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ORIGINAL ARTICLE

Addressing human security in the Arctic in the context of climate change through science and technology

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Abstract Human security, particularly in the Arctic, is being stressed by climate change and other factors. Science and technology provide one instrument for the development of strategies that will protect those living in the Arctic from threats to environmental, social and economic conditions, namely human security, incurred by climate change. This paper explores a public good approach to Canada's Science and Technology (S&T) strategy. Investigated in particular is the role of science and technology in addressing Arctic human security needs, using evolving Organisation for Economic Co-operation and Development (OECD) quality-of-life indicators to measure the ability of Canada's S&T strategy to meet these needs.

Keywords Human security · Climate change · Science and technology policy · Quality-of-life indicators

1 Introduction

In recent years the Summits of the G-8 countries have brought the issue of climate change to the forefront of governmental policy debate. The 2009 Declaration of the Leaders of the Major Economies Forum (MEF) on Energy and Climate, meeting in L'Aquila, Italy on 10 July 2009 states, "*Climate change is one of the greatest challenges of our time. As leaders of the world's major economies, both developed and developing, we intend to respond vigorously to this challenge, being convinced that climate change poses a clear danger requiring an extraordinary global response, ...*"(MEF 2009) Examining climate change in

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the context of security in a broader sense has also become prevalent in many national policy discussions. For example, the United Kingdom's national security strategy (United Kingdom 2008a) in the discussion of drivers of insecurity, noted that climate change is "*potentially the greatest challenge to global stability and security and therefore to national security. Tackling its causes, mitigating its risks and preparing for and dealing with its consequences are critical to our future security, as well as protecting global prosperity and avoiding humanitarian disaster.*"

Security as a term has evolved through the years. Although earlier defined only in terms of defence and maintenance of stability of a country, new, broader concepts of security policy extend this to include the ability to defuse political and socio-economic crises through the use of development and environmental policy measures. Actively promoted by the United Nations Development Program (United Nations 1994) as an alternative to foreign policy founded on militaristic objectives (McRae 2001), human security is defined in terms of economic, food, health, environmental, personal, community and political security, and as a freedom from "*want and fear*". The Commission on Human Security (United Nations 2003), while recognizing that the state remains the key guarantor of security, noted that states may fail to meet their security obligations to their own populations: "*The focus must broaden from the state to the security of people—to human security*". Human security has further been described as "*security against economic privation, an acceptable quality of life, and a guarantee of fundamental human rights*" (Axworthy 1997). This concept has since played a major role in shaping the international security discourse.

In this paper we wish to focus on people of the Canadian Arctic as an example of people whose human security is being threatened. The changing climate in the Canadian Arctic has increased the vulnerability of the social, economic and environmental security of Aboriginal Canadians living in the Arctic and underlines the clear need for a comprehensive Arctic strategy to address human security needs. To explore Arctic human security in this context, we propose the use of indicators based on the Millennium Development Goals (MDG) (United Nations 2002) and Organization for Economic Cooperation and Development (OECD) quality of life indicators. These indicators have been introduced as a framework for monitoring societal progress and addressing human security needs. There are several policy dimensions of this issue. In 2005, Canada produced a formal paper on the Northern Dimension of Canada's Foreign Policy (NDFP) and Fenge and Penikett (2009) examine this and present foreign policy in the context of the Arctic and its people. Another policy domain that has often been proposed as the basis for addressing human security issues is science and technology. In 2007, the Government of Canada announced a new Science and Technology (S&T) strategy (Government of Canada 2007). The focal question of this paper is how can science and technology contribute to the protection of life and property and economic and social security that are inherent in the concept of human security.

2 Arctic human security and climate change

The Arctic region is amongst the most susceptible to climate change impacts. The Arctic Climate Impact Assessment (ACIA 2005, p.8), prepared under the auspices of the Arctic Council (1996) and the International Arctic Science Committee (1990), states that climate change is projected to "*have major impacts within the Arctic, some of which are already underway.*" The ACIA describes the impacts of climate change on the Arctic evident in

polar amplification in surface air temperature, and decline in sea ice extent and thickness over the last several decades due to anthropogenic forcing. These findings are reiterated and further confirmed in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC 2007a), which states:

> Average arctic temperatures increased at almost twice the global average rate in the past 100 years. (p. 7)
>
> The Arctic is very likely to warm during this century more than the global mean. Warming is projected to be largest in winter and smallest in summer. (p. 851)

Temperatures in the Arctic are projected to increase with ranges from approximately 4°C to 11°C during winter; projections for an ice-free summer include estimates ranging from 2030 to the end of the 21st century (IPCC 2007a; Wang and Overland 2009). Indeed, recent observations show the lowest Arctic summertime ice extent on record in September, 2007 (Serreze et al. 2007; Stroeve et al. 2007).

These unprecedented changes in Arctic climate are creating increasingly vulnerable social, economic and environmental conditions, those that define human security, for Arctic communities. The ACIA chapter, "The Changing Arctic: Indigenous Perspectives", concludes with the statement:

> For the peoples of the Arctic, whose future is at stake, having the ability to make choices and changes is a matter of survival, to which all available resources must be applied. (ACIA 2005, p. 95)

This sense of choices and the information needed to make them is also stressed in the IPCC Working Group 2 (Impacts, Adaptations and Vulnerability) report with the statement:

> Already Arctic human communities are adapting to climate change, but both external and internal stressors challenge their adaptive capabilities (high confidence). Benefits associated with climate change will be regionally specific and widely variable at different locations (medium confidence). (IPCC 2007b, p. 655)

The need for increased consultation with local indigenous groups to determine a comprehensive climate change strategy for the Arctic is stressed. In addition to the Arctic Council, regional organizations such as the Nordic Council of Ministers (NCM) also recognize the importance of consultation with indigenous groups and place at the core of their objectives the preservation of "natural and cultural heritage" through initiatives dedicated to improvement in quality of life, protection of the environment, sustainability and conservation (NCM Arctic Cooperation Programme 1996). More recently, the Arctic Governance Project (2009) was established to address the scientific assessments outlined in the ACIA, while the Nordic Council, Nordic Investment Bank and Swedish Presidency of the European Union have organized a conference prior to the UN Climate Change Conference in Copenhagen (COP15) to determine financial instruments and energy solutions that will enable a low carbon economy in northern communities (Nordic Council 2009).

Although initiatives such as the Northern Strategy (Government of Canada 2005) established in May, 2005 between the federal government and governments of Nunavut, Yukon and Northwest Territories, created a framework with objectives including environmental protection, healthy communities, sustainable development, economic diversification, sovereignty reinforcement, northern science and research development, and circumpolar cooperation, a strategy for Canada's northern communities that addresses human security in the context of social, economic and environmental progress has yet to be

implemented. The Kelowna Accord (Patterson 2006) established in November, 2005, also endeavoured to promote equality amongst Canadians through a commitment to education, housing and economic opportunities. The future of both initiatives is now unclear.

3 Human security and international indicators of societal progress

Human security is characterized in the United Nations (2003) in terms of "protection and empowerment".

> Human security means protecting vital freedoms. It means protecting people from critical and pervasive threats and situations, building on their strengths and aspirations. It also means creating systems that give people the building blocks of survival, dignity and livelihood. To do this, it offers two general strategies: protection and empowerment. Protection shields people from dangers. Empowerment enables people to develop their potential and become full participants in decision-making.

The concept of human security also has embedded in its objectives the importance for domestic, national and international security of education, information technology and environmental protection. Another aspect is the formulation of a comprehensive climate change adaptation strategy that places at its core the needs of those most affected by climate change, including those in the Arctic. Although the measurement of changing physical and biological parameters in the Arctic with global climate change is relatively straightforward, measures or indicators of societal progress and human security are more difficult to assess and those will be addressed here.

The limitations of the economic indicator of Gross Domestic Product (GDP) in monitoring quality of life and societal well-being were first addressed with the establishment of the Human Development Index (HDI) in the 1990 United Nations Human Development Report. The HDI measures life expectancy at birth, education as monitored in terms of adult literacy and school enrolment, and standard of living as monitored by GDP per capita; namely in terms of life expectancy, knowledge and income. The Second OECD World Forum on Statistics, Knowledge and Policy, "Measuring and Fostering the Progress of Societies," (Istanbul, June, 2007) (OECD 2007a) highlighted the importance of quality of life as a measure of societal progress. The resulting Istanbul Declaration (OECD 2007b) states that

> A culture of evidence-based decision-making has to be promoted at all levels, to increase the welfare of societies…The availability of statistical indicators of economic, social, and environmental outcomes and their dissemination to citizens can contribute to promoting good governance and the improvement of democratic processes. It can strengthen citizens' capacity to influence the goals of societies they live in through debate and consensus building, and increase the accountability of public policies…

The terms *"evidence-based"* and *"dissemination to citizens"* are both directly related to science and technology. The Istanbul Declaration also states that "*Official statistics are a key public good that foster the progress of societies*".

The Millennium Development Goals (MDG) (United Nations 2007) set twenty-one targets with sixty indicators to be achieved by 2015 as ways to monitor a nation's progress. These goals address the challenges of human security and include such activities as the eradication of hunger and poverty, increased access to primary education, health and gender

related issues, the guarantee of environmental sustainability, and promotion of global partnerships.

In recognition of the shortcomings inherent in the composite HDI for measuring societal progress in the Arctic, the Arctic Council mandated the Arctic Human Development Report (AHDR) (2004) which provided an assessment of more general standards associated with the traditional way of life of Arctic Aboriginal communities. In the AHDR, generalized indicators were used to define the evolving Arctic Social Indicators (ASI) (2009). These included, in addition to the HDI, the concept of control of fate or an ability to determine destinies, cultural continuity, and a close relationship with the natural world. Means to define the ASI are in the process of being developed and refined to ensure availability of data and that the needs of Arctic Aboriginal communities for whom the index is created benefit from the generalized indicators outlined in the ASI.

4 Canada's science and technology strategy

Canada's Science and Technology (S&T) Strategy (2007) is based on the principle of science for the benefit of society and its citizens and it identified three pillars: the entrepreneurial advantage, whereby knowledge is translated into commercial applications and innovation is defined by technological devices and the commercialisation of technologies; the knowledge advantage, wherein research is targeted to address priority areas including environmental science and technologies, natural resources and energy, health and related technologies, and information technologies; and the people advantage, which focuses on training, education and science literacy. Hence, the S&T Strategy is potentially one resource for addressing, at least in part, the issues of Arctic human security. Further, the people advantage framework highlights: "*enhancing opportunities for science and technology graduates, increasing the supply of highly qualified and globally connected science and technology graduates, and getting Canadians excited about science and technology.*" Can the S&T strategy enable the benefits of science to meet the needs of Aboriginal Canadians?

This potential may however only be realized when measures to ensure human security within a rapidly changing climate are established as one of the principal objectives of Canada's S&T strategy, in cooperation with territorial government programs. Only then will the strategy be considered effective from both a national policy and Arctic Aboriginal community perspective; namely when national policy objectives meet Arctic Aboriginal community human security needs. As Fenge and Penikett (2009) concluded in the analysis of the Northern Dimension of Canada's Foreign Policy (NDFP), there is a "*northern foreign policy vacuum*" suggesting that Canada is neither fully prepared nor well equipped to "*influence and shape international debate on the future of this region*". In their analysis they bring forward several examples and note that the literature is not entirely consistent.

5 Indicators of progress

In order to establish the effectiveness of policies and strategies in the longer term, it is appropriate to have in place metrics or indicators against which progress can be measured. Canada's S&T strategy states that "*government will…work with the OECD and other countries to develop metrics that will enable comparisons against international benchmarks of success*." This paper is a contribution to that process and focuses on the quality of life and human security of northern Aboriginal peoples in Canada.

The OECD 2009 Fact Book of Economic, Environmental and Social Statistics uses indicators for twelve fields that build on the MDG initiatives. These are: population and migration; macroeconomic trends; economic globalisation; prices; energy; labour market; science and technology; environment; education; public finance; quality of life; and inequality. A subset of these fields provides categories for indicators of progress in societal well-being in the context of science and technology. The categories are: science and technology; environment; education, and quality of life (Table 1). It is recognized that the categories are not mutually exclusive; some issues and categories overlap. The choice of these categories and the selection of indicators for each category are based on the following logical analysis.

6 Science and technology

The focus here is primarily on the use of S&T towards the provision of public goods to Aboriginal Canadians living in the Arctic. S&T initiatives and programs can be used to encourage protection and self-sufficiency in Arctic communities through education and training, enhancement of human security and environmental protection, and scientific outreach and literacy. Public good services concern joint or collective consumption, availability of a product to consumers without threat of its depletion and non-excludability, describing the unrestricted availability of a product to all consumers (Henstra and McBean 2005; Holcombe 2000) and hence, the provision of public goods by the federal government will benefit and be available to all Canadian citizens. Initiatives that provide equality of opportunity and protection to those rendered most vulnerable by a rapidly changing climate will also enable effective implementation of the strategy from the point of view of Aboriginal Canadians living in the Arctic.

The third priority of the "people advantage" of Canada's S&T strategy, "Getting Canadians excited about science and technology", requires an investment in science literacy that reinforces and respects social and cultural identity in Canada's northern communities. Additional measures to establish science outreach and improve scientific literacy include efforts to engage northern communities in research programmes, as outlined in the report by

Table 1 Suggested indicators to monitor quality of life in the context of science and technology

Category	Indicators ->			
Science and Technology	Expenditure in R&D	Investment in information and communication technology	Computer and internet access	Development of global partnerships
Energy/ Environment	Fisheries	Air and water quality	GHG and contaminant concentrations	Environmental sector and sustainability indicators
Education	Public and private spending on primary, secondary and tertiary education	PISA outcomes	Tertiary attainment	Increase in number of educational institutions in the Arctic
Quality of Life	Life expectancy	Infant mortality	Youth inactivity	Income inequality

Inuit Tapiirit Kanatami (ITK) and the Nunavut Research Institute (NRI)(ITK-NRI 2007), "Negotiating research relationships with Inuit communities". Galleries and museums provide the community spaces necessary to instil an interest in science and technology at an early age in northern communities. Libraries as "public, collective" entities that reflect "the importance that companies and citizens attach to culture and the arts" (Simpson 2007) are essential in promoting reading, mathematical and scientific literacy in Canada's northern and remote communities, while providing forums for the imagination for Aboriginal youth. Canada's S&T strategy can also build on the expertise of existing programs dedicated to science and technology in Aboriginal communities such as the Canadian Aboriginal Science and Technology Society (CASTS 1992) and provide funds to incorporate science into the training and curricula within programs such as McGill's Office of First Nations and Inuit Education program (2009).

The cost for long-term projects dedicated to the establishment of an educational and monitoring infrastructure in Canada's northern communities will require shared commitments from provincial, territorial and federal governments to ensure that targets, based on outlined indicators, are met and opportunities for Aboriginal Canadians in Canada's science and technology sector created. The Quebec government's 2007 announcement of support for Quebec's Inuit sets a precedent for other Canadian provinces in provincial-territorial negotiations regarding Aboriginal Canadians (Curry 2007).

Through its declared commitment to international S&T missions, Canada's S&T strategy has the potential to foster partnerships with developing nations and encourage further involvement of Aboriginal Canadians in the circumpolar community. This can be achieved through internship programs in cooperation with international organizations such as Many Strong Voices (2005) that recognize the parallels in the vulnerability of those living in the Arctic and developing nations to climate change.

7 Environment

Ensuring the security of Canadian citizens requires the protection of both human and natural resources. This is none the more apparent than in the Canadian Arctic. Climate change poses a threat to those living in Canada's northern communities and by extension, to Arctic human security: the opening of the Northwest Passage and increased potential for resource exploitation and extraction as a result of longer ice-free seasons and loss in thick or multiyear ice highlights the need for a comprehensive strategy that addresses this threat. The Council of the Federation (2007) underlined the central role to be played by Aboriginal Canadians in addressing Canada's labour shortage through the creation of employment opportunities in Canada's northern and remote communities. Investment in scientific research in climate change adaptation and mitigation strategies in Canada's northern communities is in the best interest of all levels of government. A framework founded on environmental protection and indicators that abide by international treaties and conventions is essential in land use and resource negotiations in the Arctic, for the purposes of international stability and cooperation (Corell 2007).

A framework founded on climate change adaptation creates opportunities and employment for local communities. The impacts of a changing climate or disaster events are largely determined by a society's or community's vulnerability, which is a function of its exposure to climate and other hazards, its sensitivity to the stresses they impose, and its capacity to adapt to these stresses (Henstra and McBean 2009). That vulnerability can be reduced through actions to minimize exposure, reduce the sensitivity of people and

systems, and strengthen the community's adaptive capacity. Each of these requires approaches that build upon science and technology capacity. The four factors important towards adaptive capacity are: access to information, expertise with information, analyses and the translation of information into policy, fiscal capacity, and political will to act. Designing policies for adaptation to climate change and sustainable development all require: assessments of the effectiveness, costs and feasibility of measures to reduce vulnerability; stakeholder analyses to identify targets and beneficiaries of interventions; analyses of the consequences of inaction; and other factors. One aspect is the difficulties with regard to the fiscal capacity as at least some level of public expenditure will be needed and that will be limited by competing demands on scarce economic resources. In the end, a critical issue will be generation of the political will to act. Noting that "the ultimate role of government is…to protect its citizens" McBean (2006) maintains that early-warning systems play an important role in reducing social, economic and environmental devastation due to weather-climate extreme events. For Canada's Aboriginal community living in northern communities in particular, where forecasts can no longer be made based on traditional knowledge due to accelerated changes in local conditions as a result of a changing climate, these have special significance. Environmental indicator networks and emergency preparedness systems that alert individuals to potential hazards and risks with timely access, via the internet, could be founded under the auspices of Canada's S&T strategy. Investment in wireless technologies and the internet in the North will further assist in establishing an early-warning and forecasting framework. The development of an international Arctic Observing Network (AON) by the Arctic Council with its working group Arctic Monitoring and Assessment Programme (AMAP) also presents opportunities for Canada's Arctic communities.

Climate change centres would assist in achieving site- and region-specific adaptation strategies based on community needs. Canada's S&T strategy may facilitate the expansion of community-based monitoring (CBM) and training programs, by creating a CBM framework for Aboriginal communities in the Canadian Arctic. Both initiatives augment Canada's presence in the North.

8 Education

The UN Commission of Human Security underlined the importance of education in providing security for individuals, stating that "*Basic education and public information that provide knowledge, life skills and respect for diversity are particularly important for human security*" (UN Commission of Human Security 2003). Central to the advancement of science and technology in Canadian society are the educational resources that stimulate creativity and innovative thought. Canada's S&T strategy plans to "*increase access to post-secondary education*", and to "*reduce barriers to labour mobility*". These are precisely the objectives required in rural and northern communities to equip community members with the skills required for engagement in the science and technology sector.

Previous studies (Canadian Council on Learning 2007) have shown under-representation of Aboriginal Canadians in S&T occupations. Training, internship and mentorship programs as well as scholarship opportunities for Aboriginal Canadians are essential to ensure equality in access to education and to ensure the development of Canadian talent. Significant contributions to Canada's research community are to be made from the input, skills and expertise of those living in the Canadian Arctic, particularly in the area of environmental science and technologies. Cooperative programs and internships will assist

in establishing connections between universities, industry, government and community members to foster an interest in science and its role in understanding climate change, amongst other priorities, in northern communities.

Specific measures to "enhance opportunities for science and technology graduates", while "increasing the supply of globally-connected S&T graduates", as outlined in Canada's S&T "people advantage" include initiatives that provide Aboriginal Canadians with the skills and expertise for meaningful employment within their communities. Education is a public good that will benefit and should be available to all Canadians. Programs offered at the primary, secondary, and post-secondary level that integrate the science of climate change with indigenous knowledge will foster the curiosity essential to establishing adaptation initiatives by northerners, for northerners. Canada's S&T strategy can facilitate the provision of opportunities for local citizens by ensuring that Aboriginal Canadians living in the Arctic have opportunities for funding for scholarship. Training programs for such jobs as continental shelf mapping and surveying, for example, would assist Canada in meeting its targets in accordance with the requirements of the United Nations Convention on the Law of the Seas (UNCLOS), while community-based monitoring will ensure Canadian presence in the Arctic. Involvement of local aboriginal organizations in the monitoring and planning of research programmes conducted in the Arctic provides an effective means of community engagement, with participation in research and development planning committees in northern oil and gas studies as an example. Cooperative programs provide the mechanism within Canada's S&T strategy to supply Aboriginal Canadians with the skills required by Canadian companies and firms to establish businesses in local communities, in order to promote economic development and self-sufficiency in northern communities.

As climate change renders a previously inhospitable region accessible to the international community, natural resources and energy will play a fundamental role in defining the Arctic in coming decades. For this reason, it will become essential for local communities and their institutions to partner with industry for the purposes of establishing community-based engineering, manufacturing, and power companies. Imperative also in the protection of the Arctic and its people are opportunities for green energy projects in northern communities.

Education and training can be used as tools to ensure the development of alternative energy programs throughout northern Canada and in rural regions, in partnership with regional communities, territorial governments and organizations such as Arctic Energy Alliance. Imperative also in the protection of the Arctic and its people are opportunities for green energy projects in northern communities such as the Upnit Power Corporation, owned by the Hupacasath First Nation, with business partners City of Port Alberni, Ucluelet First Nation, and Synex Energy (August 2006). The interplay between climate change impacts and green energy projects could also build upon such as initiatives as the Wha 'Ti Community Energy Plan (Indian and Northern Affairs Canada 2007), where high school students could be introduced to opportunities in the area of alternative and renewable energy technologies (design, engineering, manufacturing, implementation, maintenance), through training and apprenticeship programs. The Arctic Council, Children and Youth of the Arctic Initiative (Arctic Council 2002) has the potential to play a pivotal role in Canada's science and technology strategy by establishing opportunities for Aboriginal Canadian youth within an international framework.

While the categories associated with quality of life and education can include indicators defined through the HDI, the environment category can possibly encompass the evolving ASI indicators of fate control (fisheries and resource management, water and air quality and

contaminant concentration testing to protect community health) and relationship to the natural world (environmental assessments and protection based on international sustainability indicators).

General indicators for the Arctic, as is emphasized in the AHDR, enable quality-of-life assessments from the perspective of Arctic Aboriginal communities, and incorporate values not traditionally accounted for in the GDP or even HDI description for societal progress.

9 Measuring the success of Canada's S&T strategy in meeting arctic human security needs

Within each category indicators are suggested that have been selected to highlight the importance of creating educational and employment opportunities for Aboriginal Canadians in the Arctic to ensure social equality and improvement in quality of life. Quantitative measures of societal progress are still needed to ascertain change in Canada's northern communities. It is recognized that these indicators are not mutually exclusive in the sense that indicators listed in one category may also be, at least in part, indicators for another category.

The indicators selected in this study are chosen to monitor the ability of Canada's S&T strategy to meet Arctic human security needs and to improve quality of life in the context of science and technology following its implementation relative to values established prior to its implementation. It should be noted that it is essential that the implementation of Canada's S&T strategy be done in consultation and collaboration with communities and territorial government and their programs dedicated to science and technology, sustainable development and educational initiatives. Thus, in consideration of the science and technology category in Table 1 as an example, an increase in expenditures in research and development and information and communication technology in the Arctic following implementation of the strategy relative to expenditures prior to its implementation will provide an indication of government funds directed to Arctic Aboriginal communities for the purposes of improving quality of life by offering support for innovation. Enhanced computer and internet access for the provision of scientific information and training will provide increased access to information; an important caveat to an increase in this indicator include a loss in values associated with the Arctic Aboriginal community traditional way of life, as defined through the ASI, and may detract from well-being through less physical activity. In order to assess the benefits of increased computer and internet access it may therefore be necessary to limit this index to internet use for the purposes of learning or for such features as forecasting, long-distance learning, although such usage may be difficult to monitor. Development of global partnerships through enhanced Canadian participation in the International Polar Year, the Arctic Science Committee and the Arctic Council's Sustainable Development Working Group would also ensure inclusion of Arctic Aboriginal communities in a burgeoning area of scientific research.

The OECD indicators presented in Table 1 provide a benchmark and framework against which the success of Canada's S&T strategy in meeting Arctic human security needs may be tested against indicators from the fields of science and technology, energy and the environment, education, and quality of life.

9.1 Science and technology

According to the OECD 2009 Factbook, universal indicators for Research and Development are defined in terms of basic and applied research, and experimental

development. In this instance experimental development refers to the application of science to the production of new devices, and "installing new processes, systems and services". Spending as a percentage of GDP dedicated to the development of a monitoring and early-warning system infrastructure in the context of environmental protection and security could serve as a specific indicator for research and development (R&D) expenditure. Investments in information and communication technology, computer and internet access are other measures for assessing government's commitment to the establishment of a research and monitoring framework and presence in the Arctic. Canada could also become a leader in defining evolving OECD indicators for R&D expenditure defined in terms of the creation of educational institutions, CBM programs and early-warning systems, science centres and laboratories that create employment and ensure a continued presence in Canada's Arctic, namely the provision of public goods that are to the advantage of all Canadians. If dedicated to the aforementioned objectives, Canada's S&T strategy has the potential to improve quality of life within Arctic Aboriginal communities, and to contribute to generalized ASI indicators such as fate control (with the establishment of energy partnerships), cultural continuity (through preservation of language and heritage using electronic archival methods) and relationship to the natural world (through renewed government commitment to sustainability and environmental protection, as is noted below).

Outcomes in increased accessibility to information and technology could be measured by the percentage of total government spending on programs that are established in Canada's northern communities for the purposes of environmental protection within a timeframe comparable to the 2015 deadline established for the Millennium Development Goals. Computer and Internet access can be measured, as in previous OECD surveys, on a household basis. Finally, outcomes for the development of global partnerships can be monitored based on the number of global partnerships established in addition to the traditional indicators adopted by MDG such as youth employment and internet access (MDG, 2007).

9.2 Environment

In consideration of the environment, fisheries, greenhouse gas (GHG) emissions and contaminant concentrations could be used to monitor environmental protection, in addition to environmental sustainability, or "sector" indicators modelled after those established by the United Kingdom (United Kingdom 2008b). As in previous OECD surveys, fisheries outcomes are based on fish production in specific regions relative to 2005 values when the latest surveys were conducted. Air and water quality indicators could be established through environmental monitoring programs created under the auspices of Canada's S&T strategy based on continuous weekly measurements that are compared either to levels when monitoring was first initiated, or previous measurements conducted in northern communities. Canada's S&T strategy therefore has the opportunity through the implementation of effective monitoring networks, to contribute to generalized Arctic indicators of well-being pertaining to relationship to the natural world; assessment may be made based on improvement in environmental indicators relative to values measured prior to implementation of the strategy mandate dedicated to human security in the context of energy and the environment.

9.3 Education

In regard to education indicators, the Programme for International Student Assessment (PISA) (OECD 2000) outcomes, public and private spending on all levels of education

(including tertiary attainment and number of graduates) are appropriate. Specifically, the increase in number of educational institutions in the Arctic, with a focus on an increase in the number of graduates and educational opportunities in Northern Communities, is also important. The OECD 2009 Factbook describes the importance of investment in education for poverty alleviation and development,

> Expenditure on education is an investment that can help to foster economic growth, enhance productivity, contribute to personal and social development, and reduce social inequality. The proportion of total financial resources devoted to education is one of the key choices made in each country by governments, enterprises and individual students and their families.

The report of the Commission on Human Security (United Nations 2003) highlights "empowering all people with universal basic education" as a priority in addressing human security needs. These are precisely the objectives that Canada's S&T strategy could and should pursue to improve the quality of life in Canada's Northern communities and in so doing, strengthen claims to the Arctic through a permanent presence founded on sustainability and innovation. An increase in the number of graduates in science and technology in northern communities will provide an additional measure of the success of Canada's S&T strategy in providing educational and learning opportunities for Aboriginal Canadians living in the Arctic.

9.4 Quality of life

Finally, in consideration of quality of life, life expectancy, infant mortality, youth inactivity and income inequality can be used to monitor the role of science in improving the lives of Aboriginal Canadians and creating opportunities within northern communities, for northern communities. The OECD defines youth inactivity as the percentage of youth who are neither in education nor in employment. Internship and mentorship programs as part of Canada's S&T strategy if successful and focused on education and training will assist in lowering this indicator. Training programs and climate change research programs as part of Canada's S&T strategy will further assist in promoting the curiosity essential to creating hope and increased presence in Canada's North. A comparison of incomes between Aboriginal and non-Aboriginal Canadians will provide further evidence for changes that will eliminate the distinction between Aboriginal and non-Aboriginal Canadians. Here it is argued that science and technology and an emphasis on the "people advantage", through concerted investment in education, training, and adaptation strategies that are essential to ensuring that human security needs are met, have the potential to be instrumental in eliminating this distinction.

10 Conclusions

Increased vulnerability of the social, economic and environmental security of Aboriginal Canadians living in the Arctic as a consequence of climate change underlines the need for a comprehensive Arctic strategy dedicated to human security needs. Science and technology provide one tool through which threats to Arctic human security imposed by climate change may be addressed. In this analysis we have explored the concept of human security in terms of "protection and empowerment" of the individual in the context of climate change, and introduced MDG and OECD indicators that serve as a benchmark to monitor human security needs. The potential for a public good approach to Canada's S&T strategy to meet

Arctic human security needs, based on the "people advantage", was explored in the context of science and technology, environment, and education. A proposal to measure the ability of Canada's S&T strategy to meet Arctic human security needs was presented based on a specific set of categories within MDG and OECD indicators including education, science and technology, energy and environment, and quality of life.

The success of Canada's Science and Technology strategy relies on a competitive advantage achieved through innovation and the fulfilment of a national obligation to improve the quality of life for all Canadians. Emerging indicators that identify progress in science and technology, education, environmental stewardship and quality of life will establish a benchmark against which the success of Canada's science and technology strategy may be measured, and international standards established. This is the true signature of a strategy that is to the advantage of Canada and all Canadians.

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