Resource Development and Climate Change: A Gap Analysis

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ReSDA RESOURCES and SUSTAINABLE DEVELOPMENT in the ARCTIC

Introduction

Over the past decade, Arctic resource development is often discussed as being directly related to climate change. In the media and in much of the grey literature, increased resource development in the Arctic is often portrayed as the result of climate change. There seems to be an intuitive recognition that climate change is melting the ice covering the Arctic and, as a result, resources that would have previously been inaccessible are now available for exploitation. An associated belief is that climate change, by melting ice, is making transportation easier and, as such, making it easier to ship technology in and resources out of the region. Yet, despite this seemingly intuitive idea, the limited research that has been done on the subject seems to indicate otherwise. Indeed, climate change may be making resource development more difficult – at least in the immediate term.

It is not immediately evident that looking at the relationship between resource development and climate change is likely to help us find out if and how resource development can help bring more benefits to Arctic communities. As such, some could question why ReSDA would devote any attention to the relationship between resource development and climate change. Research on climate change in the Arctic has increased substantially over the past 15 years and it is unlikely that ReSDA could add much to what current researchers are doing. Still, the fact that at least some people believe that an important causal relationship exists between the warming of the Arctic and increased interest in the development of Arctic resources means that ReSDA should at least try and discover what relationship, if any, exists. A gap analysis looking at this relationship should allow us to better understand if further research is necessary in order to assist in helping communities find ways to get more out of resource developments. At the very least, we need to help communities understand if climate change will increase resource development pressures or prove to be an obstacle to attempts by communities to use resource development as a tool to bring about a more sustainable future.

This gap analysis will consist of a literature review of the relationship between climate change and Arctic resource development. Climate change is now the most researched challenge facing the Arctic and as such there have already been a number of literature reviews of both climate change research and the social impacts of climate change. We borrow heavily from these previous studies. We summarize the existing research in an attempt to allow us to better understand what, if any, relationship exists between climate change and resource development in an attempt to understand its implications for Arctic communities.

Climate change and resource development

An article in Foreign Affairs in 2008 by Scott G. Borgerson can be used as an example of the current beliefs concerning the relationship between climate change and resource development. Borgerson starts out “Global warming has given birth to a new scramble for territory and resources among the five Arctic powers….”(Borgerson, 2008: 63) The image portrayed is that

Arctic ice has, in the past, been an obstacle to resource development in the region. One part of the perspective is that ice is seen as a cover to hide the resources and a barrier to access them. "…the great melt is likely to yield more of the very commodities that precipitated it…" (64). Another part of the perspective is that warmer temperatures will lead to easier access. "Less ice also means increased access to Arctic fish, timber, and minerals, such as lead, magnesium, nickel, and zinc…" (64). This access will be primarily through increased maritime transportation possibilities caused by melting sea ice.

This view is often seen in the global media. The New York Times published a front page story in its September 19, 2012 issue with the title "Race is On as Ice Melt Reveals Arctic Treasures". The article stated,

> "With Arctic ice melting at record pace, the world's superpowers are increasingly jockeying for…economic position in outposts like this one, previously regarded as barren wastelands. At stake are the Arctic's abundant supplies of oil, gas and minerals that are, thanks to climate change, becoming newly accessible…". (Rosenthal, 2012)

The same year The Economist, in a special report called "The Melting North" noted that the melting of Arctic ice, caused by climate change, was "going to make a lot of people rich". (Economist, 2012) They state that as the "the frozen tundra retreats northwards… much more valuable materials will become increasingly accessible". Oil and gas also becomes more accessible. "Oil companies do not like to talk about it, but this points to another positive feedback from the melt. Climate change caused by burning fossil fuels will allow more Arctic hydrocarbons to be extracted and burned." Canada's Globe and Mail noted in 2014 that the melting caused by climate change is "opening a new energy frontier".(Ritter, 2014)

Variations of this general perspective are seen in many of the articles, books, television shows, and films dealing with Arctic climate change. What is interesting is that there are very few studies that have even looked at the issue in any sort of depth. Those that do exist point to a more nuanced perspective on the relationship between climate change and resource development. Some even suggest that climate change should actually be seen as a barrier to resource development.

The 'human dimensions' of climate change

A history of the research dealing with the relationship between climate change and resource development is generally seen through the work on the "human dimensions" of climate change. While initially the work on climate change in the Arctic was dominated by the physical and biological sciences, over the past 10 years there has been a wealth of literature produced on the topic. One recent study noted that at least 117 refereed articles dealing with the human dimensions of climate change in the Eastern Canadian Arctic alone were published between 2000 and 2010. (J. D. Ford et al., 2012).

Despite this wealth of research, the same study also notes that there is actually very little solid information on specific impacts. Most of the literature is "dominated by studies examining the safety of using semi-permanent trails for hunting and recreational travel, particularly how changing snow and ice regimes, less-predictable weather, and changing wind patterns are an increasing danger, making routes less dependable and compromising the ability to engage in harvesting activities" (292). These same studies, generally based on indigenous accounts and traditional knowledge relating to climate change, also note that these impacts are currently being managed by these communities through adaptations but that barriers could arise in the future to the ability of communities to adapt.

Few studies exist that have looked in depth at other current human dimensions of climate change, including resource development. The only research noted by the above study relating to climate change and resource development indicated that climate change is causing problems for mining in that hydro-electric power is becoming less dependable due to climate change related stream flow changes (293).

The early IPCC reports

While little concrete research exists, there is a long history of commentary on the potential impacts of global warming on Arctic resource development. When the Intergovernmental Panel on Climate Change (IPCC) was created by the World Meteorological Association and the United Nations Environmental Programme in 1988, earlier reports had already indicated that climate change would impact higher latitudes more severely than lower latitudes (Bolin, 2007). As a result the first assessment published in 1990 contained an extensive discussion of potential impacts on the Arctic, including social impacts. At that time all impacts were however hypothetical as there had been no concrete evidence of social impacts of climate change on Arctic communities.

The report from Working Group II of the IPCC, which dealt with the assessment of impacts, listed a number of potential impacts of climate change in Arctic communities (IPCC FAR WG II, 1990) . It highlighted the possible negative impacts on the traditional harvesting activities of Indigenous peoples – especially in Canada (5-6). This first report also noted that melting sea ice may increase transportation possibilities in the region which would have certain security implications. It also inferred that less sea ice may have positive implications for resource development when its states that "…possibility of climate-induced changes in access and prospects for resource development may result in altered national positions and competing claims" (IPCC FAR WG I, 1990: 6-20).

Despite this comment, much of the analysis contained in these particular reports seems to stress the problems for resource development in the Arctic that would be caused by climate change. It noted the problems for infrastructure caused by melting permafrost (IPCC FAR WG II, 1990: 5-8), problems caused by loss of winter roads (5-20), and problems for hydro-electric projects, necessary for resource development, that would be caused by changes in run-off regimes (7-16). There is little evidence in the first impact report of the IPCC that resource development would be significantly enhanced by climate change. In 1992 the IPCC published a supplementary report that did not directly mention resource development in the Arctic but did note, once again, that melting sea ice in the Arctic could lengthen the shipping season in the Arctic (Houghton, Callander, & Varney, 1992: 35).

The Second IPCC Assessment of 1995 discussed in greater detail the potential impacts of climate change on humans in the Arctic. Once again the potential impacts on traditional harvesting activities were listed as the most likely negative consequence of climate change (IPCC SAR WG I, 1996: 257). The greatest economic impact of climate change in the Arctic "is likely to stem from decreases in ice thickness and bearing capacity, which could severely restrict the size and load limit of vehicular traffic" (257). While this comment seemed to refer to vehicles involved in traditional harvesting, one would presume it could also refer to vehicle involved in resource development.

More detail was included concerning potential impacts on resource development and once again, while certain potentially positive impacts were mentioned, the report seems to indicate just as many, if not more, negative impacts. The report stresses the potentially negative impacts of thawing permafrost on mining and other resource development infrastructure (257). Mining roads would be negatively affected by erosion (205).

The oil and gas industry could benefit from reduced sea ice. This would allow greater transportation possibilities (259) and "shorter winters disrupting construction, exploration, and drilling programs" (259). This may serve to reduce operating costs (383). At the same time the report mentions several potentially negative impacts of climate change on oil and gas development. In particular they cite a report on the Beaufort Sea where a longer open water season would see the frequency of extreme wave heights increase. "Present design requirements for long-lived coastal and offshore structures, such as oil installations, will be inadequate under these conditions" (259). The report also noted that oil and gas pipelines would be negatively affected by melting permafrost (382).

While these reports stress that climate change could have both positive and negative impacts on resource development, a regional report published by the IPCC indicated that the impacts are likely to be more positive. In a brief statement the report noted that while climate change related changes would be "particularly important for indigenous peoples leading traditional lifestyles" it

would also mean "new opportunities for shipping, the oil industry, fishing, mining, tourism, and migration of people. Sea ice changes projected for the Arctic have major strategic implications for trade, especially between Asia and Europe." (Watson, Zinyowera, & Moss, 1997: 8)

The 2001 Report of the IPCC repeated once again the same observations of climate change having both positive and negative potential impacts on human societies and resource development in the Arctic. Interestingly, while echoing earlier comments on the likely negative impacts of climate change on Indigenous communities, it also stressed, for the first time, that Indigenous communities "may be sufficiently resilient to cope with these changes" (IPCC TAR WG II, 2001: 805). As had the previous reports, the 2001 noted the potentially positive aspects of less sea ice on maritime transportation and oil and gas industry operating costs (805).

It is interesting that much more time was spent in this particular report discussing potential problems for extractive resource development production that could be caused by climate change as opposed to potential benefits. The issue of infrastructure problems caused by melting permafrost was repeated (946) as was the issue of increased wave action (828). A new detail that was added was that coastal erosion was increasingly a problem for communities and for oil and gas production facilities (827). This issue of storm surges and the negative impacts that this could have on resource industry production as also introduced (828).

The report went into greater detail when discussing how climate change could represent problems for resource development. It noted that although less sea ice would mean that the oil and gas industry could utilize more convention drilling techniques, these "likely changes are not without concerns" (828). While drill ships could reduce operating costs "increased wave action, storm surges, and coastal erosion may necessitate design changes to conventional offshore and coastal facilities" (828). The costs of pipeline construction would increase because extensive trenching may be needed to combat the effects of coastal instability and erosion. As concerns the oil and gas industry, the report concludes that the "impact of climate change is likely to lead to increased costs in the industry associated with design and operational changes" (828).

The Arctic Climate Impact Assessment

Following the 2001 IPCC assessment, work started on a separate climate impact assessment for the Arctic. The Arctic Climate Impact Assessment, organized under the mandate of the Arctic Council, is, to this day, the most important attempt to assess the impact of climate change on the Arctic. It entailed a much more detailed report of potential impacts of climate change on Arctic communities and on resource development. It is also unique in that while the previous discussion of climate change impacts were hypothetical, the ACIA included studies that started to see real impacts occurring on Arctic societies.

The scientific report of the ACIA is organized by chapters based on the different sectors of the Arctic environment (ACIA, 2005). Several of these chapters mention resource development relating to climate change in brief hypothetical statements. Such is the case in the chapter on Cryosphere and Hydrology, which notes that freshwater ice uncertainty could cause problems for extractive resource development (229), or the chapter on Marine Systems which noted that less sea ice will result in more possibilities in terms of maritime transportation and that this may lead to "increased exploration for reserves of oil and gas, and minerals" (519). The chapter dealing with wildlife management and conservation discusses the increased importance of resource development in the Arctic during the last half of the 20th century but does not link it to climate change. Indeed the chapter seems to indicate that the negative impacts from resource development may be more important to the Arctic than those linked to climate change. They claim that the negative impacts of this resource development on the environment makes it more difficult to isolate the specific impacts caused by climate change (621). The chapter on health impacts does not refer to extractive resource development directly but does state that increased shipping due to climate change may cause problems for Arctic communities because of the threat of "the sudden catastrophic release of hazardous materials into the local, regional, and eventually circumpolar environment" (892). According to the chapter, this is increasingly likely to happen due to the increase in extreme weather events caused by climate change.

The two chapters of the ACIA where the relationship between resource development and climate change are discussed most extensively are in the chapter dealing with renewable resources and the chapter on infrastructure. It is interesting that the renewable resources chapter does not specifically state that climate change is having an impact on Arctic communities – only that as "this assessment shows, these activities and relationships appear to be threatened by severe climate change." (651). Despite the hypothetical nature of the above statement, the chapter refers to two studies that claim to show actual impacts. They note a study by Fugal et al (2002) which shows that local anxieties over environmental changes are currently being experienced by communities in northern Quebec and Labrador, and that climate change is having an impact on human health and the availability of important traditional/country foods (656). In addition they refer to an Alaskan study by Callaway et al. (1999) which shows that climate change is increasing the monetary costs of hunting for North Slope Indigenous communities (656). Elsewhere, in addition to the above mentioned studies, they also point out that climate change related erosion has caused enormous problems for certain costal Indigenous communities such as Shishmaref (660).

In the rest of the chapter their discussion of resource development is built largely around the observation, already noted above in relation to the chapter dealing with wildlife management and conservation, that resource development may be more important than climate change in terms of challenges currently facing wildlife management and conservation. They continue the chapter by underlining the importance of global economic impacts on Arctic societies and state "(T)hus, for

some indigenous communities climate change may not be the most immediate issue of local concern." (657). They go further in stating that there "is scientific difficulty in stating how far climate change alone has affected arctic marine ecosystems in the past fifty years, for instance, as the impacts of overfishing and over-hunting may be far greater." (658). In their discussion of the potential impacts of climate change on the Inuvialuit of Canada they state that when looking at the impacts of other historical trends "…the impact of climate change is relatively minor, at least so far, and it is not beyond the ability of the community to adapt…." (670).

The authors of the chapter note the scientific studies indicating the Arctic environment will be impacted by climate change under the existing models and they state that this will likely affect subsistence activities. But at the same time, they stress that it is important to contextualize climate change impacts with reference to other changes experienced by Arctic residents. Being able to access traditional food resources and ensuring food security will be a major challenge in an Arctic affected increasingly by both climate change and global processes. (658)

The chapter authors note how the Indigenous peoples have successfully adapted to climate change in the past but state that other factors may impact their ability to do so in the future and perhaps the most important factor is resource development. Resource development can be a barrier or it can enhance their ability to adapt. The chapter seems to stress the positive impacts of resource development.

> "In addition, significant steps have been taken with innovative co-management regimes that allow for the sharing of responsibility for resource management between indigenous and other uses and the state (Huntington, 1992; Osherenko, 1988; Roberts, 1996). Examples include the Alaska Eskimo Whaling Commission, the Kola Saami Reindeer Breeding Project, the Inuvialuit Game Council, and the North Atlantic Marine Mammal Commission. Self-government is about being able to practice autonomy. The devolution of authority and the introduction of co-management allow indigenous peoples opportunities to improve the degree to which management and the regulation of resource use considers and incorporates indigenous views and traditional resource use systems (Huntington, 1992)." (665,666)

While the above chapter suggests that at least some aspects of resource development may be a source of increased capacity to deal with potential negative impacts caused by climate change, the chapter dealing with infrastructure impacts seems to suggest that these possibilities may be limited by negative impacts of climate change on resource development. Resource development depends upon stable infrastructures. Climate change represents a threat to these stable infrastructures. The chapter cites an earlier study by Esch and Osterkamp which summarizes most of the engineering concerns related to permafrost warming. These include increase in creep rate of existing piles and footings, increased creep of embankment foundations, eventual loss of

adfreeze bond support for pilings, thaw settlement during seasonal thawing, increased frost-heave forces on pilings, increased total and differential frost heave during winter, decrease in effective length of piling located in permafrost, progressive landslide movements, and progressive surface settlements (914).

In terms of coastal impacts, the chapter confirms that less ice may lead to more shipping and ease of access to resources but cautions that it will also cause increased wave generation which will lead to more erosion and other threats to coastal infrastructure. More extreme weather caused by climate change will further exacerbate the problems (922). Increased water flow in river systems may increase the transportation of materials on these rivers but increased erosion will threaten the infrastructures that permit river transportation. River ice breakup and ice jams are going to become harder to predict (923).

The chapter discusses a series of infrastructure problems for resource industries due to climate change. Northern pipelines are likely to be negatively impacted by frost heave and slope instability, shallow pile foundations settlement in permafrost could possibly be accelerated, and large tailings disposal facilities might be affected by permafrost thaw caused by climate change. Transportation routes such as roads, airports, and railways are going to be negatively impacted by destructive frost action and "…will experience increasing failure rates both in the continuous and discontinuous permafrost zones." (931).

In summarizing their discussion of the impacts of climate change on resource development infrastructure they note that impacts so far have been small. As far as future impacts, the two most important potentially positive impacts are that less sea ice would mean cost reductions in the construction of oil and gas platforms that must withstand ice force and longer maritime transportation seasons Transportation costs would be lessened by " increased drafts in harbors and channels as sea level rises, a reduced need for ice strengthening of ship hulls and off shore oil and gas platforms, and a reduced need for icebreaker support" (937). These potential positive impacts could be countered by less ability to use ice roads, the deterioration of existing infrastructure, higher costs for future infrastructure, increased wave activity and erosion.

Subsequent studies have failed to alter the inconclusive findings of the Arctic Climate Impact Assessment as regards the potential impacts of climate change on resource development. The Forth IPCC Assessment Report repeats the many of the same inconclusive statements that were contained in the earlier reports (although with less detail) (IPCC AR4 WG II, 2007) . It notes the ability of the Indigenous peoples of the Arctic to be resilient in the face of potential challenges linked to climate change but adds that "stresses in addition to climate change…will challenge adaptive capacity and increase vulnerability." (56). In other words, normally Indigenous peoples would be able to adapt to climate change but other, one would assume more important, pressures are reducing their ability to do so.

The Forth Report states that there is a very high likelihood of climate change producing what they call "positive economic benefits" for some Arctic communities and that these may include "reduced heating costs, increased agricultural and forestry opportunities, more navigable northern sea routes and marine access to resources…" (56). Elsewhere the report is more specific in terms of positive economic impacts as far as resource development is concerned in that reduced sea will probably result in increased navigation and "possibly also a rise in offshore oil operations…but there are no quantitative data to support this." (88).

While the Forth Report seems uncertain about positive impacts of climate change on resource development, it is fairly confident about the likelihood of negative impacts. It notes that the melting of permafrost "…is a risk to gas and oil pipelines, electrical transmission towers, nuclear-power plants and natural gas processing plants in the Arctic region… Structural failures in transportation and industrial infrastructure are becoming more common as a result of permafrost melting in northern Russia, the effects being more serious in the discontinuous permafrost zone." (367)

Recent research on Climate Change and Resource Development

More recent discussions of the relationship between climate change and resource development tends to confirm the discussions found in the IPCC reports and the ACIA. While the grey literature tends to highlight the positive impacts of climate change on the potential for resource development in the Arctic, the scientific literature tends to highlight the negative consequences. While, as noted earlier, there is not a great deal of research on the topic, there are several recent findings that are relevant.

In 2007 the Government of Canada undertook a survey of the existing literature in an attempt to determine the likely impacts of climate change on the various regions of the country. This review included a chapter on northern Canada (Furgal & Prowse, 2008). The section dealing with economic impacts starts out discussing hydro-electric development which, the chapter states, are increasingly important for mining operations. Hydro-electric developments will likely be negatively affected by climate change in that flows necessary for the production of power will be reduced (79). In addition, the increasing instability of water flows caused by climate change would require increased monitoring of hydro-electric structures and could cause safety concerns.

Oil and gas exploration could be positively impacted by climate change in that some areas would become easier to access due to reduction in sea ice. At the same time, design changes to drilling platforms will be necessary to deal with increased wave action and storm surges. Land-based infrastructure will be negatively impacted by thawing permafrost and the unpredictability of the winter season. According to the report one of the biggest problems is that the current practise of

dealing with drilling wastes by storing them in permafrost sumps will have to be stopped in order to ensure there is no contamination. More expensive ways to deal with the waste will have to be introduced (79). Coastal structures will be threatened by erosion and this would require mitigation technologies. Finally, pipelines necessary to transport the oil and gas would have their integrity threatened by thawing permafrost and this could represent an important danger to the environment (80).

Mining would likely experience several negative impacts from climate change. Winter ice roads are necessary for the cost effective transportation of structures and supplies to isolated mine sites. These roads would become more unpredictable with climate change forcing companies to consider more expensive options. This could negatively impact the viability of mines in Canada's Arctic (80). The other concern relates to mine waste. According to the report, the "stability of waste-rock piles, tailings piles and tailings-containment impoundments often depends on maintenance of frozen conditions to ensure that contaminants and acid-metal leachate (or acid-rock drainage) are not discharged to the environment…" (80).

It is interesting that while most of the research-based considerations of impacts stress the negative implications of climate change, a text box in the report stresses "Opportunities for Growth in the Mining and Transportation Sector" (81). According to the argument in the text box, a longer shipping season would benefit the mining sector. With a longer season new port infrastructure would become more economically feasible and would this would allow new ways of accessing resource deposits.

The Suzuki Foundation Study

In 2008 a Canadian consulting contract from the David Suzuki Foundation undertook to survey the mining industry on their perceptions of climate change and its impact on mining (J. Ford, Pearce, Duerden, Prno, & Marshall, 2008). The results of this study were published as a report (T. Pearce, Ford, Prno, & Duerden, 2009) and were reproduced in a number of articles in academic journals (J. D. Ford et al., 2010; James D Ford et al., 2011; T. D. Pearce et al., 2011). The report describes their literature review which notes a limited scientific discourse on climate change impacts relating to mining (T. D. Pearce et al., 2011). Their review of the scientific discourse echoes many of the observations mentioned above in that researchers suggest that climate change would have a negative impact on infrastructure, transportation, processing operations, and other features while there is the possibility that "(m)elting sea ice also presents a number of potential opportunities for the mining sector including longer shipping seasons, shorter transportation routes, and increased exploration opportunities." (26)

Despite the increased attention given to climate change lately, the mining industry seemed to be little concerned about climate change impacts. In their review of trade journals in Canada

between 2002 and 2009 only 4 articles can be seen to discuss impacts: two that deal with the early closure of ice roads in the Northwest Territories in 2006, one that suggests that infrastructure may be impacted in the future by climate change, and one that warned the mining industry that the public was becoming concerned about climate change and that the industry may need to develop "a green advantage and appeal to shareholders" (18). According to the authors of the report, "Absent in the trade journal literature, however, is a thorough discussion and rigorous evaluation of what climate change will mean for the physical aspects of mine operations both today and in the future, and capacity of the sector to adapt to change… "(18).

In addition to the literature review, the report details two surveys of mining industry representatives and a series of case studies examining specific mine sites. It should be pointed out that the surveys and the case studies concerned the whole of Canada and were not specific to the Arctic. At the same, as many companies have multiple mine sites which often include the north, the results of these studies are interesting as a means of better understanding the relationship between climate change and resource development in the Arctic.

The first survey that was done by the consultants was questionnaire-based interview survey that was carried out at the 2008 Prospectors and Developers Association of Canada International Convention (T. Pearce et al., 2009). This association is one of the main mining industry organizations in Canada. While the survey was limited in terms of the number of respondents (42) the results do help us better understand the feeling of the mining industry in Canada towards climate change. Generally speaking the results point to a mild degree of concern regarding climate change. When asked if climate change was currently affecting their operations, 20 (45%) of 42 said yes (39). When asked if these impacts were good or bad, 9 (45%) of these 20 said the impacts were bad while only 3 (15%) said they were good.

The respondents were then asked about perceived future impacts of climate change. At this point 21 (50%) of the 42 respondents answered yes while 19 (43%) answered no. Of these 21 respondents 12 (58%) thought the future impacts would be bad for their industry while only 2 (10%) thought future impacts would be good (40). When asked if their company was taking action to deal with future climate change impacts only 12 respondents stated that they were.

The respondents at the Prospectors and Developers Association of Canada convention represented all facets of the mining industry including consultants and suppliers. Indeed, only 38% of respondents to this first survey actually worked for a mining company. As a result the consultants decided to undertake a follow up questionnaire that would be directed exclusively at "mining practitioners working 'on the ground' at mine sites across the country" (49). This second survey used a variation of the initial questionnaire and was based on 62 telephone interviews of randomly selected mining practitioners conducted during the summer of 2008.

The second survey generally portrayed a lower level of concern about climate change than in the first survey.[1] According to the consultants, while 55% indicated that their company or organization was concerned about climate change, only 34% indicated that climate change was currently having an impact on their operations (53). This was significantly lower than in the first survey. Of those respondents who believed climate change was currently having an impact, the largest percentage (76%) thought these impacts concerned the transportation sector of their company. When asked if their company was currently taking steps to deal with the negative impacts of climate change only 21% responded yes (54). Only 8% responded that their company was currently taking action to take advantage of the positive impacts of climate change.

When asked about the future, 58%, or 36 respondents, expected climate change to impact their company sometime in the future (54). Of these 36 respondents, 44% expected future impacts to be bad for their company while 35% thought these future impacts would be good. Most thought future impacts would concern transportation. In regards to company plans regarding climate change, 40% thought their companies were currently taking actions to plan for future climate change (56).

These two surveys were supplemented by six case studies of specific mines in operation in Canada. Of these six, one was the diamond mines in the Northwest Territories, one was the mine at Voisey's Bay, Labrador, and another looked at mining in the Yukon. These case studies were based primarily on literature reviews but also included 46 semi-structured interviews (66). The case study concerning the diamond mines in the Northwest Territories was the only one of the three that detailed a climate change related impact which has already or is currently occurring. The study noted that in 2006 warm weather forced the early closure of the ice roads essential for transporting goods into the mine sites adding to operational costs (70).

The report noted several adaptations that companies were undertaking that would help them deal with climate change in the Northwest Territories but at the same time the consultants noted that many of these adaptations may not be due to any concerns about climate change.

> "It is difficult to determine exactly how many of these initiatives are linked to climate change directly. In many cases, 'energy management' initiatives are undertaken primarily with cost savings in mind. Energy for the diamond mines is produced 100% from diesel fuel and this fuel must be trucked in over the ice road or flown in by plane. Both these transportation options have significant costs attached and it is thus in the interest of mine operators to reduce fuel use wherever they can." (72)

[1] It should be noted that, unlike the first survey, the consultants did not publish all the response totals for the questionnaire. We are forced therefore to rely on unclear totals. These are primarily percentiles with inadequate explanations of what total numbers the percentiles represent.

In terms of the mining representatives in the Northwest Territories that were interviewed, climate change was a concern but a minor one. (73)

This was similar to the findings in Labrador. The report noted that the Voisey's Bay mine has no formal plan for dealing with or adapting to potential future climatic changes (98). When the initial environmental assessment was done for the mine it was expected that impacts from climate change would be minimal over the life of the mine. While more recent models of climate change suggest that impacts may be greater than previously thought, the operations of the mine have seemingly not been discernibly impacted by climate change. When mine representatives were interviewed the belief was expressed that "planning will only occur when significant climatic changes are documented and start to have a discernible impact on company operations." (98)

The Yukon case study did not detect any current climate change related impacts on mining operations in this territory but it did suggest that impacts could occur in the future. Opinions expressed by researchers point to potential future negative impacts from melting permafrost, such as threats to the transportation system and other similar types of infrastructure, as well as extreme weather events. Others note potential positive influences stemming from climate change (101). Under certain conditions, permafrost makes mining more difficult and, as such, the melting of permafrost may reduce production costs. The particular historical conditions of the Yukon and the presence of a large number of abandoned mines meant that quite a bit of concern was expressed about the impact of climate change on these sites (103).

When the results of this particular case study analysis was re-examined in a journal article, one of the main conclusions was that most in the mining industry view climate change as only a minor concern (T. D. Pearce et al., 2011: 363). This is due to the fact that there are much more important influences affecting their operations and their industry than climate change. According to the authors

> "…most respondents involved in mine administration and managerial roles (24 of 31 respondents, 77%) viewed climate change as only a minor concern, particularly when compared to more pressing issues such as meeting regulatory and human resource requirements, and managing fluctuating market conditions." (363)

That Canadian mining companies are only marginally interested in climate change and that this interest is more often than not one of concern that it will negatively impact production, is similar to the findings of a recent study looking at the potential future of the oil and gas industry in the Arctic (Harsem, Eide, & Heen, 2011). The study attempted to understand which current changes are most likely to have an impact on future Arctic oil and gas development. These changes

included climate change and as such the study tried to determine the impact of climate change on whether or not oil and gas development in the region will increase in the future.

The researchers isolate three major changes related to climate change that are likely to have an impact on oil and gas projects: ice structure and extent; extreme weather; and longer summer seasons and the Arctic tundra. They note that global warming has the potential to make offshore Arctic oil and gas development easier. They quote an earlier study by Dell and Pasteris that less ice and snow may reduce production costs "as oil companies may be able to replace ice based construction with lower cost conventional construction equipment." (8040) Summer drilling seasons could be lengthened to allow more exploration and production. Reduced ice will also create the possibilities of new shipping routes.

At the same time, the potential positive impacts of this aspect of Arctic climate change could be countered by other possible negative impacts. Rather than dealing with constant and strong ice cover, the weakening of sea ice could mean that the ice becomes more moveable and unpredictable – especially in strong winds. This weaker ice "…can therefore be expected to move at a greater speed compared to the older, more stable ice. This represents a potential risk for the oil and gas industry, as increased ice movement could interrupt drilling." (8039) Increased iceberg activity could also damage off-shore production facilities. While technologies are currently being developed to deal with these eventualities, these innovations do tend to add to production costs.

While melting sea ice is a commonly understood result of global warming, another impact which is less understood is that of extreme weather. In the case of the Arctic, researchers have suggested that climate change will result in an increase in extreme weather. According to some researchers, the number of storms and hurricanes are likely to increase in the Arctic. While there is not unanimous agreement on the extent of an increase in extreme weather due to climate change, any increase in these events would be bad for resource development. According to the authors of the study, " (a)n increase in storm frequency could prove a serious risk to the oil industry, as it has the potential to disrupt drilling, production, and transportation." (8039) Extreme weather would also mean an increase in risks relating to oil spills and the potential to contain them. One of the past advantages of the Arctic region in terms of resource production was relative stability of weather systems. Increased instability makes planning more difficult and increases both actual and potential costs related to developments.

Other negative impacts on oil and gas development are related to longer summers and the impacts on Arctic tundra. Generally speaking, the frozen tundra serves as an efficient production base for oil and gas development. A melting tundra causes a wide range of problems for land-based oil and gas development. According to the authors "…a lengthy summer season will shorten exploration activities, since drilling in the marshy Arctic tundra is not desirable, nor politically acceptable… a milder climate will affect transportation equipment and infrastructure

such as roads and pipelines." (8039) They note that a "marshy Arctic tundra makes it almost impossible to conduct large scale transportation during the summer months, as the tundra is not able to support motorised vehicles (8040).

In their overall analysis the authors come to the conclusion that climate change changes are difficult to assess in terms of their impacts on future oil and gas developments but they are likely to have more negative impacts than positive ones. In terms of whether oil and gas development in the Arctic occur, at best climate change plays a relatively minor role. The most important factor influencing future oil and gas development in the future is global demand.

> "… the state of the global economy is the single most important driving factor for increased attention to the Arctic. Considering the counterfactual, even though ice melting continues and governments are handing out new drilling licenses, a downturn in the global economy will make increased production in the Arctic less likely to occur. Furthermore, as production cost is higher in the Arctic compared to other oil and gas producing regions, the region is even more vulnerable to changes in the global economy." (8042)

Discussion

While there is an intuitive belief that climate change is currently impacting resource development in the Arctic, the actual research on the subject, although limited, tends to be inconclusive. Aside from a study looking at shifts in water flows in a hydro-electric project and an early closure to winter mining roads in Canada in 2006, there is limited evidence-based research indicating that climate change is currently having any sort of an impact on resource development. Most of the commentary in the "scientific" discourse is hypothetical in nature. Based on their assessments of current climate change models, scientists believe climate change will impact resource development in the future. They are not sure however whether these impacts will be positive or negative for resource development.

Some project that climate change will have a positive impact in two instances: increased potential for off-shore oil and gas exploration and production, and improved ease of access to the Arctic through increased shipping. According to climate change researchers, loss of sea ice will make off-shore oil and gas operations in the Arctic more likely. Less sea ice and longer ice free seasons will mean that cheaper conventional off-shore platforms can be used in the Arctic and used for longer periods of time. This makes both exploration and production cheaper and as such, make Arctic oil and gas development more viable. Likewise, melting sea ice will make shipping easier in the Arctic. This will decrease the costs of those in both mining and oil and gas who use shipping to get equipment in and production out of the Arctic. Regions will become increasing accessible from a profitability perspective and this will lead to increased resource development in the Arctic.

At the same time, many of these same researchers also point to potentially negative impacts on resource development coming from climate change. Indeed, as far as the main scientific discourse on climate change in the Arctic is concerned, it does appear that more space is devoted to discussing potentially negative impacts than potentially positive ones. In terms of land-based transportation related to resource development, most, if not all, statements made stress the problems that would be caused by climate change. Ice roads essential for both oil and gas and mining would become less useful. Permafrost melt would make building and maintaining pipelines more difficult. As well, all land-based infrastructure would be negatively impacted due to melting permafrost and increased erosion. Variation in water flows would be problematic for hydro-electric installations. In addition, the potentially positive impacts of climate change on off-shore oil and gas installations could be countered by increased wave action and increases in extreme weather. An increase in extreme weather occurrences would also have a negative impact on future Arctic shipping.

Whatever scientists may thing of the potential future influence of climate change on resource development, it is the representatives of industry that will be making the most important decisions on future resource development in the Arctic. They will decide whether to invest in the region or not and as such their opinions on the impacts of climate change are the most important to understanding the relationship between climate change and resource development. Although research is limited, existing information indicates that industry is not yet certain what impacts will be. While some seem to be aware of potential positive impacts, potentially negative impacts seem to be highlighted as concerns. What is most interesting is that industry does not seem to be that interested in the relationship between climate change and resource development. This may due to the fact, hypothesized by some researchers in the Arctic Climate Impact Assessment, that there are other more important factors, such as global demand for resources, that are more of a concern to them in so far as decisions regarding future resource development in the Arctic.

Conclusions

The analysis above is not an exhaustive review of all material discussing the relationship between Arctic resource development and climate change. The publications reviewed here do, however, represent the main arguments presented in the literature. These arguments point to an uncertain relationship between the two phenomena. There may be a relationship between climate change and a future increase in Arctic resource development but it is likely that this relationship is currently of less importance than other factors. In addition, the nature of the relationship at this point is uncertain. We do not know if climate change will have a positive impact or negative impact. While potential positive impacts are noted, negative impacts tend to be highlighted in the academic and scientific material.

In the long term climate change may lead to more Arctic resource development but in the short term it is more likely to be a barrier. While some may believe that climate change is the main

reasons for increased interest in resource development, there is evidence that the main determining factor in Arctic resource development is the needs of the global economy. So far, there is little proof that climate change has created a situation where increased ease of access will lead to more resource development in the Arctic however this may change in the future.

Key Questions

In terms of the objectives of the Resources and Sustainable Development in the Arctic project, the gap analysis here offers us little indication that there is any direct usefulness in studying the relationship between climate change and resources development. Climate change will likely only affect the benefits communities derive from resource development through its influence on decisions regarding resource development projects. For now this influence appears limited and it is uncertain whether climate change will have a positive or negative impact on these decisions. In addition, while the impacts of climate change on Arctic communities has been the most studied relationships in Arctic social science over the past decade, relatively little has been uncovered in terms of proven impacts. It is unlikely that ReSDA could add much to what other have already attempted to do.

At the same time, given the importance of climate change in the Arctic, ReSDA does need to follow developments in research involving social impacts. It may be that more direct links between the two phenomena may be discovered later. In the meantime however, rather than try and determine whether climate change is influencing resource development in the Arctic, some of the existing literature notes that it may be more useful to look at the impacts of resource development related to the ability of communities to deal with climate change. While we do not know the extent that climate change is influencing resource development and whether climate change is a positive or negative force for resource development in the Arctic, there does appear to be a consensus that resource development will have an impact on Arctic communities' abilities to deal with climate change impacts (or if climate change ends up not having a major impact – other forces). It can help or hinder. Most of the resource development in the past has reduced communities' abilities to deal with such issues. Can we change this so that can have a positive impact? Can Arctic communities create a situation where resource development will provide them with the necessary tools to ensure that they are not 'vulnerable' to climate change? Can resource development be used to help them to 'adapt' to climate change? How can resource development be done in a manner that it helps Arctic communities become 'resilient' to potential challenges such as climate change? These are key questions that should guide ReSDA research when it considers climate change impacts.

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