Future emissions from shipping and petroleum activities in the Arctic

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1. Project/ publication	Peters, G.P, T.B. Nilssen, L. Lindholt, M.S. Eide, S. Glomsrød, L.I. Eide and J.S. Fuglestvedt 2011: *Future emissions from shipping and petroleum activities in the Arctic*. Atmospheric Chemistry and Physics 11, 5305-5320, doi:10.5194/acp-11-5305-2011. Available on-line at http://www.atmos-chem-phys.net/11/5305/2011/acp-11-5305-2011.pdf See also related project reviewed in Arctic Futures (Det norske Veritas 2010).
2. Initiator	Research work by the authors. The work was funded by the Norwegian Research Council project "Unlocking the Arctic Ocean" (ArcAct), see http://www.forskningsradet.no/servlet/Satellite?c=Prosjekt&cid=1200976533742&pagename=ForskningsradetNorsk/Hovedsidemal&p=11817303342233
3. Objectives	The objective of ArcAct is to assess the overall climate effect of a shift of activities from other regions to the Arctic, and particularly whether emissions occurring in the Arctic region will be more harmful for climate than emissions occurring at lower latitudes. In this particular paper, emission inventories are made both for short-lived components (SO_2, NO_x, CO, NMVOC, BC and OC) and the long-lived greenhouse gasses (CO_2, CH_4, N_2O). This involves making future activity scenarios.
4. Geographical delimitation	The definition of the Arctic is an extension of the AMAP definition (see map in article). The Arctic Ocean is the focus area, but a wider definition of the Arctic is applied to fully capture oil and gas activities that may occur onshore, but potentially require shipping in the Arctic Ocean.
5. Time horizon	Baseline is 2004 for shipping and 2000 for oil and gas activities. Future time horizons are 2030 and 2050.
6. Thematic focus	The focus is on: • Oil and gas activities • Selected shipping activities; This covers transit shipments over the Arctic Ocean with containers and shipments related to petroleum activities (supply vessels and tankers transporting oil and gas). In order to incorporate other types of shipping activities in the final total emission calculations, 2004 data from PAME 2009 is used flat over the period. • Emissions to air from these activities
7. Images of the future	**Oil and gas:** Future Arctic oil production is simulated in a model called FRISBEE (se under method) for three exogenous given oil price scenarios. Even with the highest price (120 USD per barrel in 2005 value) no significant increase in production is estimated. For the reference scenario at 80 USD per barrel, there is a gradual decline in total oil and gas production until 2030 until a slight increase towards 2050. Production is dominated by West Russia with a strong growth in Alaska and Canada, and after 2030 in East Russia and Norway (aggregated regions). Over the entire period up till 2050 there is a slight shift of production from gas to oil, though the cumulative split is roughly 50% on each. **Shipping** Shipping will be commercially attractive in 2030 and 2050 for container traffic from the Tokyo-hub, representing the northern parts of Asia in the model. When predicted amount of containers are transferred to shipments along the Northern Sea Route, it corresponds to 480 transit voyages in 2030 and 850 in 250. This represents 8% and 10% of all container traffic estimated between Europe and Asia.

	The location of Arctic oil and gas production moves into locations requiring more ship transport relative to pipeline transport; thus petroleum-related shipping activities increase rapidly. **Emissions** The results indicate that there will not be a rapid increase in aggregated Arctic emissions up to 2050. Relatively stable oil and gas production combined with emission factor improvements for this sector is one reason. A considerable change in the location of emissions can be found. This can have consequences for their climate effects.
8. Key driving forces	Driving forces in this work should be translated into major assumptions in the model systems used (ref. description of method below). Assumptions important for the modelled oil and gas production include oil and gas prices, future Arctic production costs (assumed to be 50 – 200% higher than average) and time from investment decision to maximum production (assumed to be 50-100% longer than in non-Arctic fields). The modelling of shipping activities depends on sea ice conditions and vessel performance as a basis for calculating fuel consumption and transit time when sailing in the Arctic. This is used as input to a cost-benefit model that also incorporates additional costs for ice strengthening of vessels, and determines the selection of routes (Arctic versus Suez Canal). Total transport between Asia and Europe is calculated from future global economic development (the A2 scenario of IPCC), which historically has been strongly correlated to seaborne trade. Assumptions about how this can be broken down to Asian regions, represented in the model by three hubs (Tokyo, Hong Kong, Singapore) are also made. Europe is represented only with Rotterdam as one hub. Future emission factors are important for emission calculations and a key uncertainty. Assumed drivers behind their change are regulations and technological improvements. Costs are not mentioned.
9. Uncertainties / wildcards	In a final discussion, it is concluded that the results only should be considered as an indication of potential emissions in the Arctic. Major uncertainties in estimating future activity levels are described to arise from large uncertainties in sea-ice extent, resource availability, future economic development and future policies. Other uncertainties mentioned are uncertainties in technological improvements, emission factors, oil price scenarios and economic growth. Wildcards are not discussed or introduced in the models.
10. Accomplishment and collaboration	The authors come from CICERO, Det norske Veritas and Statistics Norway.
11. Method	Calculation of future activities is done in the following steps: • Sea ice coverage is estimated using the output of several runs from the CCSM3 climate4 model. No information is given about the climate scenario used in the simulations. • Future oil and gas production is based on a model of the global energy market adapted for this purpose (Framework of International Strategic Behaviour in Energy and Environment - FRISBEE). It calculates the Arctic share of future production in five aggregated regions: West Russia, East Russia, Alaska, Arctic Canada and Arctic Norway. Greenland was not in the model originally. • The location of the activities is allocated to a 1^o x 1^o grid in a three-step process, based on the output from FRISBEE and location of current activities, discoveries, exploration areas and undiscovered reserves. • Transit shipping is based on an engineering model of ship performance in ice covered waters and a cost-benefit analysis to compare alternative routes (see also our review of DNV 2010).

	• Oil and gas shipping is based on the output of the FRISBEE model and the ship-model. To find the emissions in 2030 and 2050, the activities as calculated above are multiplied with future emission factors (emissions of gasses per unit). The inventories constructed from this will later be input into chemical transport, radiative forcing and climate models in order to understand the forcing and climate response due to emissions occurring inside versus outside the Arctic.
12. Sources of information	A long range of sources of information are mentioned in the text. Among these are data about global shipping traffic from an inventory based on port arrival and departure data (see Dalsøren et al in reference list), trade statistics from the European Commission, climate scenarios and economic projections from IPCC, data on oil activities from AMAP 2010, US Geological Survey estimates of future Arctic petroleum reserves, emission factors from a global dataset based on voluntary reporting by the oil and gas industry, national statistics including Statistics Norway and other research works.
13. Strengths	The approach is an interesting demonstration of how different calculations and models can be tied together. The FRISBEE oil and gas production model has been described in detail in a separate paper that also involves sensitivity analysis. No sensitivity analysis is described for the shipping model, but several improvements of the model are suggested. The calculations are probably breaking new ground when it comes to forecasts of oil and gas. The authors write that they are only aware of one other study that has tried to calculate future oil and gas production in the Arctic relative to non-Arctic production (a consultancy called Wood Mackenzie and Fugro Robertson in 2006). They find that the results are broadly consistent, though there are differences. The detailed spatial calculations are probably unique. So is probably also the "bottom-up" approach for calculating Arctic emissions, building on actual data for Arctic oil and gas production instead of global data that are broken down. For shipping, many qualitative scenarios and quantitative calculations of activity level and emissions have been made before; see for example our reviews of Niini et al 2006, Brunstand et al 2007, Arctic Council 2009, Det norske Veritas 2010.
14. Weaknesses	Many of the assumptions in the calculations and the models can be discussed and still seem to be rough. The modeling in many ways is a projection of current trends. While sensitivity analysis is done on some assumptions, it is possible to foresee a number of "wildcards" that could change basic assumptions (ref. uncertainties above). The results are potentially very policy relevant for setting future emission standards for ships and petroleum activities in the Arctic. However, this is not brought into the discussion or the scope of the project.
15. Attention and significance	We have not found any information about dispersion of results and attention apart from a couple of presentations at conferences and a popular article.
16. Relevance for the Fram Centre	CICERO is a member of the Fram Centre. The research is highly relevant for the Arctic Ocean flagship. Several references are useful.