment, i.e. the impact of downstream sectors and second-round effects, as well as for the economic assessment and direct market impact of oil production, they use the general equilibrium model DART, developed by the Kiel Institute for the World Economy (see Klepper et al., 2003, for more details of the model). DART provides a comprehensive representation of the global economy, including, among other things, overall economic activity and repercussions on up- and downstream sectors, substitute fuels, international linkages through factor movements and trade in goods other than natural gas as well as CO_2-emissions.

For the analysis of the economy-wide impacts of Arctic oil production Calzadilla et al. (2014) use only the DART model. This is, on the one hand, dictated by data restrictions regarding detailed and comprehensive oil market data. On the other hand, the oil market is less complex to model, since it is, contrary to natural gas, a global market with one global price as opposed to regionalized natural gas markets with price differences across regions. For that reason, the depiction of the oil market in DART seems sufficient to analyze also intra-market developments.

Calzadilla et al. (2014) use information on cost and standard quantity estimates for Floating Production, Storage, and Offloading facilities (FPSO) from an independent engineering and consultancy company (IMPaC, 2012). They assume a standard train capacity of 5 bcm gas and 2.8 mtoe oil, respectively, and up to two trains can be built within the modelling horizon, which is until 2040. Cost assumptions are given in Table 1 (except for the Existing Locations scenario, where the cost parameters from the existing Yamal and Snøhvit projects are employed as included in the COLUMBUS model). Alternative production technologies (e.g. subsea production) are less profitable but differences between technologies are small (Calzadilla et al., 2014).

Table 1: Cost assumptions for arctic offshore oil and gas production (Floating Production and Offloading Unit)

	Development cost mio EUR (20 years lifetime)	Production Cost mio EUR/a
Natural Gas	5,530	490.0
Crude Oil	2,800	332.4

Numbers assume annual production of 3.6 mtpa (gas) or 2.7 mtpa (oil). Numbers include shipping and receiving terminal. Source: IMPaC (2012), adaptation by Calzadilla et al. (2014).

Table 2 describes the Reference Scenario and two alternative scenarios (Existing Location Scenario and Greenland Scenario) to analyze prospective natural gas production in the Arctic (Calzadilla et al., 2014). Calzadilla et al. (2014) include another scenario (Barents Sea Scenario). This scenario tests whether additional production in the Norwegian or Russian Barents Sea is profitable. Since this production cannot fall back on the already existing infrastructure in Hammerfest, Sabetta and the production sites, the cost assumptions presented in Table 1 are more demanding than the assumptions in the Existing Locations Scenario. Consequently, Calzadilla et al. (2014) find that production in new sites in the Barents Sea is not profitable and no additional production takes place. We do not consider this scenario further.

Table 2: Descriptions of scenarios for the analysis of Arctic natural gas production

Scenario	Description
Reference	Until 2018, infrastructure capacity (production facilities, pipelines, LNG-terminals, storages) is exogenously specified, including the Norwegian Snøhvit plant and the Russian Yamal LNG-project. Investment costs for these capacities are assumed to be already paid off. Beyond 2018, endogenous (i.e. "model-driven") investments in infrastructure assets are possible except for the production sites Yamal and Snøhvit. It is also assumed that LNG-tankers with destination Asia are able to pass the Northern-Sea Route during four ice-free months a year which is about one third cheaper than passing the Suez Canal. Demand developments in the model are derived from the World Energy Outlook (2013).
Existing Locations	The goal of this scenario is to see whether it is economically rational to expand the already existing capacities of locations in the Norwegian Barents and the Kara Sea; the Snøhvit and Yamal projects. Since expansions would benefit from already existing infrastructure, the cost assumptions are less demanding than the assumptions for the other gas scenarios. Additional Arctic offshore production amounts to 5.4 mtoe in Norway and 20.7 mtoe in Russia by 2040.
Greenland	This scenario tests the economic viability and effects of FPSO technology in Greenland. According to Calzadilla et al. (2014), production is economic and additional offshore production in Greenland amounts to 8.4 mtoe in 2040.

Source: Calzadilla et al. 2014.

For crude oil production, we use a Reference Scenario and three alternative scenarios (Norwegian Arctic Scenario, Russian Arctic Scenario and Greenland Scenario) of Calzadilla et al. (2014). Details are presented in Table 3.[1] All three crude oil scenarios assume FPSO technology and use the cost assumptions of Table 1Table 1.

[1] For other scenarios including the Prirazlomnaya field in Russia, which recently started production, see Calzadilla et al. (2014).

Table 3: Descriptions of scenarios for the analysis of Arctic crude oil production

Scenario	Description
Reference	No offshore oil production in the European Arctic.
Norwegian Arctic	This scenario allows for offshore production of Arctic oil in the Norwegian Arctic Ocean. Up to two standard trains of 2.3 mtpa each can be added in 2020. All other parameters are those of the Reference Scenario.
Russian Arctic	This scenario allows for offshore production of Arctic oil in the Russian Arctic Ocean. Up to two standard trains of 2.3 mtpa each can be added in 2020. All other parameters are those of the Reference Scenario.
Greenland	This scenario allows for offshore production of Arctic oil in Greenland. Up to two standard trains of 2.3 mtpa each can be added in 2020. All other parameters are those of the Reference Scenario.

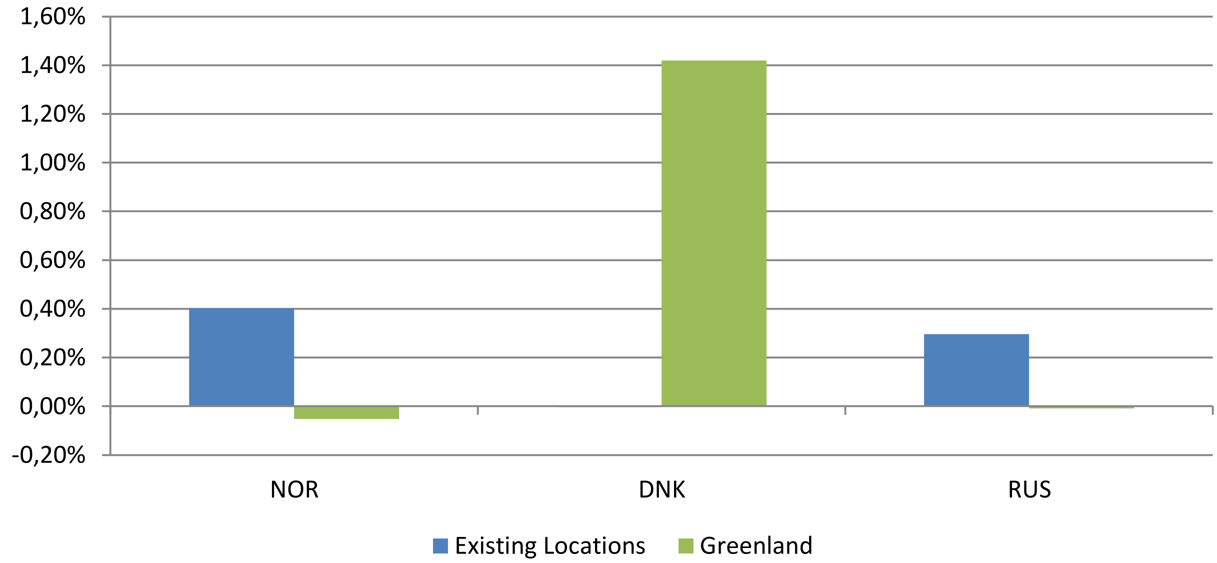
Source: Calzadilla et al. 2014.

3 Economic Development

Economic prosperity is a key objective of European governments and institutions. It is a policy goal both in its own right and because of the link between economic activity and a number of wellbeing indicators, such as employment, public and private investment, education level, or social security. GDP is probably the most widely used indicator of economic performance. Representing the value of all traded goods and services, it is frequently used as a measure of the general economic success of an economy (even though this is naturally a highly abstract and simplified view of economic success). In many countries, including both Norway and Russia, resource production constitutes a significant part of economic activity. Due to its position upstream of other production chains, resource extraction has in addition significant second round effects. As both energy resources themselves and the products of downstream production chains are traded, these second round effects spread to other countries that are not directly affected by further resource production, e.g. by cheaper or more affluent imports or by changing competition on export markets. Calzadilla et al. (2014) calculate the effects of additional natural gas production in the Arctic for the three Arctic countries (Norway, Russia and Greenland/Denmark) and for other countries that are only indirectly affected. Unfortunately, Greenland's accounts are not available separately in the DART model. For this reason, effects on Greenland are included in the effect for the Danish economy and Denmark and Greenland are presented as an aggregate.

Unsurprisingly, additional production of natural gas has an expansive effect on the economies of the producing countries (Panel a of Figure 1). Norway's (NOR) and Russia's (RUS) GDP grows in the order of 0.3 to 0.4 % in the Existing Locations scenario relative to the Reference Scenario. Despite the geographical proximity, Danish GDP is unaffected. Some other countries are, however, mildly affected (Panel b). Other natural gas producers, especially countries in North Africa (NAF), the Former Soviet Union (FSU) and the Middle East (MEA) suffer from increased competition on world gas markets and loose up to 0.08 % in GDP. Especially countries in Eastern European, being Member States of the EU (EEU) or not (NEU), benefit from additional gas supply. They gain up to 0.04 % of GDP in the case of non-EU European countries (NEU). In general, the impact on other countries' GDP remains small compared to the direct effects for Norway and Russia. While the effect of additional gas production on Norway's or Russia's GDP is considerable in the Existing Locations scenario, it is even higher for Greenland/Denmark in the Greenland scenario. Danish GDP increases by around 1.4 % relative to the Reference Scenario. Turning to the effect for other countries, the same set of countries is affected as in the Existing Locations scenario, although on an even smaller scale.

Panel a:



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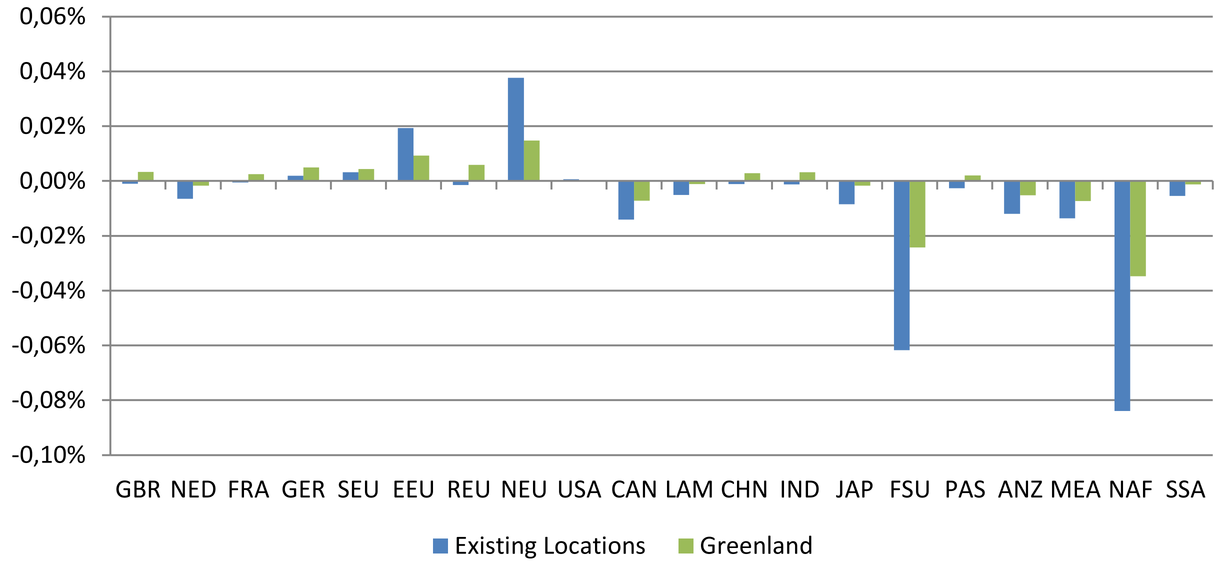

Figure 1: Change in GDP in 2040 for natural gas scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

Similar to the additional production of natural gas, also the new production of crude oil from the Arctic Ocean has a positive effect on economic activity in the producing countries (Panel a of Figure 2). GDP increases by more than 1.6 % in Norway (NOR) and Greenland (DNK). Not least because of the much larger size of the economy, Russia's GDP increases less, by just below 0.3 %. As in the case of natural gas, other oil producers suffer from increased competition on the global oil market, namely the countries of the Former Soviet Union (FSU), the Middle East (MEA), and North (NAF) as well as Sub-Saharan Africa (SSA) (Panel b). At the same time, though not to a similar extent, oil importers profit worldwide from increased production through lower prices. The gains are larger for countries being in closer proximity to the producing country or having existing trade ties (e.g. EEU and NEU in the Russian Arctic Scenario).

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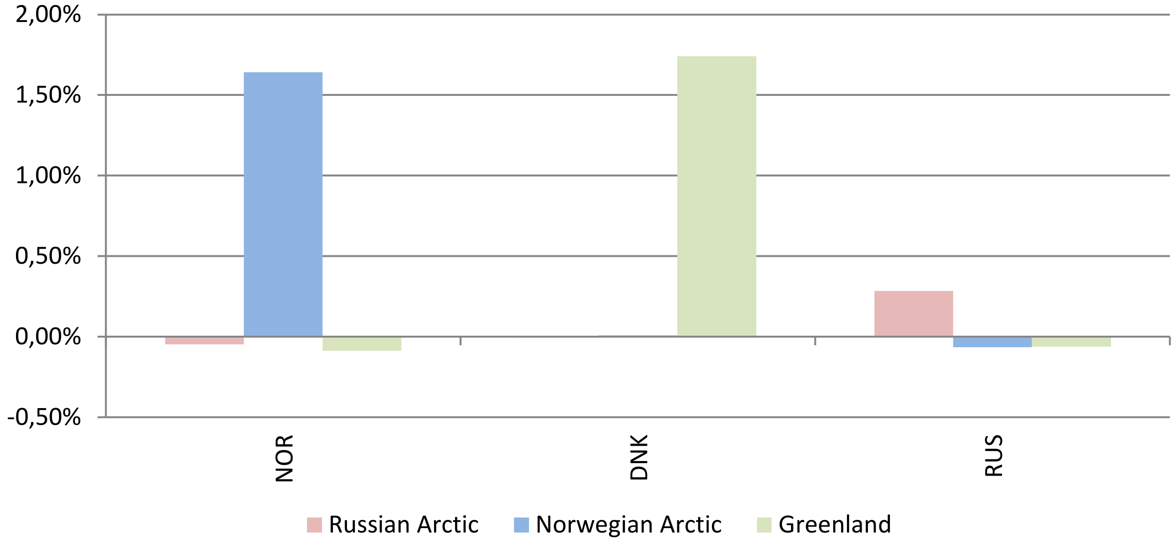

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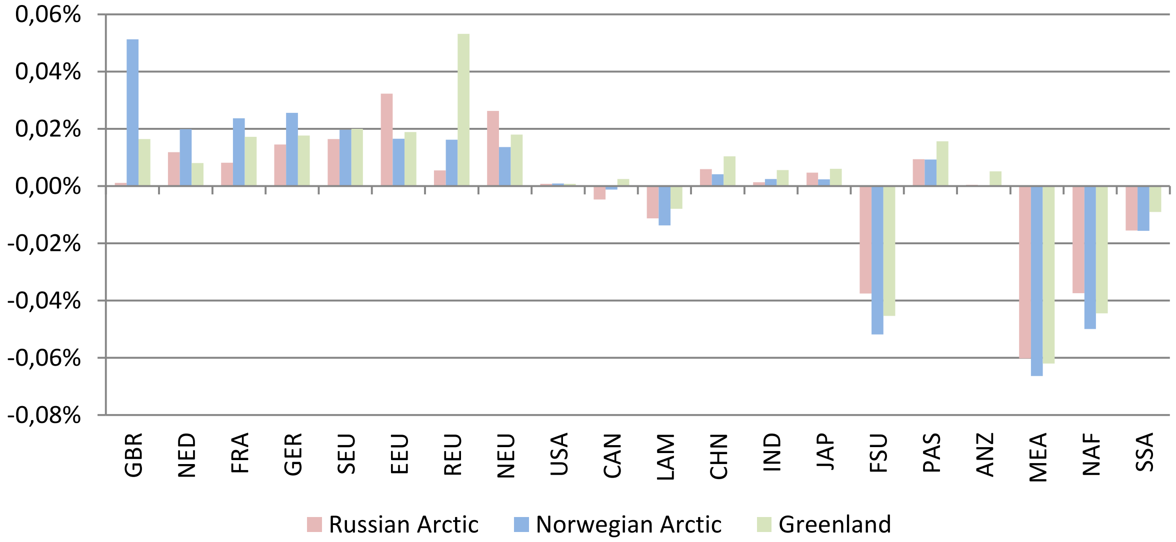


Figure 2: Change in GDP in 2040 for crude oil scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

In general, countries in Europe profit in terms of GDP from additional production of natural gas or crude oil in the Arctic, although on a very small scale. Exceptions are the Netherlands and the UK; both are natural gas producers. The gains, especially for gas importing countries are, however, unevenly distributed. Eastern European countries that heavily depend on Russian gas imports profit more from additional production than the Western and Southern European countries, especially if Russian production is increased.

Calzadilla et al. (2014) show that changes in national GDP are usually unevenly distributed across economic sectors, leading also to corresponding patterns in labor market shifts. In general, sectors that are close to the oil or gas sector in the value chain are affected most. This includes for example the oil products sector, the chemical industry and energy intensive industries.

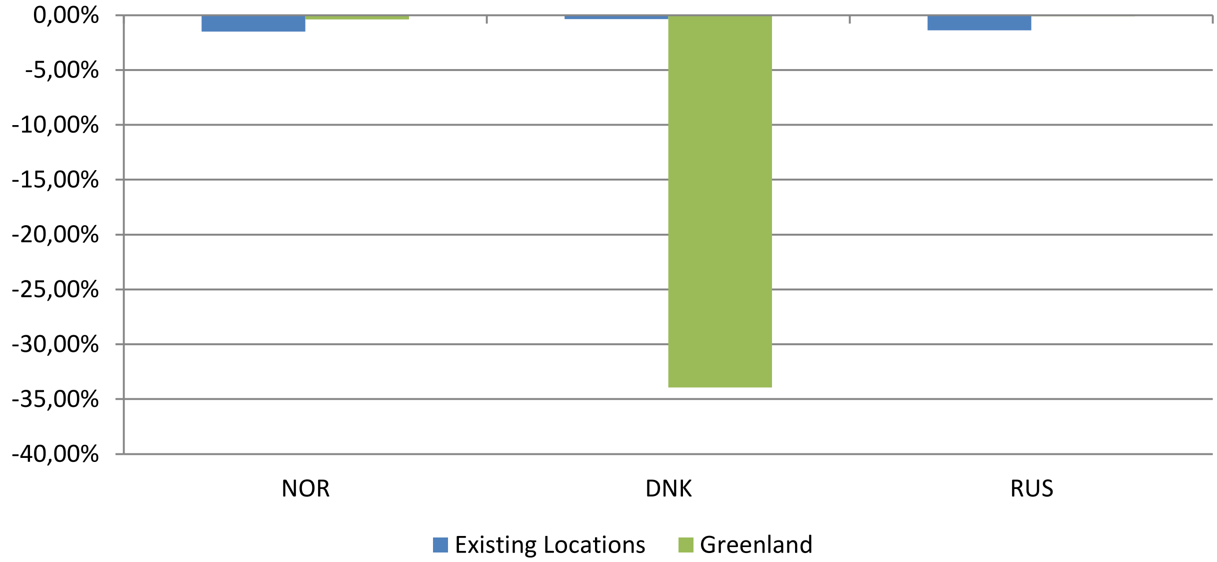
4 Price stability and inflation

Maintaining price stability is an important goal of economic policy across Europe. It was established as the primary objective of the ECB as a supra-national European institution. Excessive inflation is to be avoided, as it decreases the purchasing power of the currency and increases the opportunity cost for holding money, thus discouraging savings and impeding investment. Inflation also has distributional effects, as holders of physical assets witness an appreciation of their assets relative to holders of monetary assets, such as savings. At the same time, deflation of prices can be harmful to economies as well, as consumers and producers are holding back money through saving and underinvestment. Changes in resource supply are known to be potential causes for price movements. Additional access to resources will usually decrease prices, as additional supply of the resource enters the market.

Price changes are not restricted to the price of the resources, in our case natural gas or crude oil, but prices of other products may also be affected. There are three channels how process of other products can be affected: (1) energy as an input becomes cheaper, (2) other products compete with gas or oil in the case of substitute fuels or (3) other products compete with the gas and oil sectors on input markets, such as the labour market. Also potential Dutch disease effects, i.e. the disadvantageous appreciation of the producing country's real exchange rate, may affect prices via the exchange rate channel. While the first channel will lead to lower prices of other goods, the other channels might lead to higher prices. Thus, the overall direction of prices of other goods is unclear and depends on concrete circumstances. We study the price of natural gas (Figure 3) and the overall price level (a GDP deflator, Figure 4) for additional gas production as well as the price of crude oil (Figure 5) and the overall price level (Figure 6) for additional oil production.

Additional natural gas production in the Arctic Ocean leads to a decrease in natural gas prices both in the Arctic countries (Panel a of Figure 3) and in non-Arctic countries (Panel b). In the case of the Existing Locations scenario, the gas price decreases by 1.5 % in Norway (NOR) and 1.4 % in Russia (RUS) relative to the Reference Scenario. Other countries (including Denmark, DNK) are much less affected. Especially in Europe and in other gas exporting countries such as the Former Soviet Union (FSU) and North Africa (NF) prices decrease, with the price level in Germany being hit most. Here, gas prices decrease by 0.87 % relative to the Reference Scenario. The considerable decrease in gas prices in Norway and Russia pales, however, in comparison to the stark drop in the gas price in Denmark and Greenland (DNK) that follows additional gas production in the "Greenland" scenario. Here, the gas price drops by about a third compared to the Reference Scenario. Other countries are affected similarly to the Existing Locations scenario, with Norway, Germany and the Rest of EU Europe (REU) being affected most.

Panel a:



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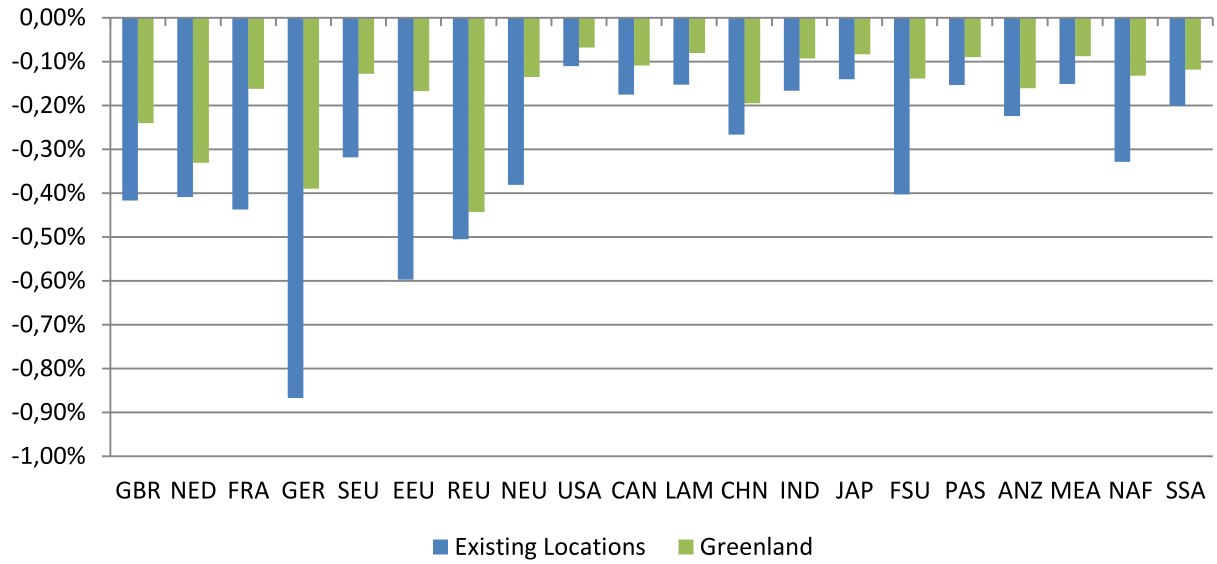
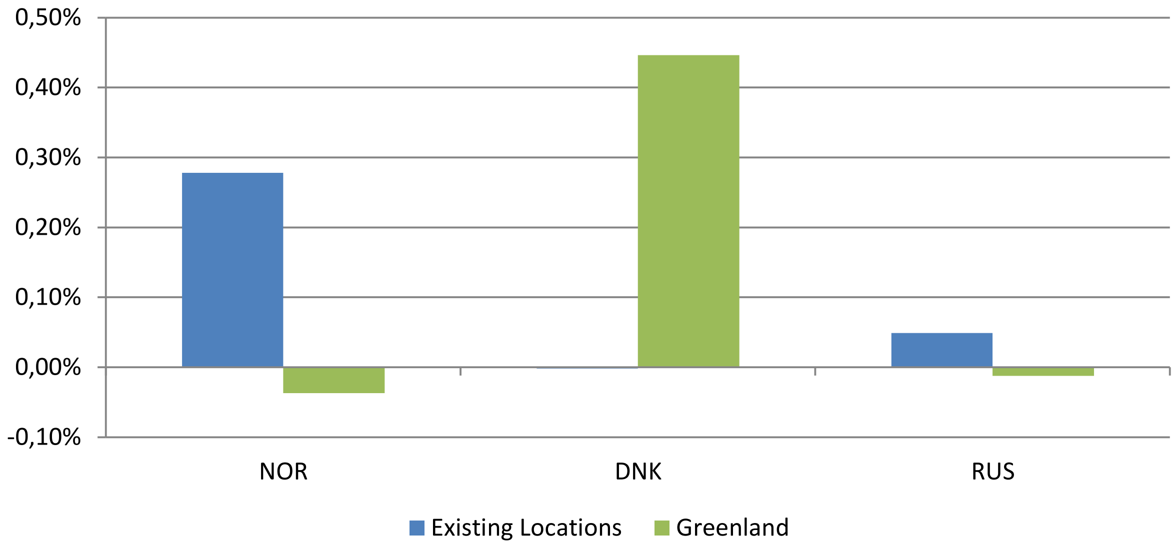


Figure 3: Change in gas price in 2040 for natural gas scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

While the gas price decreases worldwide with additional Arctic production, prices of goods other than gas change equivocally, yet not dramatically. In general, price changes for goods other than gas are largest in the countries that are directly affected by additional production. Prices rise by 0.22 % in Norway in the Existing Locations scenario and 0.28 % in Denmark and Greenland in the “Greenland” scenario. Due to the small amount of the additional natural gas from Yamal and its low significance relative to the rest of the Russian economy, prices for other goods only increase by 0.05 % in the Existing Locations scenario. Nevertheless, the price increasing effects of additional Arctic production, such as Dutch Disease effects, dominate in the directly affected countries. Effects on non-Arctic countries are small in comparison. Again, other natural gas exporters are affected most, such as countries from the former Soviet Union and North Africa. Most of the larger price level changes are negative relative to the Reference Scenario, presumably due to lower input prices.

Even though price changes in the natural gas sector are much larger than in the other sectors, the indirect price changes dominate the overall price development in most economies (Figure 4). This is because of the small size of the natural gas sector relative to the rest of the economies. Even in Denmark in the “Greenland” scenario, where we find an very significant natural gas price decrease, the overall price level increases, if only by 0.45 % compared to the Reference Scenario. The same is true for Norway and Russia in the Existing Locations scenario, though on a smaller scale (Panel a). Since price changes in non-Arctic countries are negative both for natural gas and other goods, we find a small overall negative effect for non-Arctic economies, again natural gas exporters are affected most.

Panel a:



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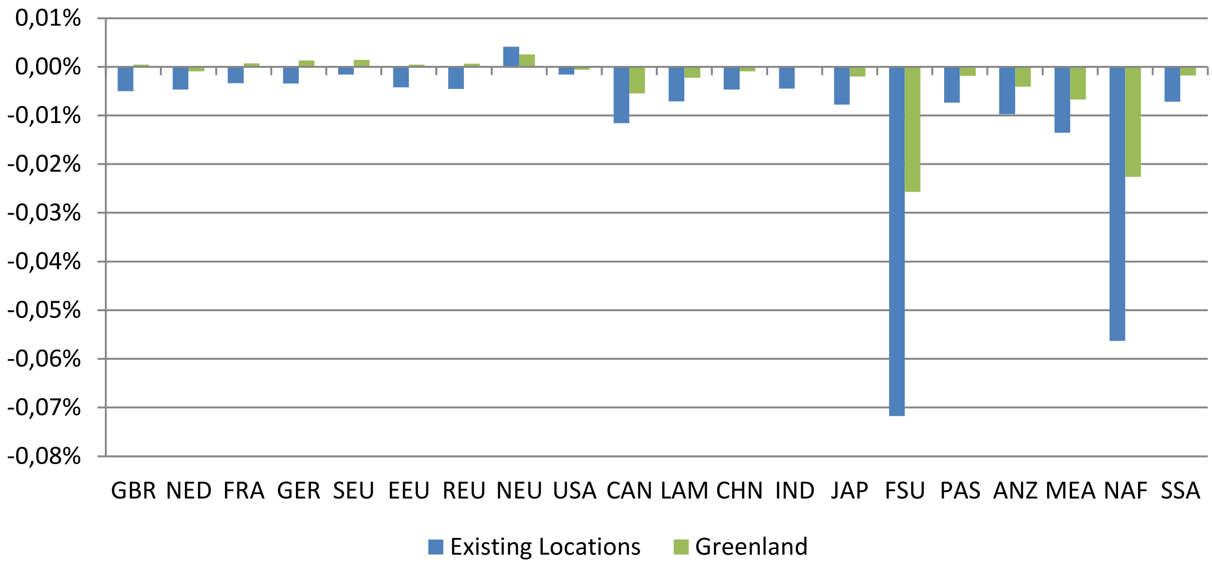
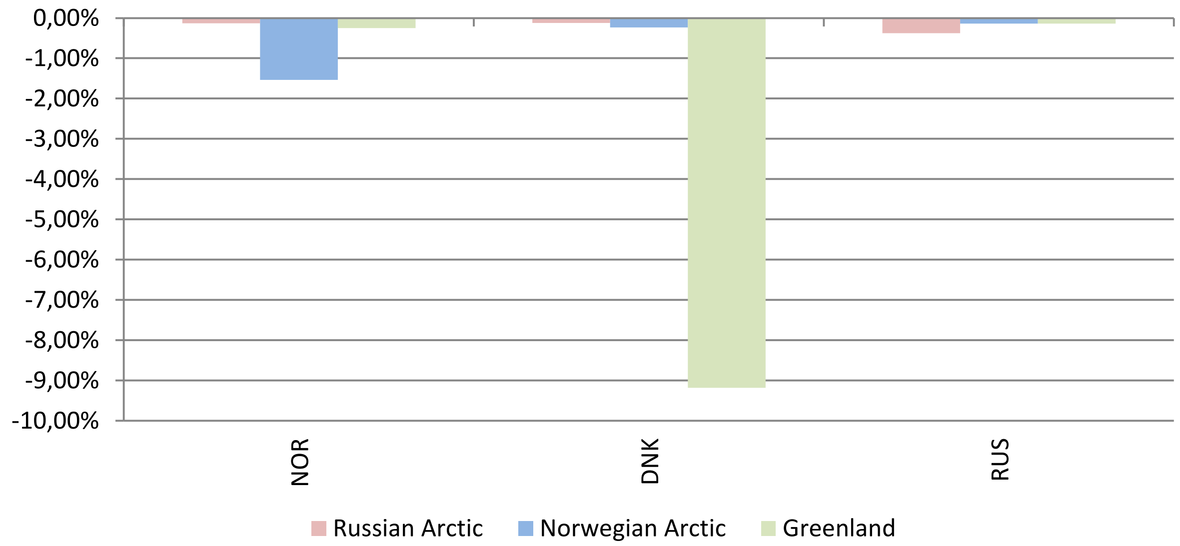


Figure 4: Change in overall price level in 2040 for natural gas scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

The oil price has been an indicator of global economic prosperity since the oil crises of the 1970s. Accordingly, it is of high importance for both oil exporting and importing countries. Additional crude oil production in the Arctic Ocean leads to a decrease in crude oil prices both in the Arctic countries (Panel a of Figure 5) and in non-Arctic countries (Panel b). The crude oil prices in Denmark (DNK) fall most significantly in the case of oil production in Greenland, with reductions beyond 9 %. But also in Norway (NOR, -1.5 %) and Russia (RUS, -0.4 %) crude oil prices fall after with additional production. Also in indirectly affected countries, the crude oil price falls, especially in countries that are close to the new production sites, such as the UK (GBR) in the case of Norwegian oil, or Eastern EU Europe (EEU) in the case of Russian oil.

Panel a:



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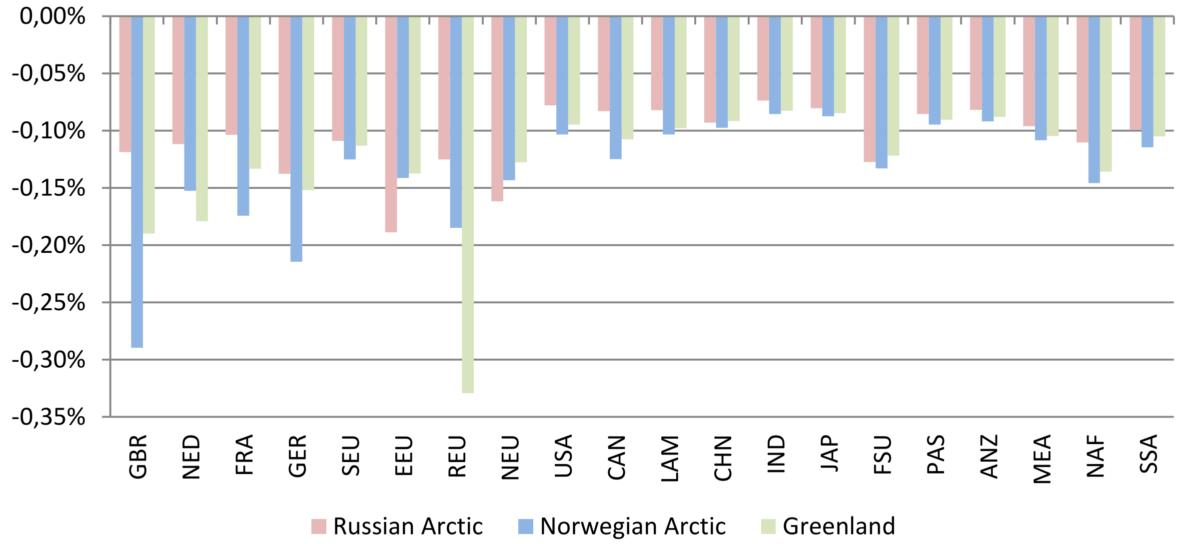
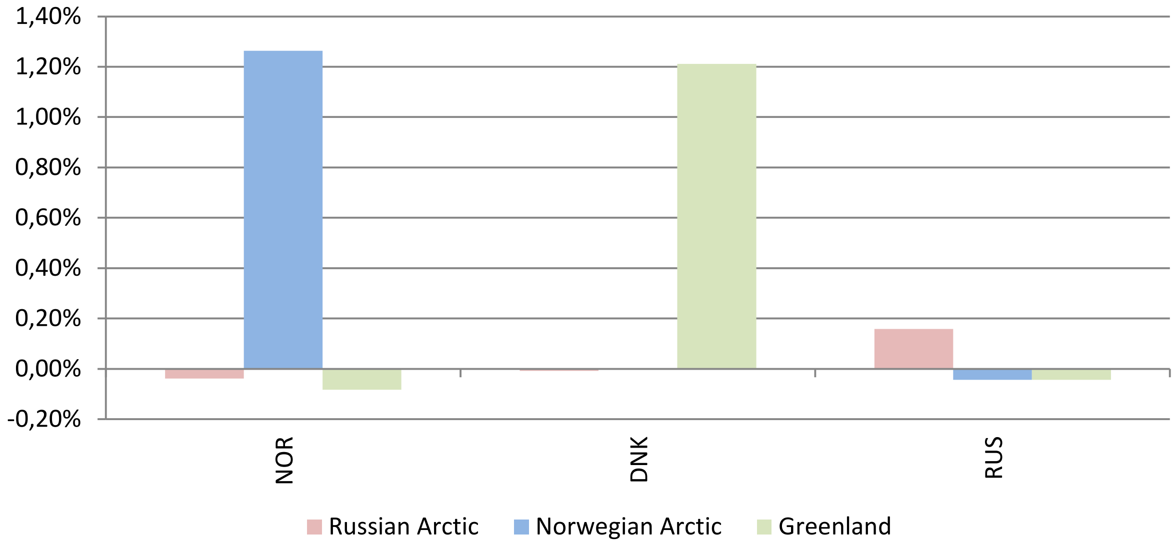


Figure 5: Change in oil price in 2040 for crude oil scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

The drop in crude oil price drops both in exporting and importing countries, trigger price changes of other goods and services. In the producing countries in the Arctic, price levels increase following additional domestic production. Especially Norway is hit in the Norway scenario, but also Greenland/Denmark is strongly affected. Again due to the larger size of the economy, Russian prices do not increase as much. As in the case of natural gas, price-increasing effects, including Dutch

Disease effects, dominate in the producing countries. In comparison, effects on indirectly affected countries are much smaller. Price movements differ qualitatively in different countries. The witnessed price decreases, especially in the Former Soviet Union states (FSU), the Middle East (MEA), and Africa (NAF and SSA) and presumably due to reduced input costs, are usually larger than price increasing effects, e.g. in the UK after additional production in Norway. Overall and on the aggregate level, the large price movements in the crude oil sector are mediated by the largely dominating other sectors. Nevertheless, the overall price level in producing countries still increases noticeably, with price increases up to 1.3 % in Norway and 1.2% in Greenland. Prices of indirectly affected other oil producers are only in a few cases significantly affected, namely in the case of the Former Soviet Union (FSU) countries, the Middle East (MEA) and North Africa (NAF). Prices decrease in all these countries, not least because of a large oil sector in these countries that suffers from reduced prices. Contrary to natural gas, we find an increase of the overall price level in some non-Arctic countries, too, such as in the UK (GBR). Nevertheless, these inflationary tendencies remain small.

Panel a:



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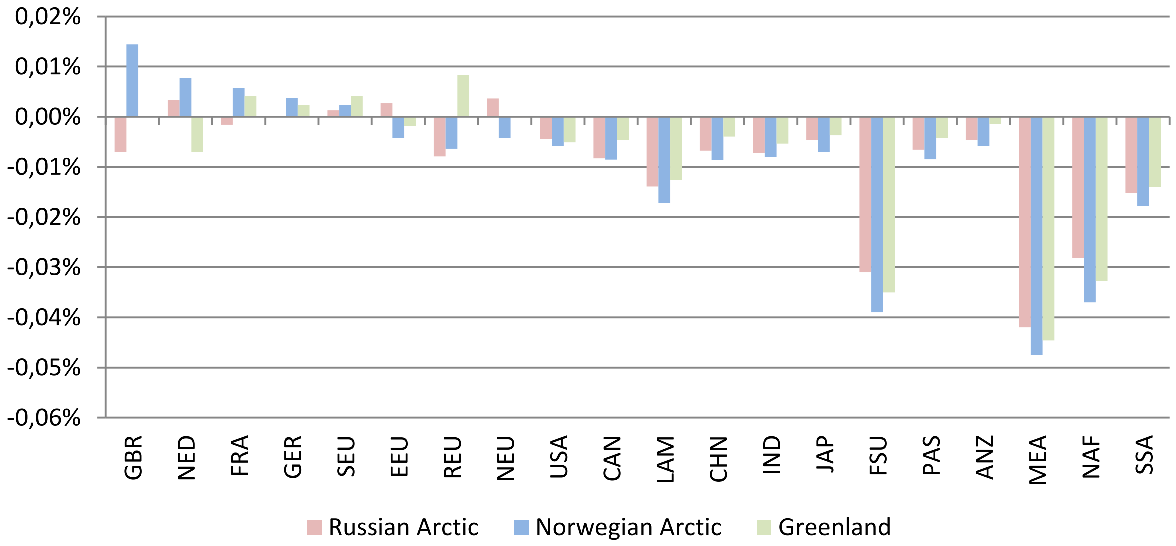


Figure 6: Change in overall price level in 2040 for crude oil scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

Additional production of natural gas or crude oil from the Arctic leads to a potentially significant price increase in producing countries, here fuelling inflation, even though the price of energy decreases. Reactions in the price level in non-Arctic countries are mostly marginal and will probably only be felt in the gas or oil sector, respectively. Here, prices fall, thus mitigating inflation or, in exceptional economic circumstances, fuelling deflation.

5 Security of energy supply

A more secure supply of imported fuels, namely for European energy consumers, is among the most prominent argument for the opening-up of the Arctic for resource exploitation. Access to sufficient and cheap energy is essential for the functioning of production processes as well as for the wellbeing of the population of importing countries. The price elasticity of energy demand is exceptionally low, as is consumers' tolerance for supply disruptions. Traditionally, the secure supply of oil is of importance for import dependent countries such as the EU. However, in recent years the security of gas supply attracted even more attention, as Western and Central European importing countries worry that natural gas supply may be used as a political lever by some exporters

We analyze a number of indicators that measure supply security, including import shares (Figure 7 and Figure 8) and import concentration (Figure 9, Figure 10 and Figure 11). We complement Calzadilla et al. (2014), who do not study security of supply explicitly. We use model output of the DART model for our calcualtions. Apart from studying security of supply here, the effect of additional Arctic energy supply on energy prices is analyzed in Secion 4.

Importers of natural gas react to additional gas supply from the Arctic by increasing imports, although only marginally (Figure 3). The most likely driver of this development is the decrease of natural gas prices. Especially large importers increase their import share, as well as importers that imported from exporters with the new sources before, such as the UK (GBR), Germany (GER), or the Eastern European EU countries (EEU) in the Existing Locations scenario. Nevertheless, the changes remain small.

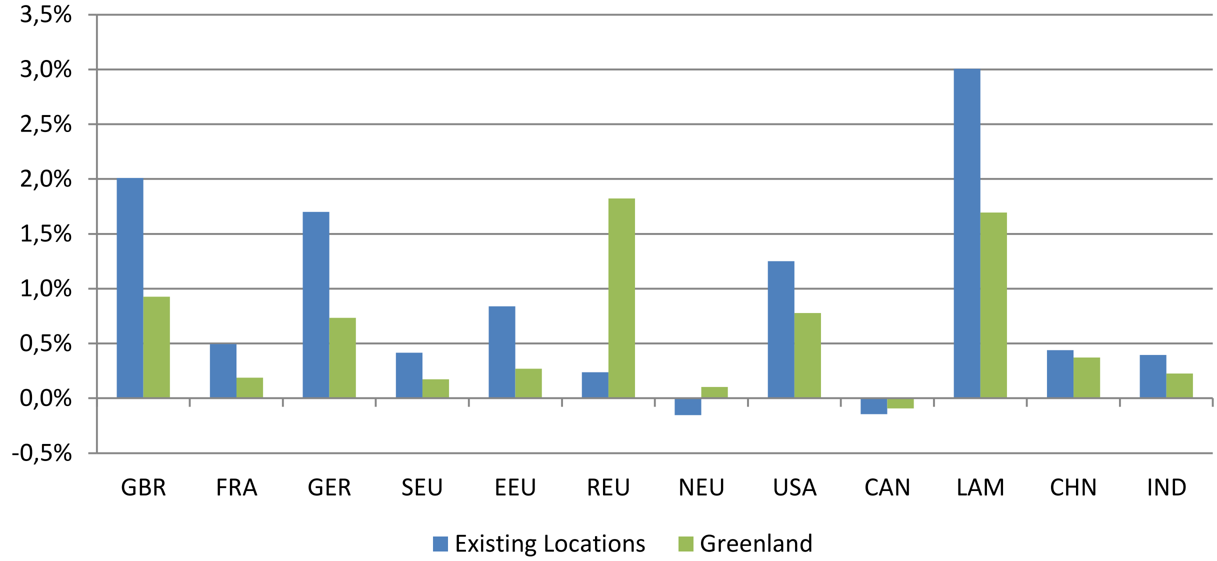


Figure 7: Change in natural gas import share in 2040 for natural gas scenarios, absolute difference to Reference Scenario (in percentage points, importers only). Source: Own presentation based on DART model results.

While the changes in import shares are small in the case of additional Arctic natural gas production, they are miniscule in the case of additional Arctic oil production. The largest change is just below 0.03 percentage points in Pacific Asia (PAS) for additional oil production in Arctic Norway. If oil production changes more regions of the world are effected. The wider distribution of changes across the world shows the larger homogeneity of the oil market compared to the regionalized nature of natural gas markets. Still, distance plays a role especially for European imports. Western and Central European Countries close to Norway, such as The Netherlands (NED), France (FRA), or Germany (GER) react stronger to additional oil production in Norway, while Eastern EU countries (EEU) react stronger to additional production in Russia.

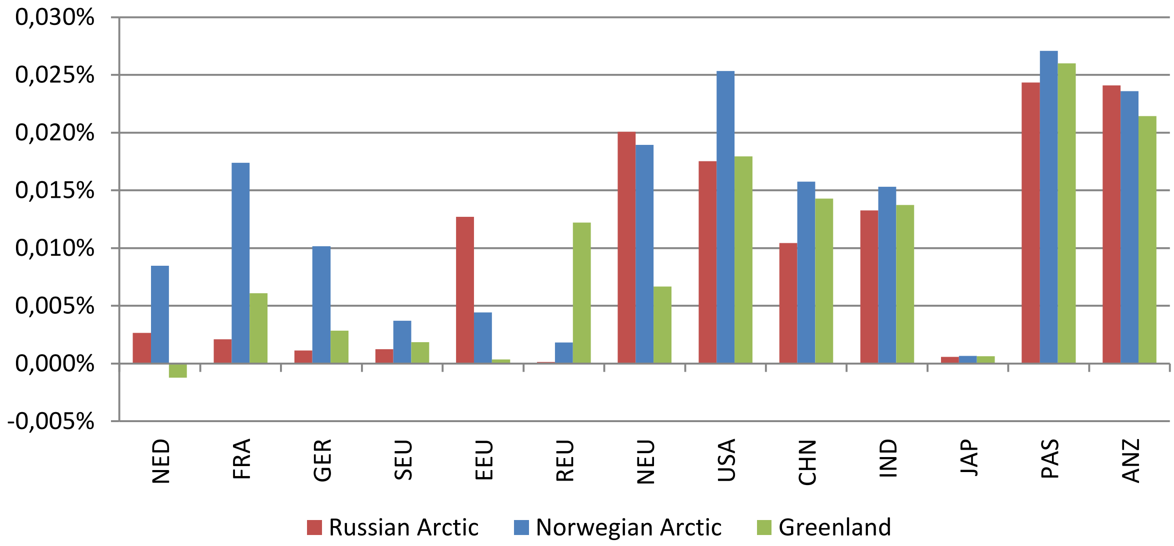


Figure 8: Change in crude oil import share in 2040 for crude oil scenarios, absolute difference to Reference Scenario (in percentage points, importers only). Source: Own presentation based on DART model results.

Next to the absolute amount of imported energy, the diversification of the import portfolio matters, as the failure of a single exporter can be more easily compensated if the portfolio is diverse and other exporters stand ready to compensate the loss. We measure the concentration of the supply portfolio using the commonly used Herfindahl Index (or Herfindahl-Hirschmann Index, HHI). It is calculated as the sum of the squared market shares of the various suppliers of a gas or oil importer and can take values between larger than 0 (many suppliers) and 1 (only one single supplier). In Europe, concentration is generally larger on the regionalized gas market, compared to the oil market (Figure 9). Especially the Eastern European Union countries (EEU), but also the Southern EU countries (SEU), France (FRA) and non-EU Europe (NEU) have a concentrated portfolio of natural gas suppliers. In the case of oil imports, only the Eastern EU countries (EEU) have a concentrated supplier portfolio in Europe.

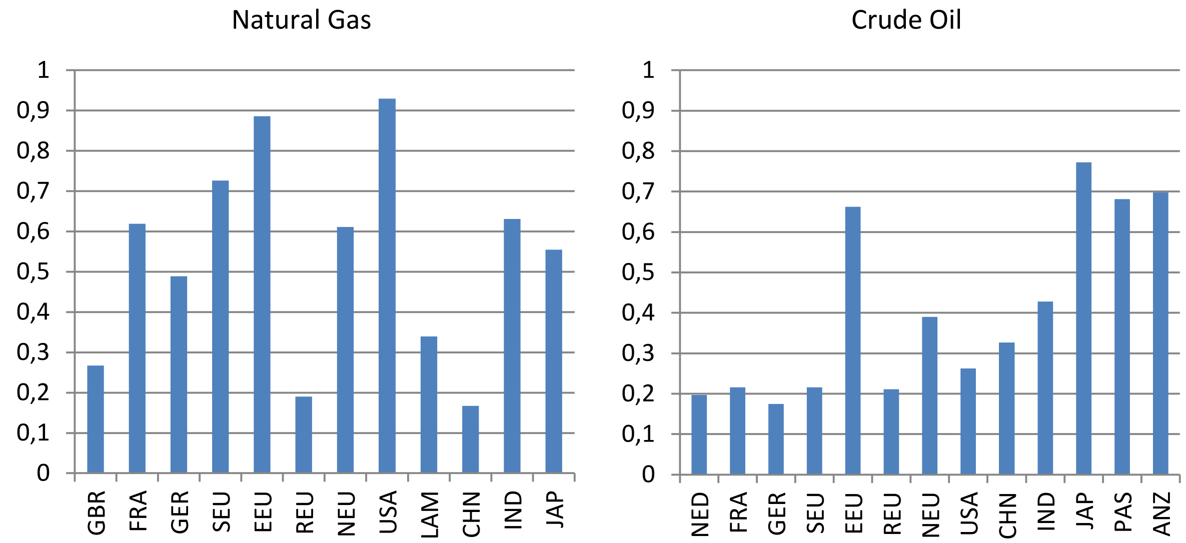


Figure 9: Herfindahl index for natural gas and oil importers in 2040 in the Reference Scenarios.

The additional supply of natural gas or oil changes import concentration non-uniformly. Changes reflect largely preexisting trade links. In the case of natural gas, the largest concentration can be observed for the German (GER) import portfolio. The Herfindahl Index for Germany increases by 7 % relative to the Reference Scenario in the Existing Locations scenario; though from a comparably low level. Import diversification can be witnessed especially in the Greenland scenario for the Rest of EU countries (REU), also from a low level and again for Germany. France, initially highly concentrated, is the only country that can diversify significantly after additional production in the Arctic. Concentration decreases by 3 % in the Existing Locations scenario. None of the countries with high import concentration, e.g. in the Eastern (EEU) or Southern EU (SEU), are able to diversify with additional Arctic production.

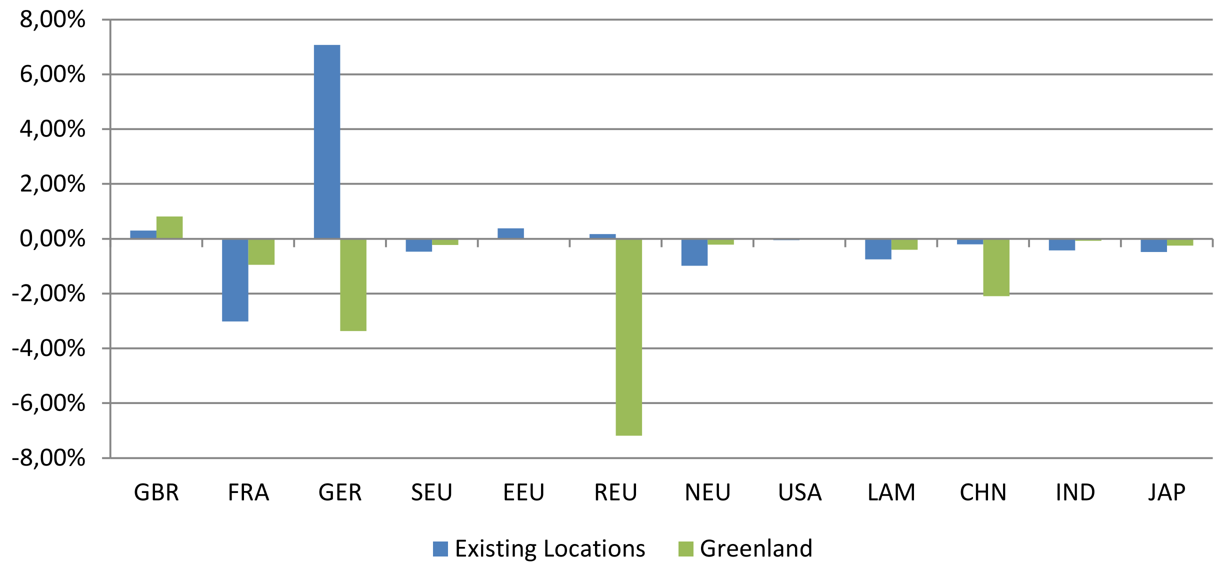


Figure 10: Change in Herfindahl index on the concentration of natural gas imports in 2040 for natural gas scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

In the case of crude oil production in the Arctic, the picture is similar, even though the changes in concentration are smaller than in the case of natural gas. Additional Russian Arctic oil production, leads some countries , such as the Eastern EU (EEU) and Non-EU Europe countries (NEU), to rely even more on their dominant supplier. Additional oil production from the smaller producers in Norway and Greenland/Denmark always has a diversifying effect. This is especially prominent in the Rest of EU countries (REU), where concentration is reduced by over 4.5 % in the Greenland scenario. The Netherlands (NED), France (FRA) and the Rest of EU countries (REU) diversify most in the Norway scenario, next to all other European countries.

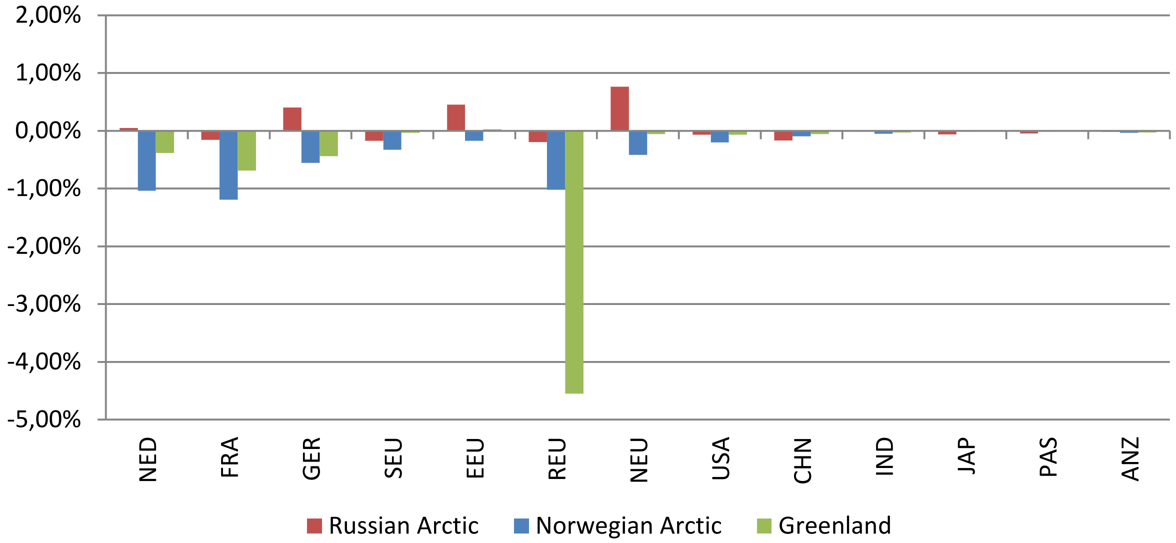


Figure 11: Change in Herfindahl index on the concentration of crude oil imports in 2040 for crude oil scenarios, difference relative to Reference Scenario (%). Source: Calzadilla et al. 2014.

Even though some decision makers put high hopes in additional Arctic production of oil and gas to mitigate the risk of supply disruptions. We find that at least for our scenarios, with relatively small but realistic production figures, supply with hydrocarbons does not become much more secure. Import shares go up in most cases following lower market prices. Even though gas and oil supply diversifies in many cases, we find no decisive change in import concentration. In particular, the highly concentrated import portfolios of Eastern Europe do not change. Single cases, such as France, are an exception of that rule. Nevertheless, additional Arctic production of gas and oil leads at least to lower import prices (see Section 4), which benefits also security of supply.

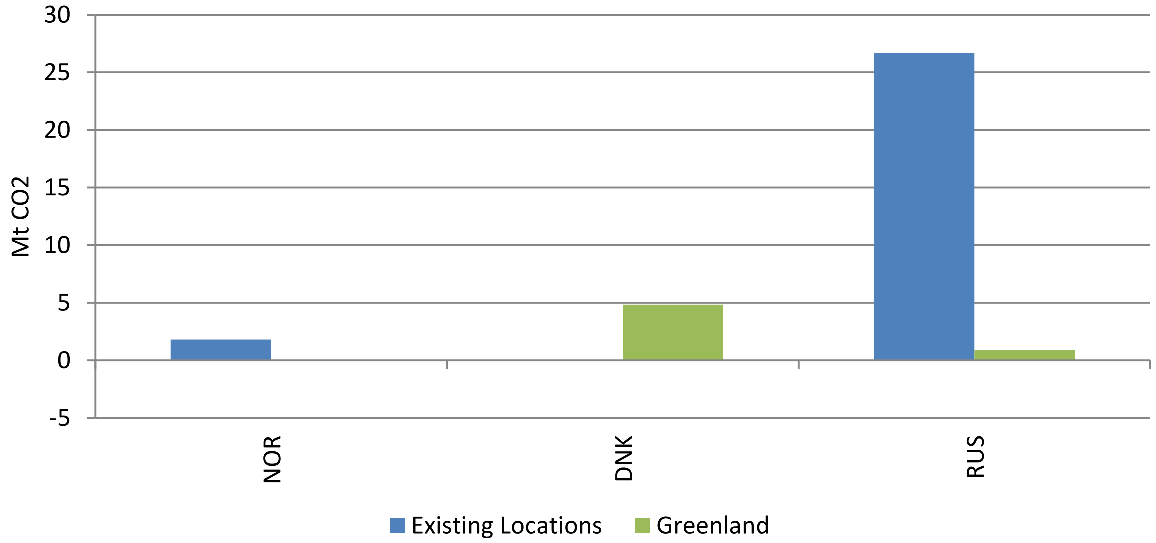
6 Carbon emissions

The decarbonisation of economic activity is one of the major policy goals in Europe, aiming at a 40 % reduction of CO_2 emissions relative to 1990 in 2030. Naturally, the composition of the European energy mix is a key determinant of CO_2 emissions in Europe, and so is the share of oil or gas in the overall energy mix. However, the effect of the two fuels differs. Natural gas has an ambiguous role for decarbonisation. On the one hand, it competes with comparably less carbon intensive renewable sources, such as wind and solar power, and nuclear power. On the other hand, it is in even more direct competition with coal and petroleum products, which are more carbon intensive. So in the case of natural gas, a crowding-out of more carbon intensive fuels may lead to a reduction in overall CO_2 emissions and not necessarily to an increase. Oil, on the other hand, is one of the most carbon intensive fuels in the energy mix. Furthermore, additional oil production (and, to a smaller extent, natural gas production) reduces energy prices and acts as a global economic stimulus, fostering economic growth and thus also CO_2 emissions. Consequently, we expect an increase in CO_2emissions in the producing countries and beyond if additional oil is produced the Arctic.

As we operate in a global general equilibrium framework, we can depict the resulting net effect on CO_2 emissions. CO_2 emissions turn out to increase following increased production of both, natural gas and oil, regionally and worldwide.

Additional production of Arctic natural gas increases global CO_2 emissions from burning coal, gas and oil increase by 58.2 mt (0.1 %) in the Existing Locations scenario and by around 22 mt in the "Greenland" scenario (0.04 %). Given the small size of the intervention in both scenarios relative to global energy production, and given that natural gas is less energy intensive than oil and coal, the increase is surprisingly sizable. In fact, we find that emission intensity increases in all countries and country groups analyzed (Figure 12). Naturally, the impact on producing countries is largest. Russia (RUS) alone accounts for almost half of the global increase in emissions in the Existing Locations scenario, with a 26.7 mt increase. Norwegian (NOR) emissions, on the other hand, increase by only 1.8 mt in the same scenario, which is surpassed even by the emission increases in Non-EU Europe (NEU), China (CHN), the Former Soviet Union (FSU) the US, and a number of other countries. Given the smaller projected size of additional production, the impact of additional production in Greenland is smaller. Greenland itself accounts for the largest share in the global emission increase, with an increase of 5 mt, followed by China, Non-EU Europe (NEU), Germany (GER), and the Middle East (MEA). Given these numbers, additional natural gas production in the Arctic is detrimental to reaching European and global climate protection goals. The hope that natural gas might replace even more carbon intensive fuels such as coal or oil does not realize.

Panel a:



Panel b:

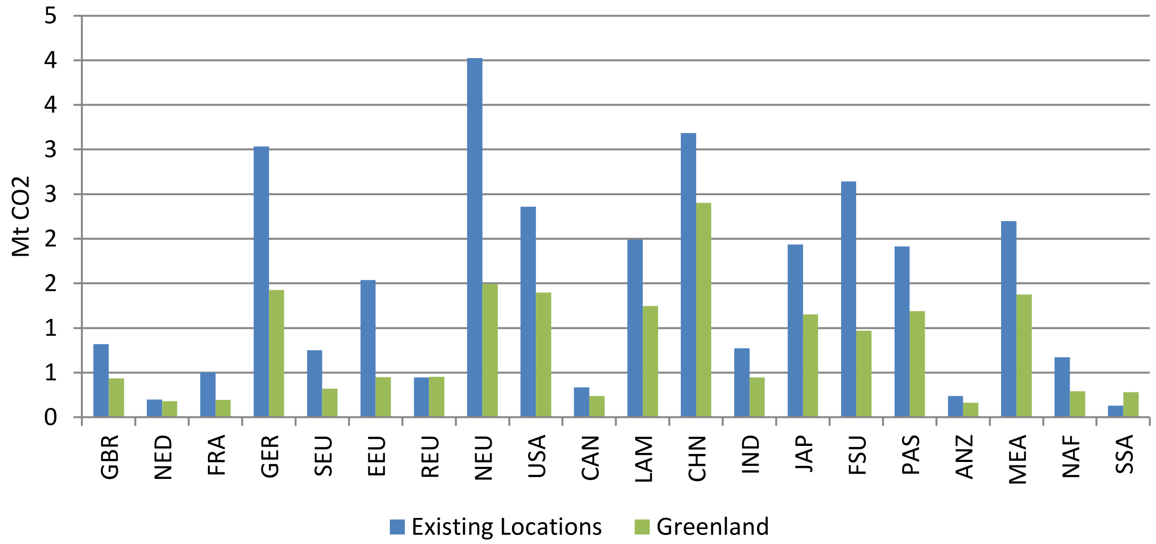
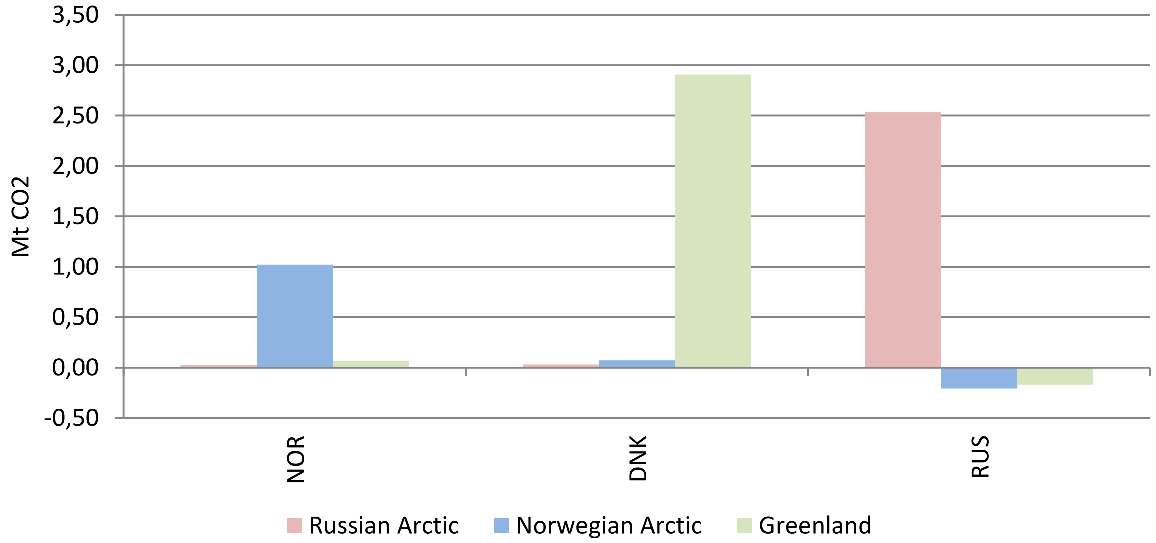


Figure 12: Change in carbon emissions from coal, gas, oil in 2040 for natural gas scenarios, absolute difference to Reference Scenario (in Mt CO2). Source: Calzadilla et al. 2014.

Additional Arctic crude oil production increases global CO_2 emissions from burning coal, gas and oil increase by 10 mt (0.02 %) in the Russia scenario, by 11 mt (0.02 %) in the Norway scenario and by 13 mt (0.03 %) in the Greenland scenario (Panel a of Figure 13). Again, given the small size of the intervention relative to global energy production, this is, again, a sizeable increase. We find that emissions increase in all countries and regions, with very few exceptions, such as Russia (RUS) in the Greenland or Norway scenarios. The highest increase takes place in Denmark (DNK) in the Greenland scenario (3 mt), but also emissions in Russia (RUS) increase significantly with additional domestic production. Other regions are largely affected similar to their original emissions, with large increases in the US, Japan (JPN), China (CHN), and Latin America (LAM) (Panel b). As could be expected, European and global climate protection efforts are undermined by additional oil production in the Arctic.

Panel a:



Panel b:

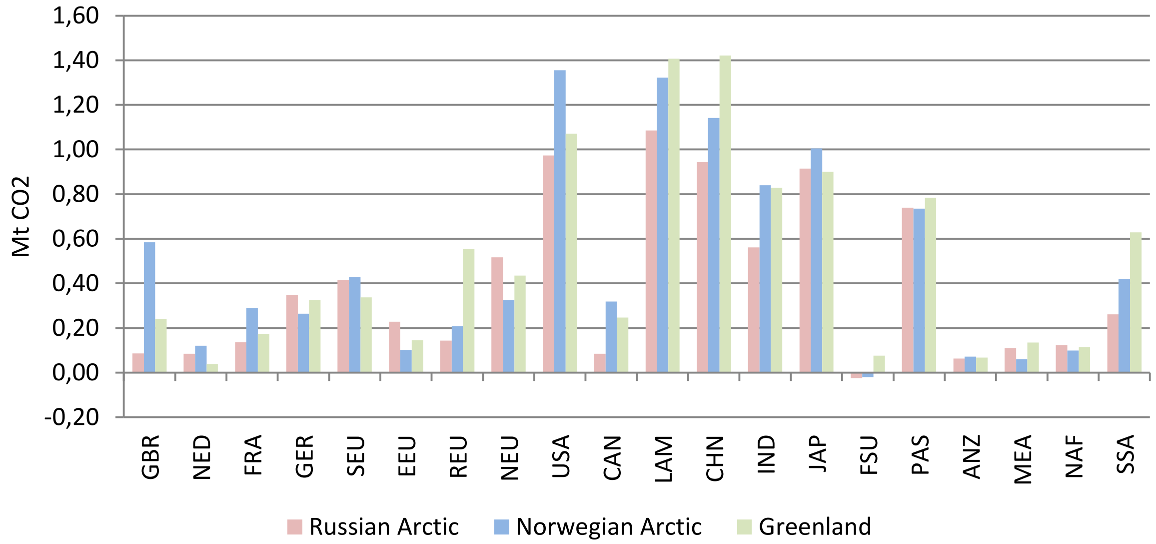


Figure 13: Change in carbon emissions from coal, gas, oil in 2040 for crude oil scenarios, absolute difference to Reference Scenario (in Mt CO2). Source: Calzadilla et al. 2014.

7 Conclusions

Production of oil and gas in the Arctic Ocean is a prospect that is anticipated by some and feared by others. With the renewed sensitivity of Europeans towards security of energy supply, the Arctic has gained importance as a potential source for diversification of the import mix and a potential source of economic growth. At the same time the associated risks for the pristine Arctic environment are high. Potential leakage of crude oil into the Arctic Ocean from an uncontrolled oil well or oil spills from tankers or support vessels are likely to damage ecosystems both in the Ocean and onshore beyond measure. This risk does not necessarily decrease with climate change, as icebergs, harsh weather conditions, darkness, and the lack of infrastructure aggravate operations in the Arctic Ocean. While local communities may on the one hand profit from the economic activity in the area, also the risk to local communities has to be taken into account. In the sparsely populated areas north of the Arctic Circle, social cohesion may be threatened by an influx of foreign workers, construction of infrastructure and damage to ecosystems that provide cultural basis and livelihood to local communities.

We analysed both the economic viability and potential economic consequences of Arctic production in the Arctic and beyond, with a special focus on economic activity, the labour market, security of supply, prices, and CO_2 emissions. As economic viability is a necessary precondition for Arctic offshore energy production and the materialisation of the risks and opportunities mentioned, we feel that a sense of the economic viability and consequences of Arctic energy production is vital for understanding threats and opportunities also beyond the economic sphere, even though we do not explicitly cover ecologic and social implications.

Our scenario analysis reveals that under certain conditions, oil and gas projects are economically viable should the necessary discoveries be made. For gas production, these include new locations in Greenland and extensions of existing locations in Norway and Russia, and in the case of oil production all locations investigated. The economic unviability of new production sites far offshore in Norway and Russia highlights the importance of existing infrastructure for economic development in the High North, which serves as a catalyst for future development.

Additional Arctic gas or oil production is likely to have a positive effect on GDP in the producing countries, even larger in the case of oil compared to gas in Norway and about the same for Greenland/Denmark and Russia, with some modest second-round effects for downstream sectors. Increases in GDP are mainly sparked by a reduction in energy prices, which acts as a stimulus program for the producing countries, Europe, and the world. This effect, however, is of course not restricted to additional production in the Arctic, but will most certainly be observed following the opening of any additional source of supply. The economic upturn leads itself to additional demand for hydrocarbons, and this demand will usually need to be imported, too, potentially from the additional sources in the Arctic. For this reason, the import shares of most European countries increase following the supply of Arctic hydrocarbons. Because new sources may be located in existing exporting countries, import concentration of European importers is often not much affected by Arctic oil or gas. While we find some limited diversification in France, Germany (except for the Russian gas scenario) and the Rest of EU countries, the very concentrated import portfolios especially in Eastern Europe do not change with Arctic supply, even if this supply comes from Norway or Greenland. Nevertheless, the price decrease observed on oil and gas markets may reduce potential worries about supply security. Any hopes that additional natural gas production might lead to reductions in CO_2 emissions do not realize. We find an increase in CO_2 emissions for both fuels and all scenarios.

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Abbreviations

Countries and regions

ANZ	Australia and New Zealand
CAN	Canada
CHN	China and Hongkong
DEK	Denmark and Greenland
EEU	Eastern Europe (Lithuania, Estonia, Latvia, Poland, Czech Republic, Slovakia, Hungary, Slovenia, Romania, Bulgaria)
FRA	France
FSU	Rest of Former Soviet Union
GBR	United Kingdom
GER	Germany
IND	India
JAP	Japan
LAM	Latin America
MEA	Middle East
NAF	Northern Africa
NED	Netherlands
NEU	Non-EU Europe (Belarus, Ukraine, Moldova, former Yugoslav countries, Turkey, Switzerland)
NOR	Norway
PAS	Pacific Asia
REU	Rest of EU (Belgium, Luxemburg, Finland, Sweden, Austria, Ireland)
RUS	Russia
SEU	Southern Europe (Italy, Spain, Portugal, Greece, Malta, Cyprus)

SSA	Subsaharan Africa
USA	USA

Other abbreviations

ECB	European Central Bank
GDP	Gross Domestic Product
HHI	Herfindahl-Hirschmann Index

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