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ARCTIC FUTURES 2050: SCENARIOS NARRATIVES

Introduction

The Arctic Futures Workshop held in April 2018 brought together participants with arctic expertise from multiple sectors, primarily government, natural and geophysical sciences, social sciences, and public service. The purpose of the workshop was for these experts to collaboratively bring their perspectives to bear on the future of the Arctic and to then produce plausible scenarios to inform the future-oriented SEARCH conference to be held in September 2019. The focal question of the workshop was: "What information is needed to successfully respond to changes in arctic environments by 2050?" Participants worked together for over two days in Seattle and then continued their efforts online. This report provides narrative scenarios based on the results of the Scenlab Robustness outputs, that in turn are direct results of the intensive work of participants. These scenarios are designed to provoke participants of the Futures 2050 Conference to consider multiple possible arctic futures and thus open the possibility of innovative thinking in relation to decisions today that can shape the future Arctic.

Scenarios are stories of possible futures. More specifically, the scenarios method offers an inclusive way of analyzing possible future events by considering multiple and contrasting alternative outcomes at different time scales. While scenarios have been used by businesses as a formal planning tool for over a half century, we all use a form of scenarios-thinking in our daily lives when we plan a trip, prepare for a meeting where the outcome is uncertain, or work through the best strategy for our household finances. To make crucial decisions in the absence of complete information, individuals, companies, and communities can consider multiple futures. Such scenario exercises do not produce forecasts of what is to come or causal relationships. Nor are they visions of what participants would like to happen. Instead, scenarios address questions of, "What would happen if…".

Scenarios create opportunities for strategic decision-making to reduce risk in future activities. Thus, they are useful for decision makers when uncertainty is high and when multiple futures are both possible and significantly different. The Study of Environmental Arctic Change (SEARCH) is using scenarios in preparation for our September 2019 conference on Arctic Futures 2050. The mission of SEARCH is to provide timely, pertinent, and useable science related to the Arctic to decision makers. Thus, we directed our workshop towards ensuring accurate information under conditions of a rapidly changing arctic social-ecological system. Engaging in scenarios planning changes the way the participants think about the future. Rather than being a concept characterized by uncertainty or trepidation, the future can become a suite of possibilities that a community, individual, or organizations can work towards to address needs, perturbations, and outcomes.

The scenario outcomes reported here use Intergovernmental Panel of Climate Change (IPCC) forecasts subject to Representative Concentrated Pathways (RCPs) of greenhouse gas emissions as key factors to consider what the future Arctic environment may look like. But, rather than functioning as a causal relationship, our

work helps a person consider multiple variables that matter to the future simultaneously. Imagine you walk into a large room, or a warehouse, full of doors. Behind each of these many doors is a different future for the Arctic in 2050. Each door represents a bundle of variables – demographics, the price of oil, greenhouse gas emissions, Indigenous legal status, ocean temperature, rate of glacial melt, public health systems – indeed as many variables as one can think of related to the Arctic. Today we do not know which door we will "walk through" in 2050. What will be the combination of geophysical, social, ecological, economic, and other factors present that make the Arctic what it will be in 2050? Nonetheless, perhaps today we must make decisions related to all these mentioned variables in order to try to shape a future for the Arctic. Rigorously "what-ifing" the key factors that will define the Arctic in 2050 is what the SEARCH scenarios process has done. While the variables may be limitless that define eventual states, experts – people from different walks of life with experience and vision related to living, working, and researching the Arctic – can narrow the variables to those that are most worth focusing our current attention on. This is what our workshop did. The experts, over the course of the workshop and in hours of follow-up work, narrowed the scope of factors key to the future of the Arctic for evaluation to a set of sixteen Key Factors. These form the basis of our scenarios method because after agreeing to what is most likely to matter behind the 2050 door, we create plausible futures for every key factor to create a range of possibilities. These are called Future Projections. But, how do we evaluate what those doors may hold behind them based on the Future Projections of the Key Factors?

We evaluate the scenarios using a *Robustness Analysis* method. As noted, participants went through a collaborative deliberative process of deciding which Key Factors will matter most to answer the focal question - "What information is needed to successfully respond to changes in Arctic environments by 2050?" In our workshop, participants narrowed the Key Factors down to 16. They then brainstormed the possible Future Projections for these, 3-5 for each Key Factor. Then, participants ranked, independently from one another, how plausible any one Future Projection is for 2050. Future projections are required to be *plausible,* so the resulting scenarios can be stories that make sense. Note that *plausibility* of a future projection is not the same as its probability of occurring. A second scoring process had participants decide how consistent each possible Future Projection is to any other Future Projection – a pairwise consistency analysis. In short, consistency analysis asks one to consider which variables in the future can coexist. For the definition of *consistency*, remember scenarios should be internally consistent, i.e., components of the scenario should not be in stark conflict to each other or mutually exclusive of occurring. For example, a future projection of the health of the marine environment that is able to provide a full range of food options that we have come to expect in the amount, and places, we expect cannot coexist with a fully degraded cryosphere because the warmer waters and lack of sea ice are inconsistent with a productive Arctic Ocean.

Both of the *consistency* and *plausibility* scorings are then combined by computer software, to determine which scenario (which is a combination of 16 Future Projections) is the most robust. A *robust* scenario is both *plausible* and *consistent* but not necessarily the <u>most</u> *plausible* or <u>most</u> *consistent* because the *plausibility* and

consistency were weighted equally. In short, our work produces not a single future that is most likely to happen. Instead, it produces multiple combinations of variables that matter and provides a method for evaluating them. One can look for only the most consistent scenario, or only the most plausible scenario. In fact, serious play is encouraged with the different possible combinations of outcomes in order to connect science and planning today to the door that will be opened in 2050.

As we turn to the results below, remember any one scenario is a suite of 16 Future Projections of identified Key Factors; each scenario is a possible door. We must remember the future is never certain, hence we employ the plural – arctic futures. This upcoming SEARCH Conference, Arctic Futures 2050, is focused on working with the expertise of Arctic residents, scholars, elected officials, and policy makers to provide a comprehensive multi-perspective view of what information matters most in relation to adaptation of the Arctic and its peoples to the ongoing and future changes of the region. Different people tell different stories based on how they perceive these key factors to operate in their livelihoods, work, jurisdictions, economic sectors, or research programs. A power of the scenarios method is that it enables interactions across domains of science production and decision-making about how we might consider and guide our path towards various futures by making decisions now. Scenarios allow us to consider what the world could look like and how we might envision it in 2050 and beyond. Below we provide the results for several scenario outcomes – what you might find behind the Arctic 2050 door - that can promote the development of indicators of change and actionable plans. The full details of our rationale, workshop, method, and outcomes can be found in the technical report from denamics.

Orientation

The 16 Key Factors produced by experts form several clusters.

	KEY FACTORS
A	Climate Change: Cryosphere
B	Climate Change: Atmosphere
C	Climate Change: Terrestrial biosphere
D	Climate Change: Marine systems
E	Arctic Regional Collaboration
F	Arctic Regional Security
G	Global Policy
H	International Security
I	Status of Indigenous Peoples
J	Access to markets
K	Economics: Extraction of Renewable Resources
L	Economics: Extraction of Non-Renewable Resources
M	Arctic Energy Systems
N	Public Health
O	Community Sustainability
P	Science Advancement & Communication

(A, B, C, D) are tied to the climate modeling using RCP forcing from the IPCC. The Future Projections of these Key Factors are tied to the amount of greenhouse gas emissions produced and the consequent warming and environmental change.

(E, F, N, O) are tied to the amount of collaboration and communication between Arctic countries, as well as physical security. E and F are intra-Arctic variables, but not without drivers from outside. Public health (N) in the Arctic is largely an internal matter but tied to social, economic, and biological (epidemiological) forces from outside the Arctic. Community sustainability in the Arctic (O) is similarly a largely internal matter to Arctic regions of Arctic nations, but it will have external drivers as well.

(G, H) relate to global trends of policy, the state of international relations across the world, and physical security. While largely external to the Arctic, G and H can be affected by Arctic Eight.

(I) is tied to legal regimes of human rights, specifically of Indigenous Peoples. These are primarily the sets of rights at the national, and subnational, levels of government in the Arctic countries, but this Key Factor is also influenced by global trends.

(J,K,L) These Key Factors are produced by interactions between national and regional policy systems and international economic trends. Such market-based Key Factors are influenced both from within the Arctic region as well as outside. These Key Factors are influenced by regulatory systems and political debate over development, extraction, and equity.

(P) stands alone, though it is and will be influenced by the social and environmental trends of A-L.

The following seven narrative scenarios are drawn both from the actual results that produced the Most Robust, Most Consistent, Most Plausible outcomes. The other scenarios were invented from the Future Projections to present a full range of possible futures. For each narrative there is an image that shows the characteristics of the Arctic and the plausibility scores given by the participants for the Future Projections in that Arctic future – **the closer to the edge the shading is, the more plausible that particular Future Projection was scored.**

A charge from us to you as you evaluate the results

Can you tell which scenario matches which outcome? Answers are in Appendix.

Most Robust – highest internal consistency along with highest plausibility _____

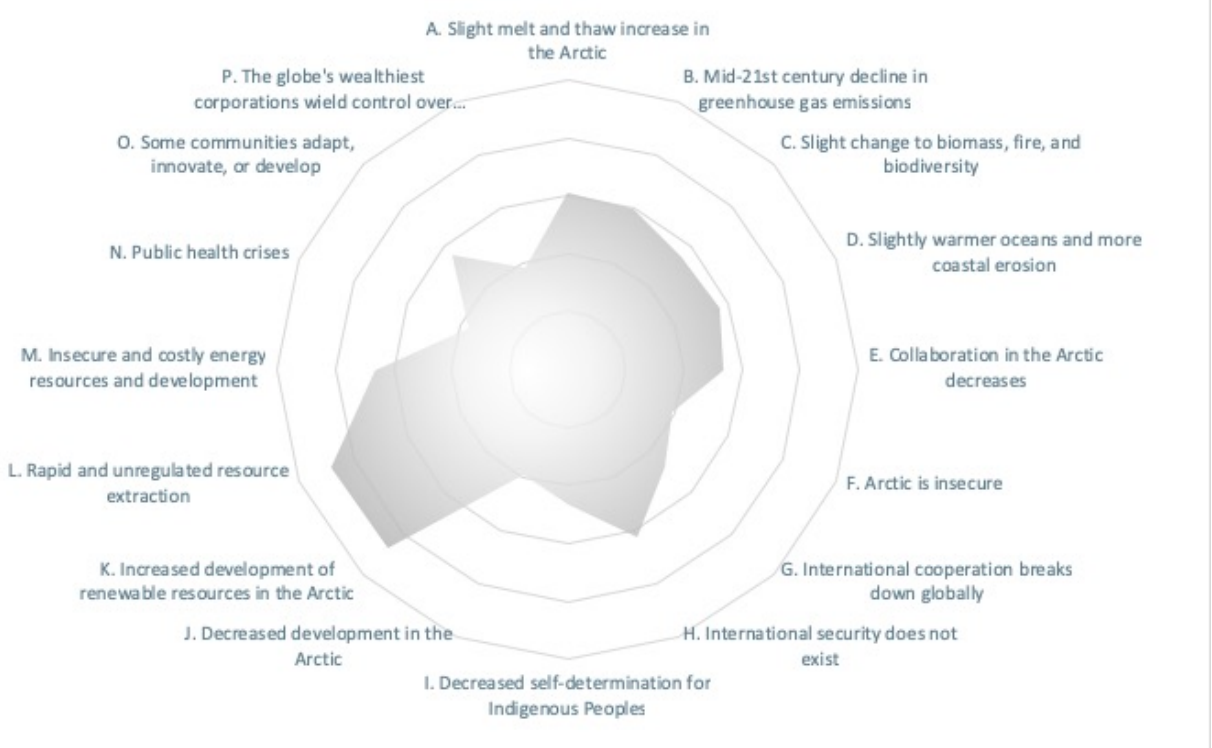
Most Consistent – highest internal consistency _____

Most Plausible – highest plausibility scores _____

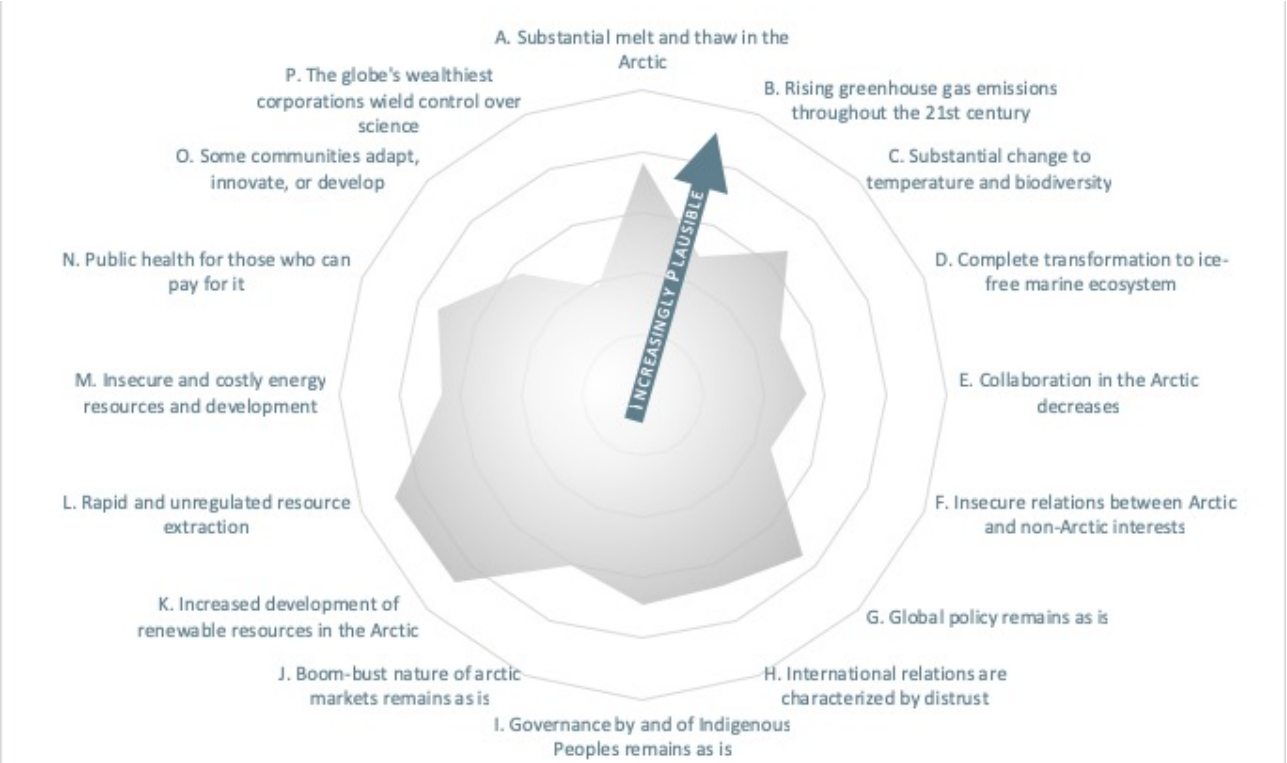
As you read through these scenarios we encourage you to ask yourself two questions:

1. *What would you want to now from the YOU living in any one of these future scenarios?*
2. *Given any of the future scenarios you might find yourself in (1-7), what do you need today to prepare to respond to this arctic future?*

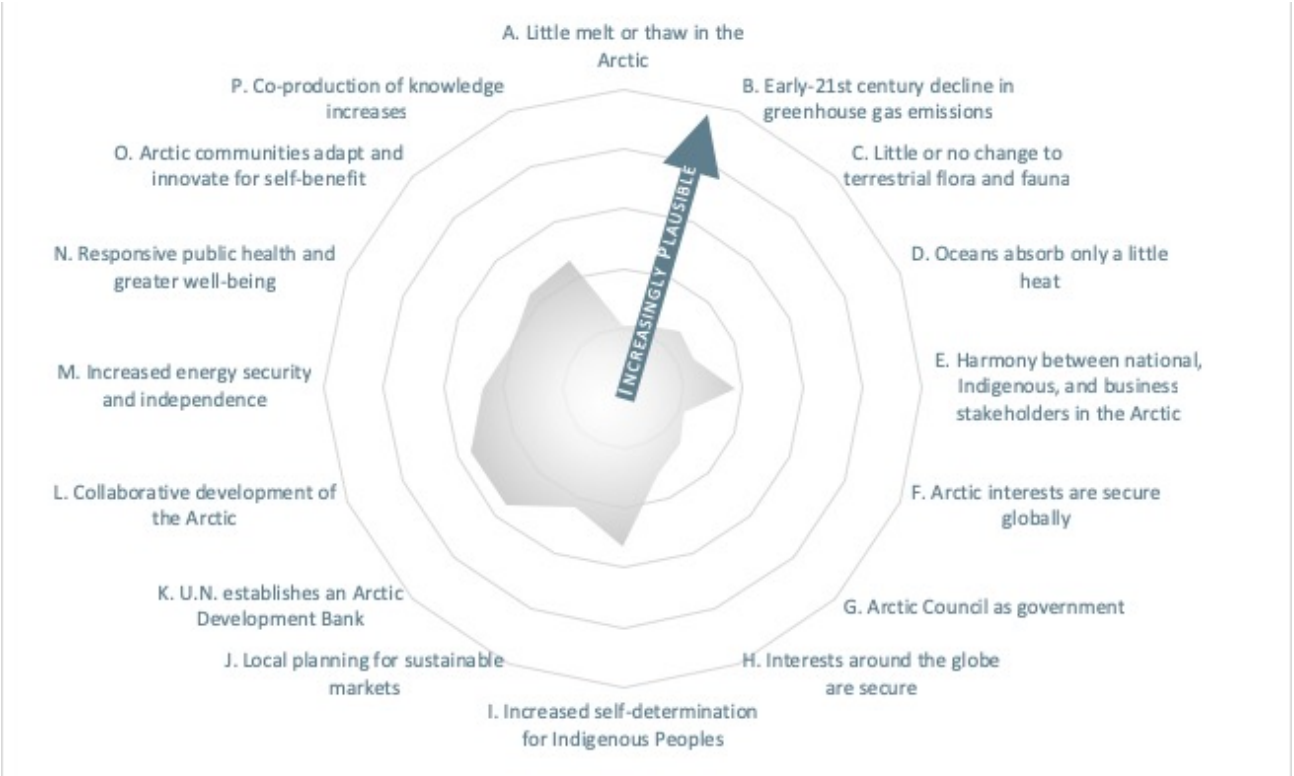
#1 An insecure Arctic in a warmer world with high resource demand. Arctic temperatures, amplified by the loss of the reflective ice and snow and changes in atmospheric dynamics, increase 13°C (23.4°F) in fall months and 5°C (9.0°F) in spring months, consistent with the RCP 8.5 emissions forcing. Moreover, the change from frozen to unfrozen triggers additional environmental changes, including magnification of climate warming, warmer oceans with significant freshwater input, greening, more fires, and changes to species composition, health, and migration patterns. There is significant intra-Arctic division and a shift to national agendas over collaborative science, resource management, and cultural programs. The region's security is compromised as Arctic nations are unable to come to resolutions related to national Arctic priorities or pan-Arctic cooperation. They begin to lose economic and territorial control as eager nations and multinational companies exploit internal divisions and promise wealth. In this future the United Nations has lost its ability to serve as a location of communication and debate. The subnational movements around the globe, through terrorism, corruptive practices, and economic leverage have destabilized the international system. Nations withdraw into domestic agendas and exhibit reduced engagement. Wealthy nations are generally able to feed their citizens and arctic nations focus on their own national policies with an emphasis on resource development and national security. Some nations remove the rights of Indigenous peoples altogether and others reduce their decision-making authority. The Arctic Council keeps Permanent Participants outside of high-level processes. Arctic Indigenous peoples and their demands for territory, management authority, and IK and language recognition are viewed as barriers to progress. Long-term expectations for growth of shipping and non-renewable extractive industries have not been met. The renewable resources of the Arctic region are extracted at intensifying rates driven by significant private investment from outside the region. Pressure on world resource markets for minerals and other non-renewable resources due to political-economic uncertainty has driven commodity prices to sustained high levels. Energy development follows (with lag) the ups and downs of the world energy resource markets, mainly oil and gas. No long-term strategy is developed for integrated energy solutions based on technology-lifetime planning horizons. Public health coverage for basic needs is not a guarantee in all the arctic nations. The vast differences in quality of and access to care means circumpolar national health systems rarely communicate with one another. Arctic peoples give up on governance structures to yield possible throughways to community sustainability. Arctic residents develop their own personalized adaptation plans for communities and even households. Some pockets of resilience remain and thrive, while other communities shrink to non-existence. Public science funding all but dries up except in areas where it can be used to further economic development and private corporations expand their internal science units. The foundations of publicly accessible science continue to erode to the point that it holds little weight in decision or policy making.



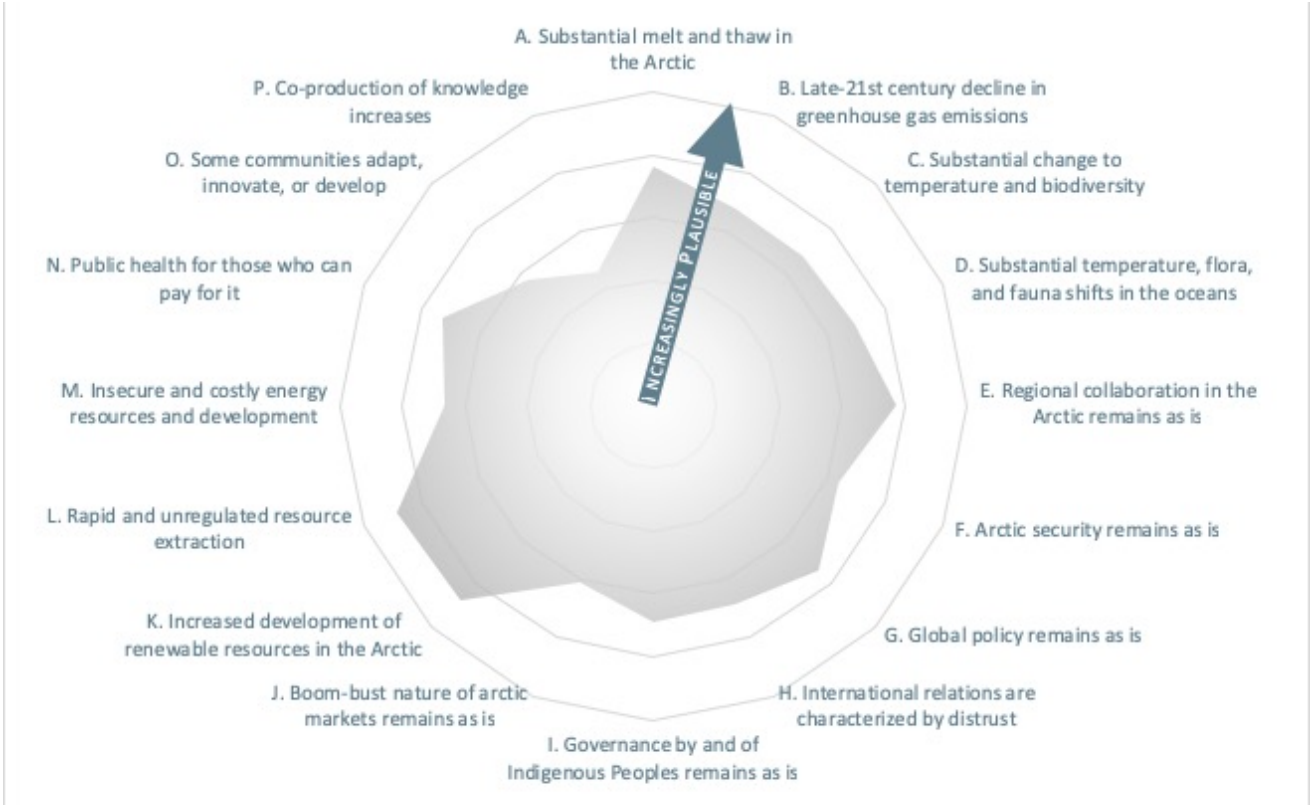
#2 Slowly rising emissions where atmosphere and marine changes are transformative as incremental social changes trend for the worse. Greenhouse gas emissions have yet to peak and global temperatures are on track to increase 2.2°C (4.0°F) by 2100, with Arctic temperatures increasing more than 10°C (18°F) in Autumn and 5°C (9°F) in Spring months. Sea ice in winter is thin and nearly absent in summer in the Arctic Ocean leading to dramatic ecosystem shifts. Rapid melting of Arctic land ice freshens waters and plant productivity increases. The Arctic contribution to sea level rise substantially impacts infrastructure, especially in lower latitudes. Arctic nations focus on national policies with an emphasis on resource development and national security. Nations withdraw into domestic agendas and exhibit reduced international engagement. Seabed and Arctic Ocean conflicts, along with other disagreements, strain Arctic Council cooperation - funding for it and pan-Arctic collaboration drops. The United Nations still exists and promotes communication and cooperation. There is weak international security at the global scale but in the rich nations, security, outside of domestic terrorism, is still fairly high. Progress for Indigenous rights occurs largely at the local level where communities of Indigenous peoples and their allies practice mixed-subsistence livelihoods. In these locations, resource managers and government officials are often themselves Indigenous and, as such, communities fly under the radar of higher-level regulatory authorities. Circumpolar communication and collaboration among different Indigenous peoples exist but with little organizational strategy and political power. Global boom and bust cycles across economic sectors affect the Arctic along with other nations. There are some periods of infrastructure development and cash flow followed by periods of high unemployment and out-migration, and lack of maintenance of previous infrastructure investments. The foundations of publicly accessible science continue to erode to the point that it holds little weight in decision or policy making. Scientists are labeled as in the way of continued growth and progress, retreating to enclaves in developing countries or becoming employees of private corporations. The renewable and non-renewable resources of the Arctic region are extracted at intensifying rates driven by significant private investment from outside the region and much of their total economic value leaves the region. Regional stakeholders have difficulty accessing capital markets. Powerful industrial interests shape land and ocean use in their best interest, which leads to competition and conflict with local stakeholders. No long-term strategy is developed for integrated energy solutions. A diversity of systems exists, from traditional diesel to integrated renewable energy systems, but costs remain high from lack of uniformity and long-term planning. National and subnational governments move to decrease the costs of maintaining Arctic populations. A public-private health care system is difficult to access. The wealthy are able to take advantage of the few and expensive programs that are holistic, but in general the marginalized do not receive quality health care beyond basic testing and emergency services. Arctic peoples give up on governance structures to yield possible throughways to community sustainability.



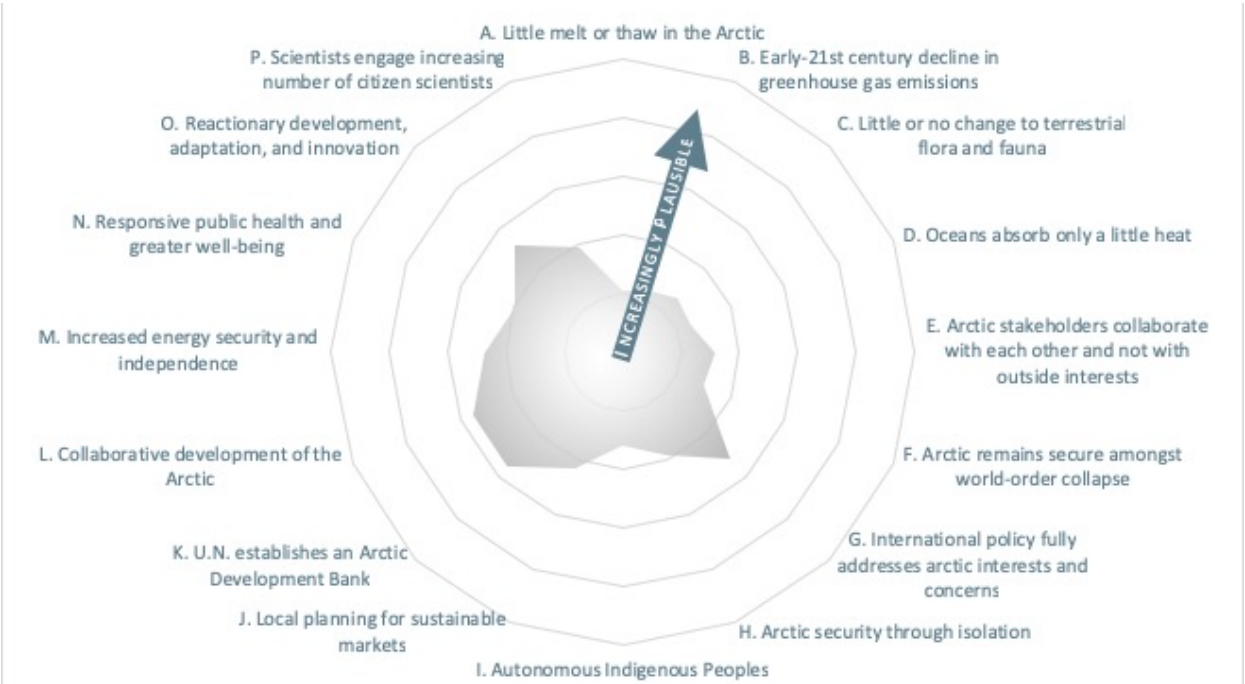
#3 Lowered emissions and harmonious regional and global relations. There is a 70% reduction in greenhouse gas emissions by 2050. Global temperatures further increase approximately 1°C (1.8°F) by 2100, and most impacts of increased emissions can be mitigated. Arctic temperatures, however, increase approximately 2-3°C (4-5°F). This early decline in greenhouse gas emissions significantly slows cryosphere decline and the pace of terrestrial change. Most of the extra heat due to warming in the first half of the century is absorbed by the ocean enhancing sea ice melt and coastal erosion. Highly collaborative international partnerships exist between Arctic and non-Arctic nations that share responsibility for sustainable development, environmental protection, and arctic regional security. Arctic countries feel strongly secure in the region and non-arctic nations feel they have dependable and fair relationships. Decades of coordinated scientific research in the Arctic help to improve system-level understanding of climate change and its impacts as well as facilitate adaptation across sectors from the local to global scales. The Arctic Council's nations have decided to make the council a governing body over environmental, but also social, protections. The eight nations create a multilateral treaty to encourage pan-Arctic cooperation and to make extractive activities costly to non-Arctic nations. The Arctic Development Bank is an eight-nation fund created to remediate externalities of development and to conserve species and territories. This fund is also accessible by Permanent Participants, whose role as part of Arctic governance has further increased. Intra-Arctic collaboration for adaptation rises, but puts these nations at odds with the priorities of the global South countries increasing tension where interests conflict. Across the Arctic there is greater self-determination for Indigenous peoples. While this varies across countries, language programs, educational control, and rights to territories are all enhanced. Budgets in the extractive-industry-based communities are directed towards long-term investments in sustainable projects for communities that provide jobs such as renewable energy systems, education centers, tourism, and health care. The regulations on sale of harvested animals and plants have been relaxed to enable a small-scale industry for traditionally made goods and foods. Programs to support Indigenous startups in product develop, attracting investment, and developing markets achieve great success rates. Arctic nations have set course toward the necessary collaboration on extraction quotas for oil, gas, and metals and minerals that can keep world resource prices at levels necessary for sustained cost-effective resource extraction from Arctic deposits. The needed infrastructure development to reach this point has proven an excellent investment for resource extraction companies and some communities. Driven by technological advancements essentially all settlements in the Arctic have the option to achieve energy independence from annual energy imports. There is widespread recognition of the concept of well-being across the Arctic and significant institutional efforts to promote quality of life in diverse populations. The changing nature of the Arctic, both social and ecological, is considered in government decisions related to public health. Capacity for adaptation rises and delivers self-reliance in many remote communities. There is a radical shift in the modes of knowledge acquisition and dissemination across the Arctic nations to include local and traditional knowledges in educational processes, formation of regulatory mechanisms and environmental management, and Arctic Council agendas and reports.



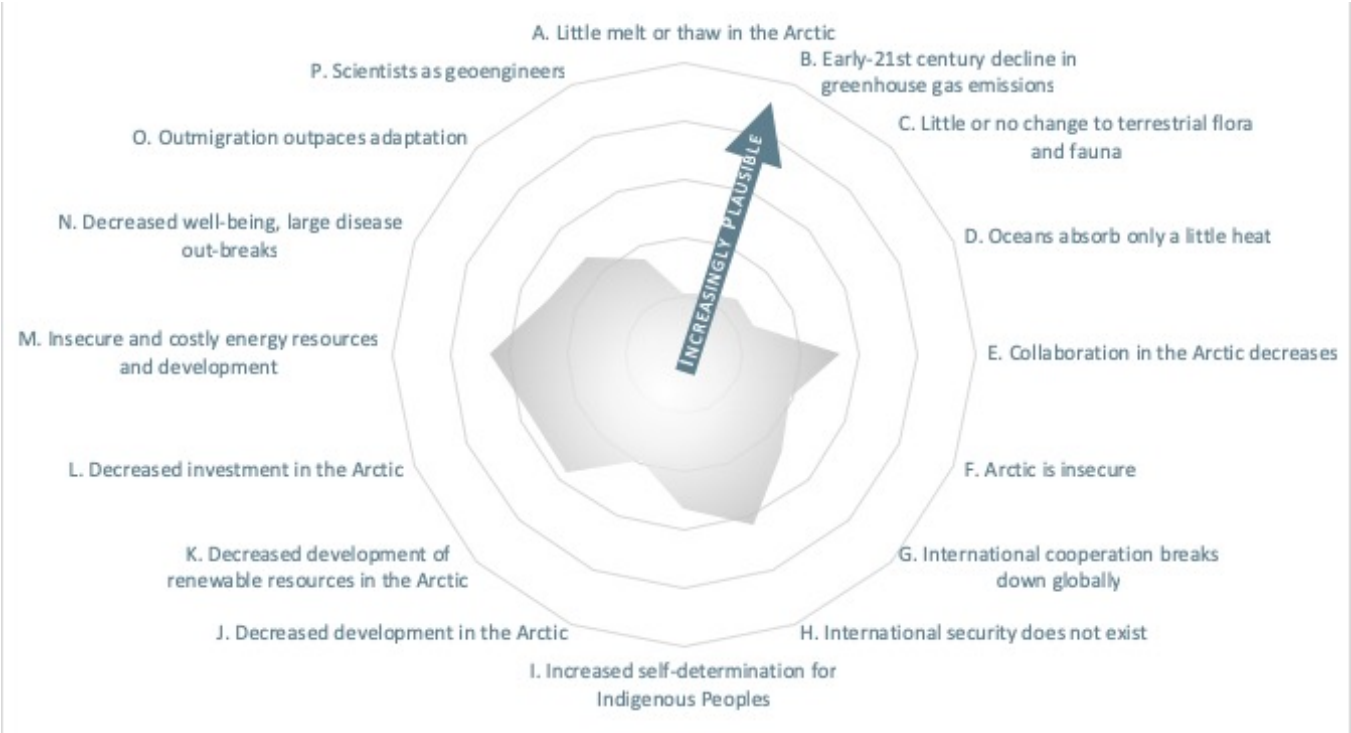
#4 On track for late century decline in emissions with little change in governance systems. Rapid increases in melt and thaw rates occur consistent with the RCP 6.0 emissions forcing in which greenhouse gas emissions are on track to peak around 2080. Global temperatures are trending to increase 2.2°C (4.0°F) by 2100, and Arctic temperatures more than 7°C (12.6°F) in fall months and 3°C (5.4°F) in spring months. The Arctic Council helps to facilitate continued cooperation in the Arctic, but strong national political-economic interests and goals of political actors outside of the Arctic result in strained relationships among Arctic states. Implementation of Arctic national strategies differ and do not uniformly align with Arctic Council recommendations. Non-Arctic states retain an Observer status in the Arctic Council and their influence varies in relation to their Arctic activities. Indigenous interests are considered important but political and economic organizations generally do not accurately understand Indigenous interests. In scientific fields, there is a radical shift in the modes of knowledge acquisition and dissemination across the Arctic nations to include local and traditional knowledge in educational processes, formation of regulatory mechanisms and environmental management, and Arctic Council agendas and reports. The United Nations still exists and promotes communication and cooperation. There is weak international security at the global scale but in the rich nations, security, outside of domestic terrorism, is still fairly high. Progress for Indigenous rights occurs largely at the local level where communities of Indigenous peoples and their allies practice mixed-subsistence livelihoods. In these locations, resource managers and government officials are often themselves Indigenous and, as such, communities fly under the radar of higher-level regulatory authorities. Circumpolar communication and collaboration among different Indigenous peoples exist but with little organizational strategy and political power. Global boom and bust cycles across economic sectors affect the Arctic along with other nations. There are some periods of infrastructure development and cash flow followed by periods of high unemployment and out-migration, and lack of maintenance of previous infrastructure investments. The renewable and non-renewable resources of the Arctic region are extracted at intensifying rates driven by significant private investment from outside the region and much of their total economic value leaves the region. Regional stakeholders have difficulty accessing capital markets. Powerful industrial interests shape land and ocean use in their best interest, which leads to competition and conflict with local stakeholders. No long-term strategy is developed for integrated energy solutions. A diversity of systems exists, from traditional diesel to integrated renewable energy systems, but costs remain high from lack of uniformity and long-term planning. National and subnational governments move to decrease the costs of maintaining Arctic populations. A public-private health care system is difficult to access. The wealthy are able to take advantage of the few and expensive programs that are holistic, but in general the marginalized do not receive quality health care beyond basic testing and emergency services. Arctic peoples give up on governance structures to yield possible throughways to community sustainability.



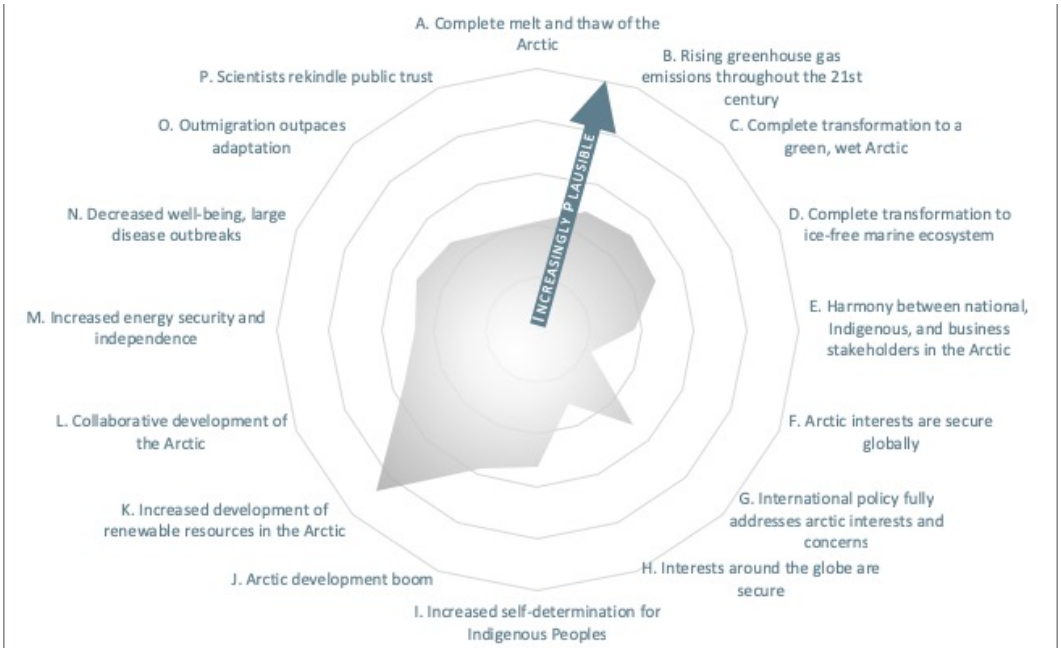
#5 Low emissions and an isolated but internally collaborative Arctic. There is a 70% reduction in greenhouse gas emissions by 2050. Global temperatures are on track to further increase approximately 1°C (1.8°F) by 2100 but for the Arctic an increase of approximately 2-3°C (4-5°F). This early decline in greenhouse gas emissions significantly slows cryosphere decline and the pace of terrestrial change in the latter part of the century. Most of the extra heat due to warming in the first half of the century is absorbed by the ocean enhancing sea ice melt and coastal erosion. Science survives numerous budget reductions, mistrust from governmental actors, and derogatory propaganda in the press through a grass-roots revolution. Now, scientists bring their findings and messages to the people. They empower them to conduct their own science within their local social-ecological systems. Multiple, user-friendly internet programs exist for citizens to track, study, share, and ask questions. Scientists not only interface with these programs but also perform research often with citizen-scientists. Strong collaboration among Arctic nations focuses on the protection of resources and careful development for the exclusive benefit of arctic nations and Indigenous residents. Non-Arctic states are increasingly shut out of Arctic resource development opportunities. In addition, agreements flourish among arctic actors granting benefits related to education, mobility, jobs and investments, and even some governmental services. The Arctic Council nations ensure that Indigenous interests are strongly represented resulting in a pace of development that emphasizes environmental protection and development for future arctic residents. Costs of using Arctic waterways or other transportation routes are high for non-Arctic nations, but lower among Arctic trading partners. Global policy globalizes Arctic concerns because the vital nature of the Arctic in relation to the mid-latitudes and global South has been recognized. However, the Arctic seeks security through isolation and international collaboration is limited to practical issues of common interest. There is a trend toward Arctic nation-states returning the governance over specific territory to Indigenous peoples. This development creates Autonomous Indigenous Territories (AITs) with relationships to their colonial countries as sovereign entities. The AITs assume responsibility for their own formation of governments, political processes, legal guarantees, enforcement capacity for these guarantees, and funding mechanisms. The Permanent Participants in the Arctic Council gain status as nations. Major regional entities are collaborating on targeted sustainable economic development through a multilateral Arctic Development Bank. Its lending practices require rigorous project parameters regarding sustainability and long-term benefit to the Arctic region. Budgets in the extractive-industry-based communities are directed towards long-term investments in sustainable projects for communities with an increased focus on education for jobs that can be “remote” (e.g. the tech sector) and on jobs that fill community needs (e.g. teachers, search and rescue). The regulations on sale of harvested animals and plants have been relaxed to enable a small-scale industry for traditionally made goods and foods. Driven by technological advancements energy essentially all settlements in the Arctic have the option to achieve independence from annual energy imports. There is widespread recognition of the concept of well-being across the Arctic and significant institutional efforts to promote quality of life in diverse populations. The changing nature of the Arctic, both social and ecological, is considered in government decisions related to public health. Capacity for adaptation rises and delivers self-reliance in many remote communities.



#6 Emissions reduced in an insecure world and depopulating Arctic. There is a 70% reduction in greenhouse gas emissions by 2050. Global temperatures are on track to further increase approximately 1°C (1.8°F) by 2100 but for the Arctic an increase of approximately 2-3°C (4-5°F). This early decline in greenhouse gas emissions will slow cryosphere decline and the pace of marine and terrestrial change in the latter part of the century. Geoengineering has gained a foothold in the area of fixing the planet's problems. Profits are to be made and state budgets to be secured, fitting the United States' and other nations' pursuit of continued economic growth. Geoengineering solutions pit some scientists against activists, non-geoengineering scientists are left without leadership. In this future the United Nations has lost its ability to serve as a location of communication and debate. Global instability in governance is the norm. The subnational movements around the globe, through terrorism, corruptive practices, and economic leverage have destabilized the international system. Nations withdraw into domestic agendas and exhibit reduced engagement. The region's security is compromised as Arctic nations are unable to come to resolutions related to national Arctic priorities or pan-Arctic cooperation. No independence or distinct national autonomy is given to Arctic Indigenous peoples but there have been several decades of research, knowledge exchanges, and governmental attention. While movements towards autonomy are squashed, in an effort to secure the Arctic region's borders and identity greater self-determination in land management and resource development is granted. The Arctic region remains economically isolated and development of renewable resources is not supported by outside investment, or policy choices. Only where economies of scale are favorable, or Arctic products are unique and in high demand, does an economy sustain (e.g., tourism). The region is unattractive to extensive development of non-renewable resource extraction due to cost, policy, and global fears of past climate instability. Investments in the necessary infrastructure to extract resources have not been made by the public and remain too risky for private investment. Long-term expectations for growth of shipping and non-renewable extractive industries have not been met. Infrastructure development slows and cash becomes scarce in the smaller communities as unemployment rises. Innovative programs in education and workforce development lose funding as industrial revenues decline. People in remote and rural areas rely more than ever on subsistence, family, and community networking to provide for themselves. The populous regions of mid-latitudes have abandoned fossil fuels. This leaves a glut of supply for remote regions driving the cost of traditional diesel-based power generation down so far that no other technology can compete. The energy fortunes of most Arctic settlements are now tied to a dying industry. The Arctic has experienced degradation of health services with climate sensitive diseases breaking out in multiple arctic locations in the 2030s. Those better off in society can afford some health care. The marginalized suffer in a public health system that has few institutional buffers to assist the poor, or those in remote areas. Investment, education, and therefore community capacity for sustainability are considerably under-realized in Arctic communities. By the time policy-makers react to out-migration the potential to turn this trend around has passed. Populations in the high Arctic dwindle, more so in the villages than the hubs. The vibrancy of the Arctic's Indigenous cultures and languages is in peril as their places depopulate and relationships are fractured. Adaptation becomes concentrated mainly in urban Arctic enclaves.



#7 Significant global collaboration for adaptation to, not mitigation of, rising greenhouse gas emissions. Arctic temperatures, amplified by the loss of reflective ice and snow and changes in atmospheric dynamics, increase 13°C (23.4°F) in fall months and 5°C (9.0°F) in spring months, consistent with RCP 8.5 greenhouse gas emissions. Moreover, the change from frozen to unfrozen triggers additional environmental changes, including magnification of climate warming, warmer oceans with significant freshwater input, greening, more fires, and changes to species composition, health, and migration patterns. Highly collaborative international partnerships exist between Arctic and non-Arctic nations. Arctic countries feel strongly secure in the region and non-arctic nations feel they have dependable and fair relationships. Decades of coordinated scientific research in the Arctic help to improve system-level understanding of climate change and its impacts as well as facilitate adaptation across sectors from the local to global scales. Effective science communication that serves the public's needs is achieved through concise and approachable communication of science research and findings. As a consequence, the communication of science to decision-makers and stakeholders is much improved and includes implications and robust adaptation strategies. There is a general turn back to science as "having the answers" and a growth in technocrats as decision-makers. Global policy globalizes Arctic concerns because the vital nature of the Arctic in relation to the mid-latitudes and global South has been recognized. However, there is also a boom in oil and gas production in northern coastal regions. Additionally, mining of rare earths and other globally desirable minerals promotes infrastructure projects and travel routes into remote arctic locations. This increases the flow of goods in both directions, and somewhat lowers costs of local goods. Communication and postal/cargo technologies are enhanced close to extractive sites creating pools of internet accessibility for buying and selling goods. The renewable resources of the Arctic region are extracted at intensifying rates driven by significant private investment from outside the region. Powerful industrial interests shape policy regarding renewable resource development and land and ocean use in their best interest, which leads to competition and conflict with local stakeholders. As a check on this, Arctic nations have increased self-determination in land and coastal management for many Arctic Indigenous peoples. With the confidence that the Arctic region controls sufficient resources to influence world markets at will, Arctic nations collaborate on extraction quotas for oil, gas, and metals and minerals to keep world resource prices at levels necessary for sustained cost-effective resource extraction. Due to strategic considerations, significant efforts have been made by all Arctic littoral states to connect their remote Arctic settlements and outposts to a large energy infrastructure system comprised of pipelines and power lines. In return, where capacities for large-scale energy generation in the Arctic exist, much of this energy is exported South. Investment outside of industrial infrastructure is small. Public health coverage for basic needs is not a guarantee in all the arctic nations. The vast differences in quality of and access to care means circumpolar national health systems rarely communicate with one another. Ungulate diseases as well as diseases affecting canines and marine mammals have begun to rapidly spread north. In locales with poor health care and poor veterinarian coverage many ill people and animals remain unknown to the health system. People resort to store-bought foods and moving south. Populations in the high Arctic dwindle, more so in the villages than the hubs. The vibrancy of the Arctic's Indigenous cultures and languages is in peril as their places depopulate and relationships are fractured. Adaptation becomes concentrated mainly in urban Arctic enclaves.



Appendix

Most Robust – highest internal consistency along with highest plausibility ____#2____

Most Consistent – highest internal consistency _____#1_____

Most Plausible – highest plausibility _____#4_____

#1 2050 Scenario – Most Consistent results

	KEY FACTOR	FUTURE PROJECTION
A	CC: Cryosphere	Slight melt and thaw increase in the Arctic
B	CC: Atmosphere	Mid-21st century decline in greenhouse gas emissions
C	CC: Terrestrial biosphere	Slight change to biomass, fire, and biodiversity
D	CC: Marine systems	Slightly warmer oceans and more coastal erosion
E	Arctic Regional Collaboration	Collaboration in the Arctic decreases
F	Arctic Regional Security	Arctic is insecure
G	Global Policy	International cooperation breaks down globally
H	International Security	International security does not exist
I	Status of Indigenous Peoples	Decreased self-determination for Indigenous Peoples
J	Access to markets	Decreased development in the Arctic
K	Econ: Extraction Renewable	Increased development of renewable resources in the Arctic
L	Econ: Extraction Non-Renewable	Rapid and unregulated resource extraction
M	Arctic Energy Systems	Insecure and costly energy resources and development
N	Public Health	Public health crises
O	Community Sustainability	Some communities adapt, innovate, or develop
P	Sci Adv & communication	The globe's wealthiest corporations wield control over science

#2 2050 Scenario – high robustness

	KEY FACTOR	FUTURE PROJECTION
A	CC: Cryosphere	Substantial melt and thaw in the Arctic
B	CC: Atmosphere	Rising greenhouse gas emissions throughout the 21st century
C	CC: Terrestrial biosphere	Substantial change to temperature and biodiversity
D	CC: Marine systems	Complete transformation to ice-free marine ecosystem
E	Arctic Regional Collaboration	Collaboration in the Arctic decreases
F	Arctic Regional Security	Insecure relations between Arctic and non-Arctic interests
G	Global Policy	Global policy remains as is
H	International Security	International relations characterized by distrust
I	Status of Indigenous Peoples	Governance by and of Indigenous peoples remains as is
J	Access to markets	Boom-bust nature of arctic markets remains as is
K	Econ: Extraction Renewable	Increased development of renewable resources in the Arctic
L	Econ: Extraction Non-Renewable	Rapid and unregulated resource extraction
M	Arctic Energy Systems	Insecure and costly energy resources and development
N	Public Health	Public health for those who can pay for it
O	Community Sustainability	Some communities adapt, innovate, or develop
P	Sci Adv & communication	The globe's wealthiest corporations wield control over science

#3 Forced RCP 2.6

	KEY FACTOR	**FUTURE PROJECTION**
A	CC: Cryosphere	Little melt or thaw in the Arctic
B	CC: Atmosphere	Early-21st century decline in greenhouse gas emissions
C	CC: Terrestrial biosphere	Little or no change to terrestrial flora and fauna
D	~~CC: Marine systems~~	Oceans absorb only a little heat
E	Arctic Regional Collaboration	Harmony between national, Indigenous, and business stakeholders in the Arctic
F	Arctic Regional Security	Arctic interests are secure globally
G	Global Policy	Arctic Council as government
H	International Security	Interests around the globe are secure
I	Status of Indigenous Peoples	Increased self-determination for Indigenous Peoples
J	Access to markets	Local planning for sustainable markets
K	Econ: Extraction Renewable	U.N. establishes an Arctic Development Bank
L	Econ: Extraction Non-Renewable	Collaborative development of the Arctic
M	Arctic Energy Systems	Increased energy security and independence
N	Public Health	Responsive public health and greater well-being
O	Community Sustainability	Arctic communities adapt and innovate for self-benefit
P	Sci Adv & communication	Co-production of knowledge increases

#4 2050 Scenario Most Plausible

	KEY FACTOR	FUTURE PROJECTION
A	CC: Cryosphere	Substantial melt and thaw of the cryosphere
B	CC: Atmosphere	Late-21st century decline in greenhouse gas emissions
C	CC: Terrestrial biosphere	Substantial change to temperature and biodiversity
D	CC: Marine systems	Substantial temperature, flora, and fauna shifts in the ocean
E	Arctic Regional Collaboration	Regional collaboration in the Arctic remains as is
F	Arctic Regional Security	Arctic security remains as is
G	Global Policy	Global policy remains as is
H	International Security	International relations are characterized by distrust
I	Status of Indigenous Peoples	Governance by and of Indigenous peoples remains as is
J	Access to markets	Boom-bust nature of arctic markets remains as is
K	Econ: Extraction Renewable	Increased development of renewable resources in the Arctic
L	Econ: Extraction Non-Renewable	Rapid and unregulated resource extraction
M	Arctic Energy Systems	Insecure and costly energy resources and development
N	Public Health	Public health for those who can pay for it
O	Community Sustainability	Some communities adapt, innovate, or develop
P	Sci Adv & communication	Co-production of knowledge increases

#5 2050 Scenario - Best emissions, but inward looking Arctic

	KEY FACTOR	FUTURE PROJECTION
A	CC: Cryosphere	Little melt or thaw in the Arctic
B	CC: Atmosphere	Early-21st century decline in greenhouse gas emissions
C	CC: Terrestrial biosphere	Little or no change to terrestrial flora and fauna
D	CC: Marine systems	Oceans absorb only a little heat
E	Arctic Regional Collaboration	Arctic stakeholders collaborate with each other and not with outside interests
F	Arctic Regional Security	Arctic remains secure amongst world-order collapse
G	Global Policy	International policy fully addresses arctic interests and concerns
H	International Security	Arctic security through isolation
I	Status of Indigenous Peoples	Autonomous Indigenous Peoples
J	Access to markets	Local planning for sustainable markets
K	Econ: Extraction Renewable	U.N. establishes Arctic Development Bank
L	Econ: Extraction Non-Renewable	Collaborative development of the Arctic
M	Arctic Energy Systems	Increased energy security and independence
N	Public Health	Responsive public health and greater well-being
O	Community Sustainability	Reactionary development, adaptation, and innovation
P	Sci Adv & communication	Scientists engage increasing number of citizen scientists

#6 2050 Scenario Best emissions "worst" world

	KEY FACTOR	FUTURE PROJECTION
A	CC: Cryosphere	Little melt or thaw in the Arctic
B	CC: Atmosphere	Early-21st century decline in greenhouse gas emissions
C	CC: Terrestrial biosphere	Little or no change to terrestrial flora and fauna
D	CC: Marine systems	Oceans absorb only a little heat
E	Arctic Regional Collaboration	Collaboration in the Arctic decreases
F	Arctic Regional Security	Arctic is insecure
G	Global Policy	International cooperation breaks down globally
H	International Security	International security does not exist
I	Status of Indigenous Peoples	Increased self-determination for Indigenous Peoples
J	Access to markets	Decreased development in the Arctic
K	Econ: Extraction Renewable	Decreased development of renewable resources in the Arctic
L	Econ: Extraction Non-Renewable	Decreased investment in the Arctic
M	Arctic Energy Systems	Insecure and costly energy resources and development
N	Public Health	Decreased well-being, large disease outbreaks
O	Community Sustainability	Outmigration outpaces adaptation
P	Sci Adv & communication	Scientists as geoengineers

#7 2050 Scenario High Emissions, high collaboration, no results

	KEY FACTOR	FUTURE PROJECTION
A	CC: Cryosphere	Complete melt and thaw of the Arctic
B	CC: Atmosphere	Rising greenhouse gas emissions throughout the 21st century
C	CC: Terrestrial biosphere	Complete transformation to a green, wet Arctic
D	CC: Marine systems	Complete transformation to ice-free marine ecosystem
E	Arctic Regional Collaboration	Harmony between national, Indigenous, and business stakeholders in the Arctic
F	Arctic Regional Security	Arctic interests are secure globally
G	Global Policy	International policy fully addresses arctic interests and concerns
H	International Security	Interests around the globe are secure
I	Status of Indigenous Peoples	Increased self-determination for Indigenous Peoples
J	Access to markets	Arctic development boom
K	Econ: Extraction Renewable	Increased development of renewable resources in the Arctic
L	Econ: Extraction Non-Renewable	Collaborative development of the Arctic
M	Arctic Energy Systems	Increased energy security and independence
N	Public Health	Decreased well-being, large disease outbreaks
O	Community Sustainability	Outmigration outpaces adaptation
P	Sci Adv & communication	Scientists rekindle public trust