

# SEARCH Scenarios Project

## Arctic Futures 2050

### Technical Documentation

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# Introduction

Almost all scenarios projects formally begin with a workshop in which the future of a particular topic area is discussed and explored in more or less formal exercises. Quite a number of these projects also ends shortly after this workshop with a quick set of narrative scenarios. An informal collection of impressions from such scenario projects was the impetus of developing a methodology that allows for engagement for a longer period of time and deeper delving into the subject matter.

This document provides the technical summary for the execution of a scenarios process using the Robustness Analysis Method. Specifically, we are outlining the Arctic Futures 2050 Scenarios Project initiated by the Study of Environmental Arctic Change (SEARCH).

We introduce and discuss some [Practical and Technical Aspects](#) of the initial scenarios workshop and the post-workshop interaction with workshop participants through an online discussion and survey tool. The detailed outlines of several key documents are provided in Appendices for replication and improvement.

The [Robustness Analysis Method](#) is outlined with its key concepts here, and put into the context of the project at hand. This also provides insight regarding how the data collected in the workshop and post-workshop interactions is further refined and distilled into a final scenarios product.

The core of this document is the description of the [Results](#) of the project, with the most plausible, consistent and robust raw scenario bundles. A couple of additional interesting counterpoint scenario bundles are also introduced.

The reader will notice that the scenario narratives themselves are absent from this documentation. The intent of this document is to provide a record of the technical road to the final product. However, the scenario narratives themselves are subject of their own write up.

# Practical and Technical Aspects

A quantitative scenario project with strong stakeholder engagement requires significant efforts regarding coordination, workshop organization, and pre- and post-workshop engagement. The following sections serve as a high-level illustration of the approach taken in the various stages of this project with detailed materials being provided in the appendices.

## Workshop Planning and Implementation

A scenario workshop serves two main functions. It creates buy-in from stakeholders that are invited to participate and it serves as a vehicle for data collection and information exchange that informs the further scenario process. Ideally, during the workshop, some time is also spent on the introduction of the concept of strategic scenarios in general, and the specific methodology utilized in the project. However, it is not recommended to go into more technical detail than is absolutely necessary.

For the SEARCH Arctic Futures 2050 Scenario Workshop a group of about 50 stakeholders were invited. The invitees were deliberately selected to provide a good representation of members of the community of decision-makers from the local to the international level, with particular emphasis on representation of Arctic Indigenous Peoples, as well as members from the scientific community with particular focus on specialists for Arctic issues from policy to climate.

Since the workshop was intended to be interactive and collaborative, much time was spent in breakout groups. In order to effectively capture the discussions in these groups eight notetakers were employed throughout. Their notes, and additional photos of workshop materials were the basis for the further steps of [Key Factor and Future Projection](#) development.

Prior to the workshop a full script and associated presentations, a bill of materials, a staff presentation and a handbook were developed. A selection of these materials is available in [Appendix A](#). Materials distributed to workshop participants prior to and during the workshop are provided in [Appendix B](#).

The workshop was held over the course of three days, with the first day providing an introduction to the general audience at the Arctic Encounters Symposium 2018, where an initial selection of Key Factors was collected. This was followed by one and a half days of intensive, invitation-only workshop.

## Post-Workshop Interaction

After the workshop, the workshop notes and photos of workshop materials were used as a basis for consolidation of the list of Key Factors to a manageable, yet representative size. This initial step still mostly provides brief titles for each Key Factor, but no extensive definitions. The

process is illustrated in the Results chapter, with full details on how initial Key Factors were mapped to the final list given in [Appendix E](#). Workshop participants were invited to comment, discuss, and make suggestion regarding the consolidation of the initial list.

The core scenarios team, comprised of D.S. Cost, B.P. Kelly, A.L. Lovecraft, and M. Müller-Stoffels, then used the consolidated sixteen Key Factor titles as a starting point for research and extended definition of each Key Factor. Furthermore, the team developed three to five Future Projections for each Key Factor. After an initial round of draft development, each Key Factor and Future Projection was reviewed by the core scenarios team, and external expert reviews (from the pool of workshop participants) for each were solicited.

Final drafts were made available via a website with a discussion tool for review by all workshop participants and submitted suggestions, discussions, comments and concerns were worked into the final version of each Key Factor and associated Future Projections. The final version of each Key Factor and associated Future Projections is given in [Appendix E](#).

The process of collecting [Plausibility Scores](#) leveraged a survey tool on the same web platform used for the Key Factor and Future Projection discussion. Instructions regarding the scoring were made available as a [video](#).

Last, [Consistency Scores](#) were collected. For this, two options were made available: (1) via the scenario management software ScenLab, and (2) via an Excel spreadsheet. Videos regarding [consistency scoring in general](#), and the use of [ScenLab](#) and the [spreadsheet](#) in particular were made available.

## Technical Systems

As mentioned above, a website was used to manage much of the post-workshop interaction with workshop participants. This website was powered by the Drupal content management system with added features for conducting surveys. The site was access controlled via username/password for each individual participant.

Internal documents were generally developed using Google Docs and Sheets first, and only final drafts were ported to the website for general review.

For the [Consistency Scoring](#), as well as for the [Raw Scenario development](#) the ScenLab scenario management software version 1.8.1 was used.

## Lessons Learned

The lessons learned fall roughly into two categories, process and technical.

The first day of the workshop was an open-to-the-public breakout session at the Arctic Encounters Symposium. This session garnered a lot of interest, which generally is good.

However, this also meant a very large list of Key Factor suggestions, as everyone in the session was asked to come up with two to three suggestions for Key Factors. This caused quite a bit of friction in the following days. In the future, a more guided form of activity, instead of free-form suggestions of Key Factors, should be used.

Also a result of the initially very long list of Key Factors, was the significant consolidation that became necessary. Here, the major issue was to get positive buy-in. In the future, it would be advisable to contact stakeholders more directly regarding those Key Factors they might have direct interest in.

There were also issues with the access management of the web platform. This was setup in such a way that passwords would expire if users did not log in for more than 30 days, and the login page did not seem to provide an obvious mechanism for password resets. Here, it might be good to find other mechanisms for credential handling, or make reset instructions easier to identify on the login page.

Lastly, since many users were utilizing computers provided by their organization, installation of the ScenLab Group Client software for the consistency scoring was a major issue, at least on Windows operating systems. In the short-term this was mitigated by also making available a spreadsheet version of the consistency matrix for review and editing of consistency scores. However, in the long-run porting of the ScenLab Group Client to a web-based tool will be the better option.

# Robustness Analysis Method

The Robustness Analysis is a quantitative scenario method that was developed by evolve:IT LLP (Drs. Erik Gauger and Marc Müller-Stoffels) in collaboration with Z\_punkt GmbH. It is based on the Consistency Analysis (extensively described in Gausemeier, et al. 1996). Where the Consistency Analysis treats Plausibility and Consistency scores strictly separately, the Robustness Analysis recognized that a good (or robust) scenario is required to be plausible and self-consistent at the same time, and takes this under consideration in the calculation of viable raw scenarios.

Any scenario project using the Robustness Analysis has the following flow:

1. Define the focal question and time frame. This generally is a premise for the entire process and should be settled prior to any workshop as otherwise workshop preparation becomes difficult. A focal question should constrain the area of investigation to a manageable size, and the time frame should be generally further out than just a few years.
2. [Key Factor and Future Projection development](#). The initial steps for this are generally performed during a workshop. However, for expediency, but at the cost of inclusiveness, some Key Factors could be pre-determined prior to a workshop. Further definition and fleshing out of Key Factors and Future Projections is usually done by a core team and reviewed by the stakeholder group.
3. To calculate the most robust scenarios a [Plausibility](#) and [Consistency](#) scoring is performed. This can be done by the core team, or by a larger stakeholder group.
4. The scoring in the previous step is the basis for calculating the viable [Raw Scenario Bundles](#) out of what usually is billions of possible raw scenario bundles.
5. Raw scenario bundles can then be used as the framework for narrative scenarios, and other developments, e.g., scenario games.

## Key Factor and Future Projection Development

At the core of a scenario project are the Key Factors and Future Projections. Key Factors are those factors that are most influential in the development of the area selected in the focal question. A scenario project usually has between 10 and 20 Key Factors.

Future Projections describe potential developments of each Key Factor by the selected time frame. They do not all have to be equally plausible. However, any given Future Projection should lie within the realm of the plausible. That is, if no reasonably conceivable pathway without major disruptive events from the current state of the Key Factor to a specific Future Projection can be described, that Future Projection should be considered a Wild Card. Wild Cards are events of very low likelihood to occur. Yet, if they occur they are very disruptive and affect significant change.

Usually, Key Factor titles and some initial input on possible Future Projections are collected via a workshop setting through various exercises such as development of mini-scenarios. Post workshop Key Factor titles need to be turned into fully described Key Factors, which requires literature research to understand good delineations, develop a good understanding of underlying concepts, and ensure that workshop participant intent of the Key Factor title is honored.

Once Key Factors are defined, Future Projections are assigned. It is recommended to have between three and five Future Projections for each Key Factor, but no less than two. These Future Projections should cover the range from (perceived) worst-case to best-case developments. Future Projections must also be defined, where possible, by citing trends described in the literature specific to a Key Factor or some parallel area. However, some speculation and outside-the-box thinking is wanted during Future Projection development, within the confines of plausible developments.

It is important that definitions are sufficiently clear, yet sufficiently brief, so that they can provide a good basis for the scoring exercises that are to follow.

## Plausibility Scoring

Plausibility scores provide a relative ranking of Future Projections of a particular Key Factor. The objective is to provide a weight towards those Future Projections that appear, to the scoring individual, more plausible to become the actual future of a given Key Factor. For this, *Individual Plausibility Scores* are assigned to each Future Projection.

For internal consistency, the scoring is governed by the following constraints:

1. Any Individual Plausibility Score can be an integer between 0 and 10,
2. The sum of the Individual Plausibility Scores distributed to the Future Projections of a particular Key Factor has be 10.
3. Future Projections that receive an Individual Plausibility Score of 0 are considered Wild Cards that are removed from the core pool of Future Projections.

## Collection of Plausibility Scores

A total of 64 Individual Plausibility Scores had to be assigned. These were collected via an online survey tool. On each page of the survey the user was provided with one Key Factor and associated Future Projections. For each Future Projection the user could select a score from 0 to 10 (in integer steps) from a drop-down menu. If the user selected 0, which essentially excludes a Future Projection from further consideration, a dialog window prompted the user to confirm this choice. That is, the user was not prohibited from making this choice, but it was ensured that it was a conscious one. Upon completion of a page of the survey, the system also checked that the Individual Plausibility Scores provided added up to 10, and if they didn't prompt the user to adjust the scoring to meet the constraint. The system recorded all scores for each

individual user, and users were allowed to save intermediate steps and resume scoring later. Of the 36 individuals invited to complete the survey 24 were responsive, and 22 provided a completed survey. This includes the four core scenarios team members.

## Plausibility Score Analysis and Collation

The Individual Plausibility Scores collected via the survey were imported into a spreadsheet for further analysis. Data was checked for integrity by running checksums for each set of Individual Plausibility Scores. Data analysis proceeded with a count of survey participants that had scored a zero for a particular Individual Plausibility Score. This was done in order to identify if there was consensus amongst survey responses that a particular Future Projection should be moved into Wild Card status. A total of twelve zero scores were given. The most zero scores an individual Future Projection received was 4, that is, 18% of valid responses suggested that this Future Projection be moved to Wild Card status; this percentage was not considered high enough to warrant reclassification of the Future Projection.

To arrive at a final Individual Plausibility Score for each Future Projection, the mean of the survey responses was calculated. Standard deviation from the mean of individual scores was generally less than 1, with a range from 0.21 to 1.36. That is, statistical variability of scores for this size sample, was within acceptable bounds. The final Individual Plausibility Scores and some statistical data can be found in [Appendix C](#).

## Consistency Scoring

Consistency scores are designed to provide a metric to determine if two Future Projections from two *different* Key Factors are consistent to appear in the same scenario. For this each possible pair of Future Projections that are not of the same Key Factor is assigned a *Pairwise Consistency Score*. The objective of the Pairwise Consistency Score is to ensure that those combinations of Future Projections receiving a high Pairwise Consistency Score rank higher in the search for final scenarios, and that those combinations that receive very low Pairwise Consistency Score, i.e., that a totally inconsistent to appear in the same scenario, are excluded from the final ranking altogether.

The following points govern Pairwise Consistency Scores and their allocation:

1. Pairwise Consistency Scores range from -2 to 2 with decimal numbers in this range being allowable scores.
2. Pairwise Consistency Scores lesser or equal to -1.5 denote *total inconsistencies*, and scenarios exhibiting one of these Pairwise Consistency Scores will be excluded from the final list of scenarios.
3. Pairwise Consistency Scores lesser or equal to -1, but greater -1.5 are denoted *partial inconsistencies* and scenarios exhibiting such scores will be penalized in the final ranking for each occurrence.



4. Pairwise Consistency Scores greater -1 do not carry a special designation or handling, but the higher a Pairwise Consistency Score the likelier a scenario exhibiting this pair of Future Projections to rank high [barring other contributing factors, see Raw Scenario Development]
5. Typically Pairwise Consistency Scores lay between -0.5 and 0.5, i.e., most combinations of Future Projections are neither very consistent, nor very inconsistent. Extreme scores should only be distributed where this can be well justified.

## Collection of Consistency Scores

Since, for this project, there were 1088 Pairwise Consistency Scores to be evaluated, it was decided that, instead of requesting participants to score a blank matrix, to review a prescored matrix and make changes to those scores as they saw fit. That is, the entire consistency matrix was scored by a member of the core scenarios team (Müller-Stoffels) and then distributed for review. A total of five scenario workshop participants completed this review and returned individual consistency matrices (four participants) or indicated that they did not change anything (one participant).

## Consistency Score Analysis and Collation

Each matrix was checked for issues with scoring individually to ensure that the scores provided could yield any raw scenario bundles. This is necessary because a condition can occur where all combinations of Future Projections of two Key Factors are scored totally inconsistent. At that point, all possible raw scenario bundles would be invalid. None of the consistency matrices at hand exhibited any technical issues.

The six available consistency matrices were collated by calculating the average of each individual Pairwise Consistency Score for the final consistency matrix. The final matrix is shown in [Appendix D](#). For this matrix, the average Pairwise Consistency Score was calculated. This serves as a check regarding a general bias toward positive or negative scores. In balanced scoring the average Pairwise Consistency Score should be close to zero. The average Pairwise Consistency Score for this project was 0.05, which is sufficiently close to zero to assume balanced scoring.

## Raw Scenario Bundle Development

A *Raw Scenario Bundle* is a collection of Future Projections, one from each Key Factor. In this particular project, that technically means that over 3.7 billion possible combinations need to be evaluated based on their Individual Plausibility Scores and Pairwise Consistency Scores. However, the computations for this would be extremely time-consuming; therefore, a genetic

algorithm<sup>1</sup> is deployed to search for the highest scoring Raw Scenario Bundles without evaluating absolutely all possible Raw Scenario Bundles.

Each Raw Scenario Bundle can be assigned several distinct scores:

1. A *Bundle Plausibility Score*, which is the product of the Individual Plausibility Scores for the Future Projections present in the bundle
2. An *Average Bundle Consistency Score*, which is the sum of the Pairwise Consistency Scores between the Future Projections present in the bundle, normalized by the maximum theoretical consistency achievable in the project
3. A *Number of Partial Inconsistencies* which is a count of Pairwise Consistency Scores between -1 and -1.5 between the Future Projections present in the bundle
4. A *Robustness Value* which is defined to be  $R = \left( \frac{\log(BPS) \cdot aBCS}{1 + NPI} \right)^{1/2}$ , where BPS denotes the Bundle Plausibility Score, aBCS denotes the average Bundle Consistency Score, and NPI denotes the Number of Partial Inconsistencies
5. A *Number of Total Inconsistencies* which is defined as a count of Pairwise Consistency Scores lesser or equal to -1.5. Any bundle having Number of Total Inconsistencies > 0 is discarded.

Even with the use of a genetic algorithm-based search and the constraint that any Raw Scenario Bundle exhibiting a total inconsistency is discarded, the final result list typically is quite long and difficult to manage. In order to mitigate this issue, secondary algorithms are used to find similar Raw Scenario Bundles and discard some of them to reduce list length. For this several list reduction approaches are available:

**Trivial Reduction:** This method simply truncates the list of Raw Scenario Bundles at the desired list length, i.e., it sorts the list in descending order by Robustness Value [or Average Bundle Consistency Score, or Bundle Plausibility Score] and discards all items ranking lower than the desired list length.

**Complete Projection Scanning:** This method searches the list of Raw Scenario Bundles for the  $n$  Raw Scenario Bundles containing Future Projection 1 of Key Factor A with the highest Robustness Value [or Average Bundle Consistency Score, or Bundle Plausibility Score], where  $n$  is a user adjustable value. It then proceeds searching the high value bundles containing Future Projection 2 of Key Factor A, then with Future Projection 1 of Key Factor B and so forth.

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<sup>1</sup> Genetic algorithms are random directed search algorithms that use principles of natural selection from evolutionary theory to effectively solve optimization and search problems. They are particularly deployed in situations where solving the problem analytically requires too much computational resources. For example, see Z. Michalewicz, *Genetic Algorithms + Data Structure = Evolutionary Programs*, Springer, Ney York, 1996.

**Example:** Assume a project with four Key Factors A, B, C, D with two Future Projections each. The following table shows all possible projection bundles with their overall Robustness Values (rVal below for brevity).

Bundle No.	Raw Scenario Bundle	rVal	Bundle No.	Raw Scenario Bundle	rVal
1	A1B2C1D2	0.45	9	A1B1C1D1	0.29
2	A2B1C2D2	0.44	10	A2B2C1D1	0.26
3	A1B1C2D2	0.41	11	A1B2C2D2	0.24
4	A1B1C1D2	0.41	12	A2B2C2D2	0.14
5	A2B2C1D2	0.39	13	A1B2C1D1	0.14
6	A2B1C2D1	0.37	14	A1B2C2D1	0.11
7	A2B1C1D2	0.37	15	A2B1C1D1	0.09
8	A1B1C2D1	0.33	16	A2B1C1D1	0.07

If a Complete Projection Scanning is run on the above list with  $n = 3$ , then the three bundles with the highest Robustness Value for each Future Projection will result in the following reduced list.

Bundle No.	rVal	No. of Picks
1	0.45	4
2	0.44	4
3	0.41	4
4	0.41	3
5	0.39	3
6	0.37	3
8	0.33	1
10	0.26	1
11	0.24	1

The result is, that bundles 8, 10, and 11 will be in the list even though are a considerably smaller Robustness Value. They are unlikely to have been in a list that would have been simply truncated at one-third of its size.

So even in this small example project the different reduction method affects significant changes to the outcome of the reduction.

Another important point that can be seen in the example is that reduction by complete projection scanning ensures that the projection bundles with the highest Robustness Values will remain in

*the list. In fact they usually represent more than one Future Projection and are therefore picked more than once.*

*In a small project like this it might be significant if even one of the Future Projections in a Raw Scenario Bundle is different. But in bigger projects, where the use of a reduction method is necessary to keep the amount of results manageable, this is not the case. If two projection bundles differ only in one or two future projections they are still very similar and it might therefore be sufficient to keep just one of them.*

**Complete Combination Scanning:** This method works similar to the Complete Projection Scanning except that the scanning is done on combinations of Future Projections. In the example above one would look for all Raw Scenario Bundles that contain the pair A1B1, then A1B2, ..., C2D1, and C2D2.

Which list truncation method to use requires some experimentation and depends on the objective - Trivial Reduction only yields high scoring Raw Scenario Bundles without regard for diversity, Complete Combination Scanning provides more diverse results list that generally is longer, and includes lower scoring Raw Scenario Bundles.

For the final list, clustering and multi-dimensional scaling algorithms are available to visually compartmentalize results further.

The final objective is to choose three to five Raw Scenario Bundles of sufficiently high Robustness (or Bundle Plausibility Score, or Average Bundle Consistency Score) that span a range of futures from a perceived best- to worst-case with one of two scenarios being more middle of the road. These final Raw Scenario Bundles can then be further developed into a brief narrative, a long story, or any other scenario product, e.g., as the basis for a game, animated movie, visioning exercise, etc.

# Results

The findings of this project can be broken out into several discrete intermediate steps which are defined by specific participant input, and core scenarios team activities. The first such step is the development of [Key Factors and Future Projections](#) through collection of input via a workshop, consolidation based on categories and scoring from the workshop, and research of individual items by the core scenarios team. The second step revolved around the [scoring of individual plausibilities for each Future Projection](#) by the project participants and the analysis of these scores by the core scenarios team. The third step was the [scoring of the consistency of each pair of Future Projections](#) by the core scenarios team, the review and editing of these scores by project participants, and the final collation and analysis to the project consistency matrix. Last, the combined scores were used by the core scenarios team to calculate the [Raw Scenario bundles](#).

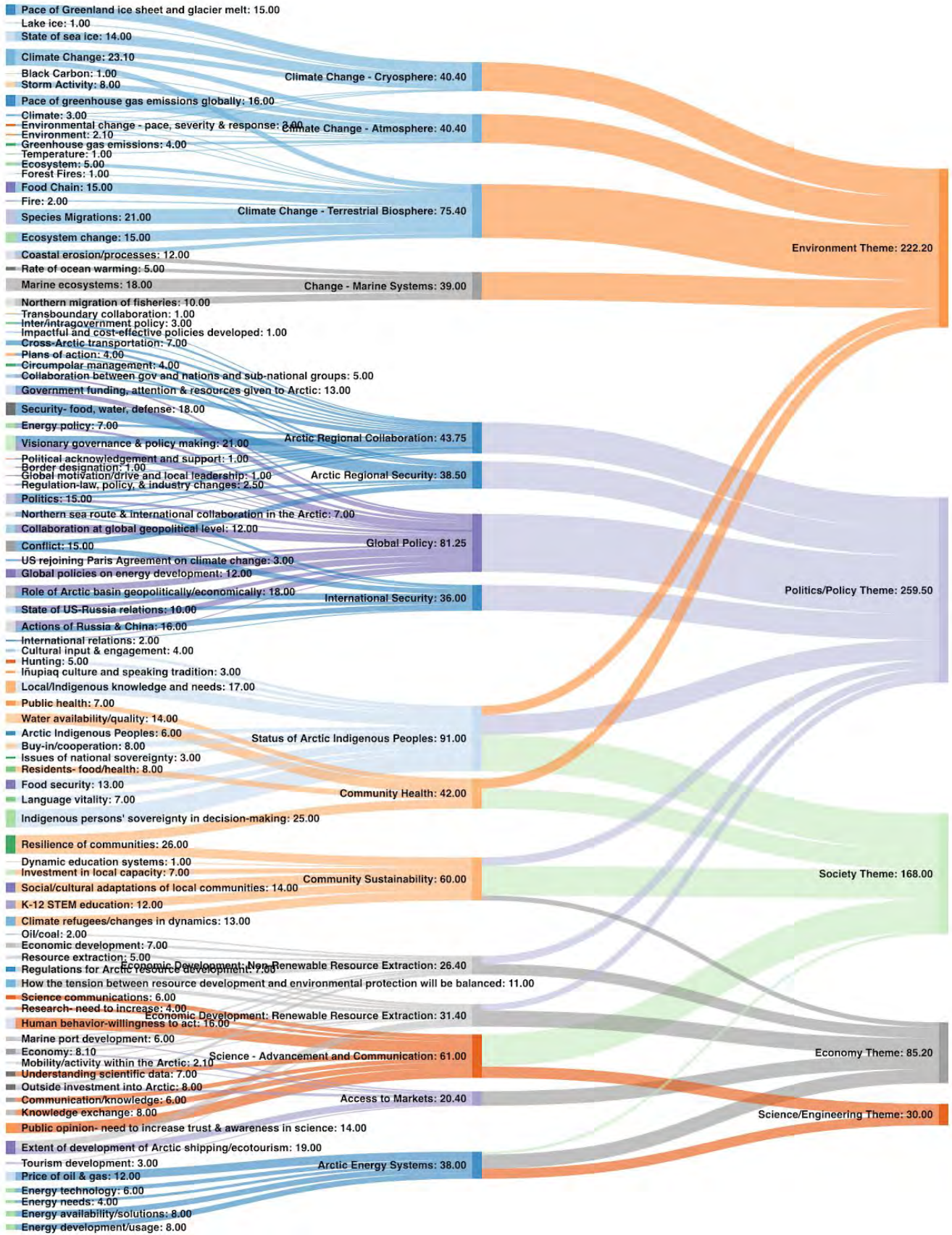
## Key Factors and Future Projections

Development of the final list of 16 Key Factors began with an exercise during the scenarios workshop, which provided more than 100 distinct Key Factors as input from workshop participants.

These initial Key Factors were scored by workshop participants for their importance and uncertainty. The scoring did not yield an obvious break point to reduce the initial list down to manageable size. Thus, initial Key Factors were categorized instead, and bundled into the final 16 Key Factors after the workshop by the core scenarios team. How initial, and final Key Factors and the selected categories are connected is shown in the Sankey Diagram below. The following table shows the final set of Key Factors. The importance and uncertainty scores given are the sums of the importance and uncertainty scores of the initial Key Factors. Most initial Key Factors were directly attributed to a single final Key Factor. However, some were distributed across several final Key Factors, where this was the case the importance and uncertainty scores of this initial Key Factor were distributed evenly toward the respective final Key Factors.

<b>ID</b>	<b>New Key Factor</b>	<b>Importance</b>	<b>Uncertainty</b>	<b>Importance + Uncertainty</b>
A	Climate Change - Cryosphere	23.3	17.0	40.3
B	Climate Change - Atmosphere	26.3	14.0	40.3
C	Climate Change - Terrestrial Biosphere	25.3	50.0	75.3
D	Marine System Change	20	19	39
E	Arctic Regional Collaboration	23.5	20.25	43.75
F	Arctic Regional Security	18.5	20	38.5
G	Global Policy	34.5	46.75	81.25
H	International Security	7.5	28.5	36
I	Status of Arctic Indigenous Peoples	64	27	91
J	Access to Markets	7.3	13	20.3
K	Economic Development: Renewable Resource Extraction	9.8	21.5	31.3
L	Economic Development: Non-Renewable Resource Extraction	7.8	18.5	26.3
M	Arctic Energy Systems	27	11	38
N	Public Health	25.5	16.5	42
O	Arctic Community Sustainability Doug	25.5	34.5	60
P	Science Advancement and Communication	37	24	61

The list of final Key Factors was made available to workshop participants for review and suggestions. No requests or comments were received.



The final list of Key Factor titles, together with the extensive notes taken during the workshop, as well as research by the core scenarios team regarding each Key Factor were used to develop definitions for each Key Factor (about half a page each, with variations).

At the same time, three to five Future Projections were developed for each Key Factor, each with a brief definition. The core scenarios team invited select workshop participants to perform an initial review of the Key Factors and Future Projections. After edits based on this review, the Key Factors and Future Projections were provided to all project participants for review in a discussion forum (website). The comments and discussion provided were integrated in improvements and edits for each Key Factor and Future Projections. All final Key Factors and their associated Future Projections are given in [Appendix E](#).

## Plausibility Scores

Individual Plausibility Scores were collected as described [above](#). The collected scores were tested for their integrity and self-consistency by considering the observed deviations from the mean, the range between minimum and maximum for a given Individual Plausibility Score, and the occurrence of zeros. For a detailed view of all scores and some statistical data please see [Appendix C](#).

There are two major indicators regarding the integrity of the scoring. For one, it can be expected that a group of people will score the Future Projections closest to a status quo development the most plausible. This is the case across the board in this project, particularly, where the status quo distinctly is given as a Future Projection. A second, more project specific indicator is that Future Projections of the four climate-related Key Factors (A through D) received the same ranking in terms of Individual Plausibility Scores in each Key Factor. This is important because underlying to the Future Projections of these four Key Factors are the Intergovernmental Panel on Climate Change's (IPCC) Representative Concentration Pathways (RCP) scenarios. Across Key Factors A through D, the Future Projections associated with RCP 6.0 were scored the most plausible, followed by RCP 4.5, RCP 8.5, and RCP 2.6 in that order.

It appears a hallmark of our times that Future Projections describing collaborative developments were given relatively low Individual Plausibility Scores by the group.

## Consistency Scores

Pairwise consistency scores were collected as described [above](#). The individual consistency matrices were checked for methodological issues; particularly, for excessive use of total inconsistencies, as this can create a situation where no scenarios are viable. Then all consistency matrices were collated into a master matrix by averaging each Pairwise Consistency Score. The final matrix was checked again for methodological issues. The expectations for a consistency matrix are that the mean across all Pairwise Consistency Score values falls around zero, as occurred in this case, with a Pairwise Consistency Score average of



0.05. In addition, the number of total inconsistencies, i.e., Pairwise Consistency Scores that are less than or equal to -1.5, should be low, as in this consistency matrix with only 29 total inconsistencies (2.7 % of all Pairwise Consistency Scores). Furthermore, the total inconsistencies mostly resided in fields that clearly warrant such an evaluation, e.g., a Future Projection in the climate-related Key Factors that represents RCP 2.6 should be totally inconsistent with a Future Projection representing RCP 8.5.

The final consistency matrix is provided in [Appendix D](#).

## Raw Scenarios

Raw Scenario Bundles were developed using the ScenLab Scenario Software and following the definitions given [above](#).

The following approach was taken in searching for Raw Scenario Bundles. The ScenLab algorithm was instructed to search for the most robust, most plausible and most consistent Raw Scenario Bundle in individual algorithm runs. In addition, algorithm runs were dispatched to search for variations in prevalent features in the most robust and most consistent Raw Scenario Bundles. This was done in order to check if the most consistent and most robust scenario are volatile or stable under small variations.

An additional set of algorithm runs was set up to investigate the effect that predetermination of the future development of the four climate-related Key Factors (A through D) might have on the overall scenario development.

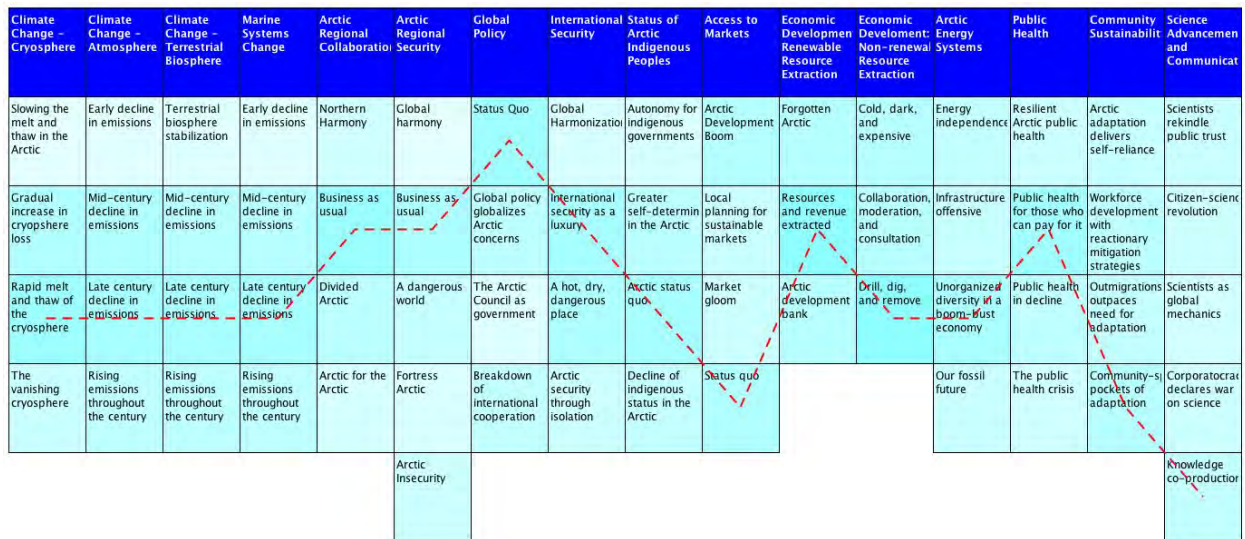
Note that larger versions of the images shown in this section are provided in Appendix F.

## Most Plausible Scenario - Status Quo

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.449	0.4201	<b>3.77x10<sup>-8</sup></b>	2

The most plausible Raw Scenario Bundle describes a status quo development in those Key Factors where a 'status quo' Future Projection was given. This is framed by the expectation that the climate-related Key Factors develop toward RCP 6.0. The selected Future Projections in this Raw Scenario Bundle follow the highest Individual Plausibility Scores, which is what should happen as long as two plausible developments are not inconsistent with each other.

The Bundle Plausibility Score for this Raw Scenario Bundle is  $3.77 \times 10^{-8}$ , which is the highest theoretical value achievable for this project as well. However, both the BCS and Robustness are significantly lower than the maximum possible value, which means, that while this scenario strand is highly plausible, the consistency and robustness of this development are marginal.



The figure shows the most plausible Raw Scenario bundle. For each Key Factor, the most plausible Future Projection (darkest hue in each column) is selected.

## Most Consistent Scenario - Gloomy Development

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.346	<b>0.5701</b>	$3.62 \times 10^{-10}$	2

The most consistent Raw Scenario Bundle describes a rather gloomy development into the future. Framed by a climate catastrophe (RCP 8.5), political and societal divisions regionally and globally are exploited by corporate players to maximize exploitation of the Arctic.

This Raw Scenario Bundle scores quite high on consistency with a BCS of 68.417. However, its Robustness is low with only 0.346 and the Bundle Plausibility Score is two orders of magnitude lower than that for the most plausible Raw Scenario Bundle. This is not an extremely low plausibility, but still it is what severely impacts the Robustness value.

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboratio	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewal Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainabilit	Science Advancement and Communicat
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determin in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scient revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community-s pockets of adaptation	Corporatocra declares war on science
				Arctic Insecurity											Knowledge co-producer

The figure shows the most consistent Raw Scenario Bundle found.

## Most Robust

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
<b>0.7470</b>	0.4451	1.54x10 <sup>-8</sup>	0

The most robust Raw Scenario Bundle provides a somewhat middle of the road outcome between the most consistent and most plausible, with an RCP 6.0 climate development, and much status quo development in the other Key Factors, yet with more divisions than was seen in the most plausible Raw Scenario Bundle.

Of note is that this Raw Scenario Bundle does not exhibit any partial inconsistencies, and that its Robustness is significantly higher than that of the most consistent and most plausible while still maintaining fairly high BCS and Bundle Plausibility Score.

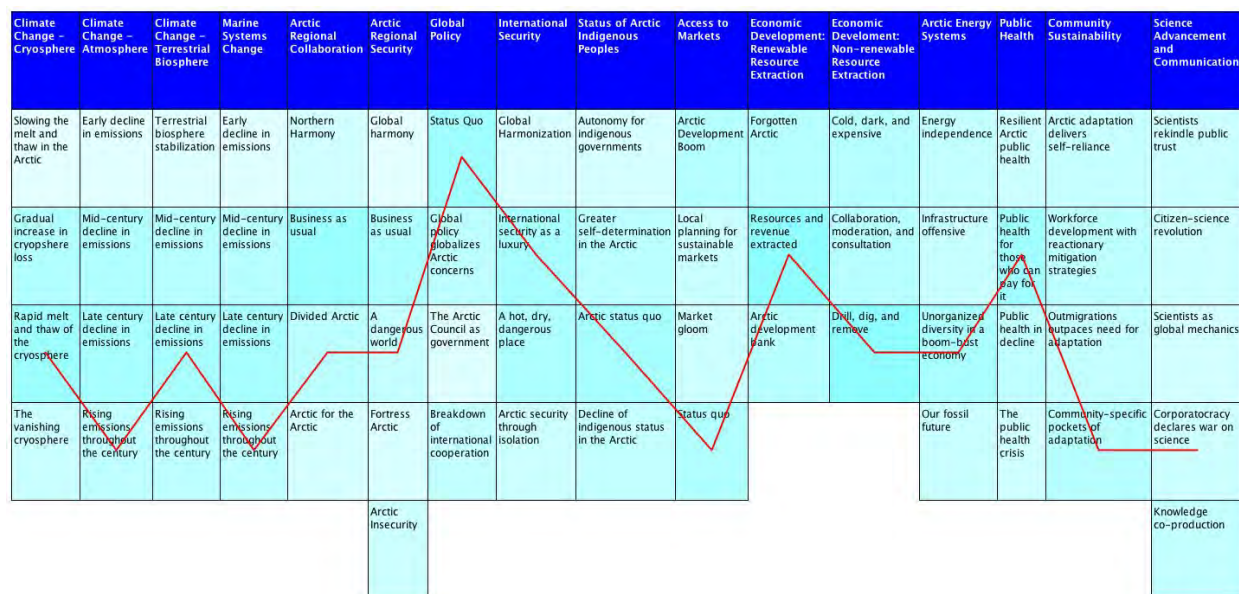
Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboratio	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewal Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainabilit	Science Advancement and Communicat
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determin in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scient revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community-s pockets of adaptation	Corporatocrac declares war on science
				Arctic Insecurity											Knowledge co-productior

The figure shows the most robust Raw Scenario Bundle.

## High Robustness

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
<b>0.7153</b>	0.4035	$7.88 \times 10^{-9}$	0

An additional search for a highly robust Raw Scenario Bundle was performed to test the volatility of the outcomes for the most robust Raw Scenario Bundle. Here, a representative candidate of this search is presented. Notably, the most robust scenario appears quite stable under small changes, expressed here as a climate outcome trending from RCP 6.0 to RCP 8.5, with all other Future Projections remaining the same as for the most robust.



The figure shows are highly robust Raw Scenario Bundle with changes trending from RCP 6.0 to RCP 8.5 in two of the climate-related Key Factors compared to the most robust Raw Scenario Bundle.

## High Consistency

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.3821	<b>0.4806</b>	$1.71 \times 10^{-9}$	2

The most consistent Raw Scenario Bundle's stability to small variations was tested. The Raw Scenario Bundle presented here is representative of this investigation. It shows that the developments described in the most consistent Raw Scenario Bundle are fairly stable even if the climate-related Key Factors develop along the lines of RCP 6.0 instead of RCP 8.5.

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboration	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development: Renewable Resource Extraction	Economic Development: Non-renewal Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determin in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-science revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community-s pockets of adaptation	Corporatocracy declares war on science
				Arctic Insecurity											Knowledge co-production

The figure shows a highly consistent Raw Scenario Bundle, which expresses RCP 6.0 in the climate-related Key Factors (A through D) instead of RCP 8.5, as the most consistent Raw Scenario Bundle does.

## RCP 2.6 Representative Bundle

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.1604	0.4841	$8.71 \times 10^{-15}$	0

Since the climate outcomes representing RCP 6.0 and RCP 8.5 are dominant in the very high scoring Raw Scenario Bundles, an additional analysis was done searching for scenarios with RCP 2.6 and RCP 4.5 expressed in the climate-related Key Factors.

When holding the outcome for Key Factor A through D fixed for RCP 2.6 a very positive future development is found with a highly collaborative regional and international development, and prosperity and great independence for Arctic peoples.

It has to be noted though, that this Raw Scenario Bundle by no means fulfills the requirements of being robust, and plausible; however, it is quite consistent.

Climate Change – Cryosphere	Climate Change – Atmosphere	Climate Change – Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaborative	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication	RCP2.6 Fixed
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independent	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust	Wild Card
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determination in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scientist revolution	No Wild Card
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigration outpaces need for adaptation	Scientists as global mechanics	
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community pockets of adaptation	Corporations declares war on science	
				Arctic Insecurity										Knowledge co-production		

The figure shows a highly consistent Raw Scenario with climate outcome forced to RCP 2.6. Note that the 'Wild Card' outcome in the far right column is an artifact of forcing the RCP 2.6 outcome.

## RCP 4.5 Representative Bundle

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.5949	0.4589	$6.08 \times 10^{-11}$	0
0.4239	0.2886	$1.55 \times 10^{-8}$	2

Since the climate outcomes representing RCP 6.0 and RCP 8.5 are dominant in the very high scoring Raw Scenario Bundles, an additional analysis was done searching for scenarios with RCP 2.6 and RCP 4.5 expressed in the climate-related Key Factors.

When holding the outcome for Key Factor A through D fixed for RCP 4.5 it is observed that both fairly positive, as well as more status quo towards negative developments are part of the representative mix of Raw Scenario Bundles. Here two Raw Scenario Bundles with divergent developments are shown.

The first Raw Scenario Bundle representative of a fixed RCP 4.5 climate outcome shows a highly collaborative political climate regionally and globally, with economic and societal developments point towards independence and greater sovereignty of Arctic peoples. This Raw Scenario Bundle has a fairly high consistency and a reasonably high robustness, yet it scores poorly on plausibility.

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaborative	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication	RCP4.5 Fixed
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independent	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust	Wild Card
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determination in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scientist revolution	No Wild Card
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigration outpaces need for adaptation	Scientists as global mechanics	
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community pockets of adaptation	Corporations declares war on science	
					Arctic insecurity										Knowledge co-production	

The figure shows a highly consistent Raw Scenario with climate outcome forced to RCP 4.5. Note that the 'Wild Card' outcome in the far right column is an artifact of forcing the RCP 4.5 outcome.



The second Raw Scenario Bundle representative of a fixed RCP 4.5 climate outcome shows a much more negative outcome with the general theme being a development along the lines of the status quo, with only a more positive outcome in the science Key Factor. This Raw Scenario Bundle scores significantly higher on plausibility, yet its robustness and consistency are low.

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaborative	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication	RCP4.5 Fixed
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independent	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust	Wild Card
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Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigration outpaces need for adaptation	Scientists as global mechanics	
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community pockets of adaptation	Corporatocracy declares war on science	
					Arctic Insecurity										Knowledge co-production	

The figure shows a highly consistent Raw Scenario with climate outcome forced to RCP 4.5. Note that the 'Wild Card' outcome in the far right column is an artifact of forcing the RCP 4.5 outcome.

## Comments

The results presented show clearly why both plausibility and consistency are important measures, and why robustness may be a good proxy to reconcile between the extremely plausible and the extremely consistent.

The Raw Scenario Bundles show a clear dichotomy along the more moderate climate developments of RCP 2.6 and RCP 4.5, and the developments of RCP 6.0 and RCP 8.5. The former coexpress a collaborative future, while the latter point towards divisive developments. This immediately raises a question of causality. Does the somewhat tempered climate development result in a more collaborative environment overall? Or does the more collaborative development of society as a whole lay the groundwork for more moderate climate outcomes? Clearly, either point could be argued, and cannot be resolved by the analysis at this point.

## Appendix A: Workshop Planning Materials

This appendix includes the handbook developed for the scenarios workshop, the presentation provided to staff prior to the workshop and the handbook provided to the notetakers for the workshop.

Workshop Handbook [following 19 pages]

# Arctic Futures 2050

## Seattle Workshop Master Plan

A Scenario Workshop Planning Framework

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#### [Future Projections, Plausibility and Consistency - A3.3](#)

#### [Future Projections: Group Exercises - A3.4](#)

#### [Future Projections: Plenary discussion - A3.5](#)

#### [Plausibility and consistency: Group exercise - A3.6](#)

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[Roles](#)

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# Overview

This document provides a Scenario Workshop Planning Framework and an implementation plan for the Arctic Futures 2050 Scenario Workshop, April 20 through 22, in Seattle, WA.

The agenda, as proposed is given first, subsequent sections describe the objective and intended outcome for each of the agenda items. Where suitable there will be cross-references to the appendix where group exercises and activities are described in more detail.

Where suitable there are links to additional files, such as spreadsheets for scoring exercises. The appendix also gives a list of anticipated materials required for the workshop.

Currently, 40 workshop participants are expected, with an additional ~10 participating 'support personnel'.

# Agenda

The workshop consists of agenda items on three different days. On day 1, only a brief overview and public introduction to the project is given during a break out session at the Arctic Encounters Symposium, followed by a first 'train of thought' collection of key factors. On day 2, a full day, the focus is on the development of key factors and the downselect to a manageable number of key factors. Day 3 serves to initiate some discussion on future projections and outline the later scoring process.

Each activity has been assigned an ID for easier tracking of necessary materials and slide decks. The IDs all start with `A` followed by the day number, a dot and then an sequential number, e.g., A2.3 would be the third activity on day 2.

The following table gives the overview agenda. Each item is linked to a subsequent section where it is explained.

Day	Time	Activity	Lead
<a href="#">Day 1 - April 20</a>	11:00 to 11:05	<a href="#">Introduction to SEARCH and the fundamental drivers of Arctic Change</a>	Brendan Kelly
	11:06 to 11:16	<a href="#">Introduction to Scenarios as a Tool for Strategic Planning</a>	Amy Lovecraft and Marc Müller-Stoffels
	11:17 to 11:45	<a href="#">SEARCH Action Team Briefings</a>	SEARCH Action Teams, moderated by Brendan Kelly
	11:46 to 12:10	<a href="#">Key Factor Discussion through an activity</a>	Marc Müller-Stoffels
	12:10 to 12:15	<a href="#">Lead out</a>	Amy Lovecraft
<a href="#">Day 2 - April 21</a>	8:30 to 8:45	<a href="#">Convening and team introductions</a>	Brendan Kelly
	8:45 to 9:30	<a href="#">Ice breaker and group introductions</a>	Amy Lovecraft
	9:30 to 10:00	<a href="#">Focal Question(s): Recap and</a>	Brendan Kelly and Amy Lovecraft



		<a href="#">discussion</a>	
	10:00 to 10:15	Coffee Break	
	10:15 to 11:00	<a href="#">Key Factors: Group Exercise</a>	Marc Müller-Stoffels
	11:00 to 12:00	<a href="#">Key Factors: Plenary Discussion</a>	Amy Lovecraft
	12:00 to 12:30	<a href="#">Importance and Uncertainty: Group Exercise</a>	Marc Müller-Stoffels
	12:30 to 13:30	Lunch	
	13:30 to 14:30	<a href="#">Key Factors: Ranking in Plenary</a>	Amy Lovecraft and Marc Müller-Stoffels
	14:30 to 15:15	<a href="#">Uncertainty and Wild Cards: Group Exercise</a>	Marc Müller-Stoffels
	15:15 to 15:30	Coffee Break	
	15:30 to 16:00	<a href="#">Wild Cards: Plenary and Discussion</a>	Amy Lovecraft
	16:00 to 16:45	<a href="#">Scenario building: Group Exercise</a>	Marc Müller-Stoffels
	16:45 to 17:30	<a href="#">Groups present scenarios and report out</a>	Amy Lovecraft and Marc Müller-Stoffels
<a href="#">Day 3 - April 22</a>	8:30 to 8:45	<a href="#">Recap and impressions from day 2</a>	Brendan Kelly
	8:45 to 9:15	<a href="#">Participant review of day 2: Like and Like-to-have</a>	Amy Lovecraft
	9:15 to 9:45	<a href="#">Future Projections, Plausibility and Consistency</a>	Marc Müller-Stoffels
	9:45 to 10:45	<a href="#">Future Projections: Group Exercises</a>	Amy Lovecraft and Marc Müller-Stoffels

	10:45 to 11:00	Coffee Break	
	11:00 to 11:45	<a href="#">Future Projections: Plenary discussion</a>	Amy Lovecraft
	11:45 to 12:15	<a href="#">Plausibility and Consistency: Group Exercise</a>	Marc Müller-Stoffels
	12:15 to 12:45	<a href="#">Plausibility scoring: Individual exercise</a>	Marc Müller-Stoffels
	12:45 to 13:00	<a href="#">Next steps and lead out</a>	Amy Lovecraft and Brendan Kelly

## Day 1 - April 20, 2018

On day 1, only a brief breakout session during the Arctic Encounters Symposium (AES) is held. Unlike the other workshop days, this session is open to the public (those present at AES) and they are invited to participate in the activities taking place.

### Preparation - A1.0

#### Surveys

Workshop participants (as opposed to people attending the breakout session only) will be asked to fill out a survey. These surveys will be distributed at the beginning of the breakout session. The completed surveys are expected to be returned at the beginning of day 2.

**Responsibility:** Amy and Doug

**Materials:** Sufficient number of printed surveys

#### Read ahead materials

A compilation of materials will be sent out for participants to peruse prior to the workshop. This will include:

- Scenario method briefing (Marc)
- SEARCH Action Team Briefings (Brendan)

Some of the above items may be made part of the workshop briefing booklet.

### Introduction to SEARCH and the fundamental drivers of Arctic Change - A1.1

**Timing:** 11:00 to 11:05

**Lead:** Brendan

**Materials:** slides (up to Brendan)

Welcome and brief introduction to the SEARCH program and the idea behind the scenario project.

### Introduction to Scenarios as a Tool for Strategic Planning - A1.2

**Timing:** 11:06 to 11:16

**Lead:** Amy and Marc

**Materials:** slides

This will be a very brief introduction zooming from an overview of scenarios as a tool for strategic thinking and policy development (Amy) through to a sketch of the Robustness Analysis as the specific method used (Marc).

Each presenter has 3 minutes max for this and there are 4 minutes for Q&A after.

The slide deck used should be very visual in nature, without much text on them. One slide per minute should suffice.

### SEARCH Action Team Briefings - A1.3

**Timing:** 11:17 to 11:45

**Lead:** Moderator: Brendan; SEARCH Action Teams

**Materials:** slides (?), clock widget on computer [for teams to see]

This program item consists of brief 'pitch-style' presentations by the three SEARCH Action Teams. Each team will have **4 minutes** to present their topic followed by **4 minutes** Q&A and about **1 minute** for transitions.

### Key Factor Discussion through an activity - A1.4

**Timing:** 11:46 to 12:10

**Lead:** Marc

**Materials:** Slides on Key Factors, pens (100), adhesive notepads (100), timer

*5 minutes:* Key Factors slides, explanation of activity

*6 minutes:* Participants will be asked to write down three Key Factors that they find to be important drivers of the Arctic future by 2050 (use 5.5x8 inch stickies and have them put all three on one)

*10 minutes:* They then will find a conversation partner around the room whom they do not know (if possible) and exchange their key factors notes. The conversation partner chooses one key factor to be explained to them for 1 minute. After the explanation, the conversation partner gives 1 minute of **positive** feedback (doesn't mean they have to agree). The same is repeated with roles reversed.

*Time permitting:* a second round of conversation about other key factors.

### Lead out - A1.5

**Timing:** 12:10 to 12:15

**Lead:** Amy

**Materials:** slide (?), poster boards (or other place to collect key factor sticky notes on)

Brief recap, reminder for workshop participants to be back the next day, and instruction for all to post their sticky notes with key factors on their way out.

Remind people that Brendan, Amy, and Marc will be available for questions in the room through the entire lunch hour.

### Post session work - A1.6

Compile all Key Factors into Spreadsheet and onto large paper (Easel pads) to hang around the room.

## Day 2 - April 21, 2018

### Convening and team introductions - A2.1

**Timing:** 8:30 to 8:45

**Lead:** Brendan

**Materials:** slides (?)

Brief convening of the workshop and introduction of the key team members.

### Ice breaker and group introductions - A2.2

**Timing:** 8:45 to 9:30

**Lead:** Amy

**Materials:** Timer, one slide (?)

The ice breaker will consist of again everyone finding a conversation partner (ideally someone they do not know yet). The first person spends **1 minute** introducing themselves, and explaining what they think about the future of the Arctic. After this, the listener gives **1 minute** of positive feedback. Then roles are reversed.

In the plenary, the two conversation partners introduce each other in no more than 30 seconds each.

### Focal Question(s): Recap and discussion - A2.3

**Timing:** 9:30 to 10:00

**Lead:** Brendan and Amy

**Materials:** slides regarding what a focal question serves as in a scenario process, and how SEARCH arrived at the focal question at hand.

Brief presentation/recap how SEARCH arrived at the focal question and what that focal question is, and what it encompasses. Then opening for discussion, suggestions, criticism, and further explanation as needed.

As time permits this is also the space for a brief general Q&A at the beginning of the day.

**Note:** we do not want to get to a point where we are voting on changing the focal question (this would throw a massive wrench in the works) unless some very valid point is made for this.

### Key Factors: Group Exercise - A2.4

**Timing:** 10:15 to 11:00

**Lead:** Marc

**Materials:** Easel pads and markers. One slide.

Groups to select two KF freely, or come up with one new one. Develop two mini-scenarios: the best case scenario and the worst case scenario for the development of the two KF (note that these terms are subjective). Think about how life in 2050 might be like in an Arctic community under each of these scenarios. Each mini-scenario should be documented on an easel pad.

## Key Factors: Plenary Discussion - A2.5

**Timing:** 11:00 to 12:00

**Lead:** Amy, with Marc as Spreadsheet-Jockey

**Materials:** Visualization of all KF given and proposed consolidation of that list [GoogleSheet].

Begin with suggestions by the scenario team for combination/consolidation of KF from first day.

Discussion of the list of KF that was developed through the first day and the previous exercise.

Some room should be given here for people to air any misgivings they may have and to outline their own priorities. It is important to remind people what the focal question is. This should also serve as keeping the discussion on course.

Some time should be allocated to discussing the difficulty of selecting a 'cut-off point' for a list of final key factors.

## Importance and Uncertainty: Group Exercise - A2.6

**Timing:** 12:00 to 12:30

**Lead:** Marc

**Materials:** none

Participants will organize in groups of three. In these groups they will take turns to spend **1 minute** to talk about what they believe the **most important** KF to be. The other two group members will have **1 minute** each to give **positive** feedback. Everybody takes a turn as the one presenting their most important KF.

The exercise is repeated for the perceived most uncertain KF.

## Lunch - Key Factor Ranking - A2.7

**Timing:** 12:30 to 13:00 [not entire lunch hour]

**Lead:** Amy and Marc

**Materials:** Poster boards/Large sticky notes with all KF listed; two colors of sticky dots [10 of each color for each participant]. Prepared GoogleSheet to collect the scores.

Participants are asked to distribute 10 dots of one color for their most important KF by sticking the dots close to the KF that will be listed on large poster boards or large sticky notes. They are free to either give all dots to a single KF or one to ten different KF. With a second color dots (10 as well) they are asked to do the same for their most uncertain KF.

The scoring should be completed during the first half of the lunch hour, such that the moderators have sufficient time to tally the numbers for the next session.

## Key Factors: Ranking in Plenary - A2.8

**Timing:** 13:30 to 14:30

**Lead:** Amy

**Materials:** GoogleSheet showing the rankings of importance and uncertainty. A plot of uncertainty vs importance.

The objective of this session is to limit the number of KF to no more than 20 (better 15) that will be used for all subsequent stages of the project. If the scoring does not provide good natural points for cut off based on importance, uncertainty or a blend, this will require some discussion. Worst case is, to get the group to consent to a smaller list of KF, and promise that the set of 'runners up' will be carefully considered, and a suggestion to their selection will be made via email in about two weeks time.

## Uncertainty and Wild Cards: Group Exercise - A2.9

**Timing:** 14:30 to 15:15

**Lead:** Marc

**Materials:** Slide on Introduction to Wild Cards. Easel pads and markers.

Seriously think outside the box and need for diversity of knowledge; the more empirical evidence we have from different sources the more likely we can "see" (perceive, take notice of) trends or possible events.

With one of the mini-scenarios developed [previously](#) for each group, the groups are asked to come up with a disruptive event/development that is highly unlikely, but would significantly shift the development away from the described future. With this disruption in mind, the groups will adjust the mini-scenarios. *If there was considerable dissent regarding KF ranking and selection, some of the discarded KF may be pulled to be used as basis for Wild Cards.*

## Wild Cards: Plenary and Discussion - A2.10

**Timing:** 15:30 to 16:00

**Lead:** Amy

**Materials:** A couple of slides with further disruptive events (Arctic relevant) to get discussion going if needed.

The groups will be asked to briefly present their Wild Card to the plenary. The intent then is to have a discussion that leads to the understanding that (a) Wild Cards are not as clear cut as one might think, (b) true Wild Cards are unknowable, (c) thinking linearly about the future omits Wild Cards (amongst other things).

## Scenario building: Group Exercise - A2.11

**Timing:** 16:00 to 16:45

**Lead:** Marc

**Materials:** Intro slide Plausibility and Consistency; Easel pads and markers.

The intent of this exercise is to develop an understanding of consistency and plausibility. For this, groups will be assigned two KF that are somewhat orthogonal (or from different areas, e.g., economics and ecology). Groups will have to come up with a future trajectory for each of the KF. The individual trajectories have to be plausible and the two trajectories have to be consistent to appear in the same future. Based on them a mini-scenario is developed, which has to be plausible and consistent.

## Groups present scenarios and report out - A2.12

**Timing:** 16:45 to 17:30

**Lead:** Amy and Marc

**Materials:** A slide with a brief recap/preview - from KF to FP.

Groups will present their scenarios to the plenary. Focal question: what were the difficulties in combining plausibility and consistency?

Brief recap and preview of the next day.

General comments/concerns (if it gets too much, with reference that there is dedicated space for more process related feedback the next morning).



## Day 3 - April 22, 2018

### Recap and impressions from day 2 - A3.1

**Timing:** 8:30 to 8:45

**Lead:** Brendan

**Materials:** none

This slot is meant to provide the space to lead participants back into the workshop, look back at the previous day, and, if necessary, address any issues.

### Participant review of day 2: Like and Like-to-have - A3.2

**Timing:** 8:45 to 9:15

**Lead:** Amy

**Materials:** Easel Pads

Participants are invited to provide feedback regarding things they liked or would like to have. Facilitators will take notes on separate Easel Pads for 'Like' and 'Like to have'. These will remain up throughout the day and participants are invited to add to them during breaks.

### Future Projections, Plausibility and Consistency - A3.3

**Timing:** 9:15 to 9:45-

**Lead:** Marc

**Materials:** Slides

Presentation on how Future Projections and the Plausibility and Consistency scoring works. This will look back at the [previous day's group exercise](#) that began to introduce the concepts of plausibility and consistency and extend this into the formal scoring processes.

### Future Projections: Group Exercises - A3.4

**Timing:** 9:45 to 10:45

**Lead:** Amy and Marc

**Materials:** Previous day's scenarios from [last exercise](#). Easel Pads and markers.

Groups will be asked to develop opposite future projections to the ones used for the development of the previous plausible and consistent mini-scenarios and develop new mini-scenarios for these. Are these scenarios as plausible and consistent as the original ones? Also ask groups to come up with a middle of the road (plausible and consistent) mini-scenario, i.e., develop another set of two FP for the KF at hand.

### Future Projections: Plenary discussion - A3.5

**Timing:** 11:00 to 11:45

**Lead:** Amy

**Materials:** none

Teams present their Future Projections in the context of their new mini-scenarios. Discussion of what they found w.r.t. Developing robust scenarios.

### Plausibility and consistency: Group exercise - A3.6

**Timing:** 11:45 to 12:15

**Lead:** Marc

**Materials:** Easel pads and markers

Each group will be given two KF with three FP each. For these they will be asked to develop plausibility scores and a pairwise consistency scoring and put the matrix on the Easel pad.

### Plausibility scoring: Individual exercise - A3.7

**Timing:** 12:15 to 12:45

**Lead:** Marc

**Materials:** Easel pads with KF and associated FP. Green sticky dots (1 per/KF and participant). Red sticky dots (5 per participant).

Each participant is asked to place a **green** sticky dots at the FP of every KF that they think is most plausible. In addition, each participant has 5 **red** sticky dots. They can use those to mark FP they think should have very low plausibility scores, i.e., that they think should be wild cards instead of FP.

### Next steps and lead out - A3.8

**Timing:** 12:45 to 13:00

**Lead:** Brendan

**Materials:** Slide with project plan and web addresses to track project.

Brief 'next steps' and further engagement presentation. Final thoughts, comments, thank you and adjourn.

# Roles

The workshop is comprised of several distinct groups that each have their specific roles and (some) responsibilities.

## Convenor

Brendan Kelly will act as the convenor of the workshop. That is the person that has, or is leading the organization that has initiated the scenarios process. The convenor can participate regularly in the workshop. However, he or she should not be influencing the process overtly.

## Facilitators

There are two main facilitators, Amy L. Lovecraft and Marc Müller-Stoffels, who own the workshop agenda and will guide the overall workshop, lead plenary sessions, and will not be attached to any specific breakout groups during group exercises, but rather will jump from group to group to ensure progress and redirect those that are stuck.

## Scenario veterans

There will be a handful of people familiar with the explorative scenarios process, the overarching goals, and many (similar) exercises. Some of these will not be given formal roles, but rather might be asked to help out if there seems to be some undesirable dynamic developing in a subset of the groups.

## Supporting staff

A group of people will be available to help with taking notes and photos to ensure we have a solid record of plenary and breakout sessions. Support staff may participate in the group exercises at their leisure and their comfort level. They are not required to try facilitate discussion or work toward the goal during breakout sessions, but nor are they discouraged to do so. The facilitators do rely on them though to be informed if things are not working out during breakout sessions, and to get overall feedback on the mood of the overall group.

### **Supporting staff:**

**Douglas Cost** will provide key support to the facilitators. He will handle surveys, release forms, and will ensure a complete visual record is created of all workshop materials.

**Helen Wiggins** will provide infrastructure and logistics support.

**Andrea Fisher, Brit Myers, Alex Long, Michael Diamond, Christiana Dietzen, Judy Twedt, Lauren Schmeisser, and Valerie Cleland** will be the primary note-takers that will be to each group during exercises.

## Group exercises

There are two different group exercise concepts. One is geared more towards individual one-on-one/two work, the other is work in small groups with one '[supporting staff](#)' to each group.

### Individual groups

This format will be used for the [breakout session key factor exercise](#), and the [ice breaker](#) during the workshop proper. Participants are asked to work with one or two people they do not know yet if possible, or someone they do not know well. The intent with this is also to get to know new people and grow the individual networks. Thus, on a second exercise, everyone should find new partners.

It is important to stress to participants, that in the exercises discussion and disagreement is desired, but only positive feedback is allowed.

### Breakout groups

These groups should consist of 5 members each. At the current number of proper attendees, 40 people, this should yield 8 individual groups. It should be stressed that no group may have less than 4 or more than 6 members, not counting note takers.

Depending on group dynamics it might be necessary to strongly encourage recombination of groups for each exercise. For example, if a group spends much of an exercise discussing other business, or gets stuck in the weeds without moving towards the goal of the exercise, they should be re-assigned for the next exercise. Note that this will make it necessary to design all exercises such that group can pick up and build on other groups work from previous exercises.

**Note takers:** for these exercises, it will be very important to note the names of everyone in the group.

## Venue

Three rooms at the Bell Harbor International Conference Center are available: Cove, Marina and Pacific Boardroom are available for plenary and breakout group activities. See the floor plan [here](#).

## List of Materials

Item No.	Item	Comment
M1	Workshop Briefing Booklet	Compilation of Workshop Materials/Read ahead materials, etc.
M2	Timer	A digital `egg timer` to track presentations.
M3	Pens (100)	Pens for Day 1 (A1.4).
M4	Adhesive notepads (Post its); (100)	Notepads for KF exercise on day 1 (A1.4). Do not need thick notepads, ~10 sheets/pad would do.
M5	Poster boards/large adhesive easel pads (or similar) (12 with 25 pages each)	Place to collect sticky notes from KF exercise on day one (A1.4) . Add more KF. A2.4, A2.9, A2.11, A3.4, A3.6
M6	Markers, multiple colors sets (12 sets)	A2.4, A2.9, A2.11, A3.4, A3.6
M7	Sticky dots green (500), blue (500),	Colors are secondary as long as they are distinct. A2.7
M8	Sticky dots green (1000) and red (200)	Colors are secondary as long as they are distinct, A3.7
M9	Scissors	For cutting up dot strips to hand to participants
M10	Digital camera	For pictures of the process but also to record all the materials produced
M11	Easels	To support the flip charts (M5)
M12	Name Tags	Will be included in participant folders distributed at registration if not an AES registrant.
M13	Participant Folders	Labeled folders to include: pre-survey, participant booklet, photo release, informed consent form, nametags, AT briefs
M14	Post surveys & self-addressed stamped envelopes	For distribution on Sunday.
M15	Sign-In sheet for AES breakout (Day 1)	Printed sign-in sheet & clipboard on Day 1.

M16	Presentation computer	Presentation computer for use Day 2 and 3 - this could be accessed by workshop facilitators in advance if they need to load presentation slides onto the laptop.
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# ARCTIC FUTURES 2050

STAFF MEETING, APRIL 12, 2018



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## PEOPLE

- **Brendan Kelly, Executive Director, SEARCH – Workshop Convener**
- **Amy Lovecraft, Department Chair, Political Science, UAF – Workshop Facilitator/Content**
- **Marc Müller-Stoffels, CEO, denamics GmbH – Workshop Facilitator/Methodology**
- **Doug Cost, Asst. Prof., School of Ed, UAF – Scenario Veteran, Chief record keeper**
- **Helen Wiggins, Director of Programs, ARCUS – Planning, Logistics, Infrastructure**
- **Brit Myers, Project Manager, ARCUS – Planning, Logistics, Infrastructure, Notetaker**
- **Andrea Fisher, Grad Student, Middlebury – Workshop prep/Notetaking/Post-workshop production**
- **Christiana Dietzen, Grad Student, UW – Notetaker**
- **Judy Twedt, Grad Student, UW – Notetaker**
- **Lauren Schmeisser, Grad Student, UW – Notetaker**
- **Michael Diamond, Grad Student, UW – Notetaker**
- **Valerie Cleland, Grad Student, UW -- Notetaker**

## WORKSHOP AGENDA

- **Venue:** Bell Harbor Conference Center, 2211 Alaskan Way, Seattle, WA 98121, USA
- **Day 1:** Breakout session at Arctic Encounters Symposium, 11:00 am to 12:15 pm
  - No note-takers required. You may attend this session though.
- **Day 2:** All day: 8:00 am to 6:00 pm (staff times)
- **Day 3:** Half day: 8:00 am to 13:30 pm (staff times)

## CHATHAM HOUSE RULE

- When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the information received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.



## ACTIVITY REFERENCE CODES

- Each activity has a code number for internal reference, and used together with long titles in the internal schedule and other docs.
- All codes begin with 'A' for activity, followed by a number (1,2, or 3) for the day, and a running number starting with 0.
- Example:A2.4 refers to the fourth activity on day 2.

## NOTE TAKING

- There will be a brief handbook by Wednesday
- You need **your own laptop**.
- Notes are taking during plenary sessions and breakout group exercises
  - Plenary: two note-takers, rotating through. A schedule will be provided.
  - Breakout groups: all note-takers.
- Preferably you will take notes on a Google Doc provided (Word doc as backup option if network is unreliable)
- Notes are **internal** documents
- In the notes attributed comments, discussion, etc. to specific people where possible.
- After the workshop, and transfer of a copy of notes to the facilitators, you must destroy all other copies (Chatham House Rule and IRB requirement).

## OTHER RESPONSIBILITIES

- See 'Staff Schedule' for overview
- See 'SEAWorkshop\_master\_plan' for description of all activities
- See 'WorkshopPrep\_Responsibilities' for pre-workshop deadlines and bill of materials

Notetaker's Handbook [following 6 pages]

# SEARCH

## Arctic Futures 2050 Scenario Workshop: Notetaker's Handbook

This document serves as the basic instructions for taking and handling notes taken during the SEARCH Arctic Futures 2050 Scenario Workshop, April 20 through 22, 2018 in Seattle, WA.

### Objective

The objective of taking notes at the scenario workshop is to document the discussions that will take place in plenary and group sessions. These notes will form part of the basis of future scenario development by the workshop facilitators. As such, a reviewed and redacted form of the notes will become public record, which should be kept in mind when creating them.

### Workshop format

The scenario workshop will take place over three days:

- **Day 1:** There will be a breakout session at the Arctic Encounter Symposium, on April 20, 11:00 am through 12:15 pm. On this day *no notetakers are required*. However, those taking notes may enter the Arctic Encounters Symposium free of charge *for the purpose of attending the breakout session only*. This is highly encouraged, but not required.
- **Day 2:** This will be a full day of workshop with an interplay of plenary and group sessions. Notetakers are expected to be 'on deck' at 8:00 am sharp for a briefing, final prep, etc. Meals and coffee/tea will be provided on this day.
- **Day 3:** This will be half a day with an interplay of plenary and group sessions. Notetakers are expected to be 'on deck' at 8:00 am sharp for a briefing, final prep, etc. Meals and coffee/tea will be provided on this day.

*Dress code* for Day 2 and 3 is business casual. Day 1 is part of the Arctic Encounters Symposium and follows that meetings dress code [business formal].

## What you need

Final notes are expected to be in electronic text format (Google Doc [preferred], or MS Word). Thus, for simplicity, you will need a laptop computer or tablet that you can write on at sufficient speed. A Google Doc template will be made available to you [wifi is available on site]. If you elect to use MS Word please follow the format shown in the GoogleDoc, and email a copy of your notes to the facilitators at the end of each workshop day.

You may elect to take notes by hand, but are required to (a) provide scanned copies/photos immediately at the end of the day, and (b) transcribe them within 3 days after the last day of the workshop into one of the above electronic formats.

## Note requirements and format

Notes are expected to be clear, yet concise. Where possible statements made should be attributed to the person that has made them. Discussions do not have to be recorded verbatim. However, the notes should reflect the core arguments, agreements and disagreements. In addition, the notes are meant to record how products during group exercises were developed (this is in addition to any written materials the workshop participants may develop during exercises).

Each specific activity has been given a control number which can be found in the agenda below. These control numbers should be used on each page that contains notes for a particular exercise. Do not use the same page for notes from more than one exercise.

For notes from group exercises, at the top of the page, record which participants were part of the particular group you are taking notes for.

## Schedule

Most group exercises will require one notetaker to each breakout group discussions during these exercises should be captured as completely as possible. During plenary sessions note taking will rotate with two note takers being on duty at each time; only question and answer session/comments from the audience and replies need be recorded, presentations by facilitators will not need to be recorded. Below is a schedule showing the rotation of note takers for plenary sessions.

<b>Activity Reference</b>	<b>Activity Title</b>	<b>Activity Time</b>	<b>Dedicated Notetakers</b>
A2.1	Convening and team introductions	8:30 to 8:45	Andrea and Brit
A2.2	Ice breaker and group introductions	8:45 to 9:30	none
A2.3	Focal Question(s): Recap and discussion	9:30 to 10:00	Alex and Michael
A2.4	Key Factor Group Exercise	10:15 to 11:00	all
A2.5	Key Factor Plenary Discussion	11:00 to 12:00	Christiana and Judy
A2.6	Importance and Uncertainty Group Exercise	12:00 to 12:30	none
A2.7	Lunch: Key Factor Ranking	12:30 to 13:00	none
	Lunch: Break	13:00 to 13:30	none
A2.8	Key Factor Ranking in Plenary	13:30 to 14:30	Lauren and Valerie
A2.9	Uncertainty and Wild Cards: Group Exercise	14:30 to 15:15	all
A2.10	Wild Cards Plenary and Discussion	15:30 to 16:00	Andrea and Michael
A2.11	Scenario Building Group Exercise	16:00 to 16:45	all
A2.12	Groups Present Scenarios and Report Out	16:45 to 17:30	Brit and Alex
A3.1	Recap and impressions from day 2	8:30 to 8:45	Andrea and Valerie
A3.2	Participant review of day 2	8:45 to 9:15	Andrea and Valerie
A3.3	Future Projections, Plausibility and Consistency	9:15 to 9:45	Michael and Lauren
A3.4	Future Projections Group Exercises	9:45 to 10:45	all
A3.5	Future Projections Plenary Discussion	11:00 to 11:45	Brit and Judy

## Notetaker Handbook - Arctic Futures 2050 Scenarios Workshop

A3.6	Plausibility and Consistency Group Exercises	11:45 to 12:15	all
A3.7	Plausibility Scoring Individual Exercise	12:15 to 12:45	none
A3.8	Next Steps and Lead Out	12:45 to 13:00	Alex and Christiana

## Participant Privacy

The entire workshop is covered by Chatham House Rule<sup>1</sup>. Thus, all present can expect that what they say will not leak to the public attributable to them or their organization. This might seem like a contradiction to the above request that you use names in your notes. However, it merely means that the facilitators have a record including identifiable information (and can ask individuals later for release from Chatham House Rule). As a notetaker, to protect the process of the workshop, you are asked to not retain a copy of your notes after you have rendered a final version to the facilitators.

In addition, there are parts of this workshop covered by the rules of the Internal Review Board (IRB) of UAF. Particularly, some surveys will be used to ascertain participants views and opinions. ***Unless you know you are named on the pertinent IRB protocol, do not handle the surveys. If there are any questions about this please contact Amy Lovecraft or Doug Cost immediately.***

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<sup>1</sup> When a meeting, or part thereof, is held under the Chatham House Rule, participants are free to use the [information](#) received, but neither the identity nor the affiliation of the speaker(s), nor that of any other participant, may be revealed.



## Contacts

If there are any questions, or you cannot make it to one or all workshop days please inform:  
Marc Müller-Stoffels

Contact information removed.

# Arctic Futures 2050

Scenarios as a Tool for Collaboration Among Scientists and Policymakers



# The Changing Arctic Environment







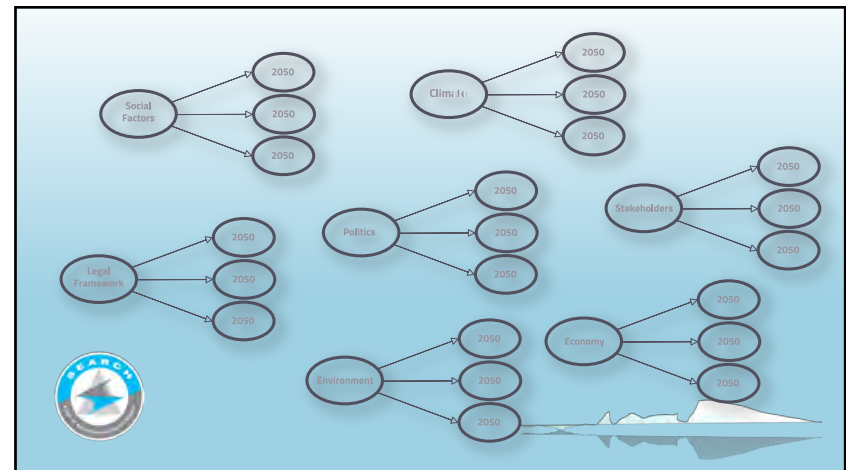
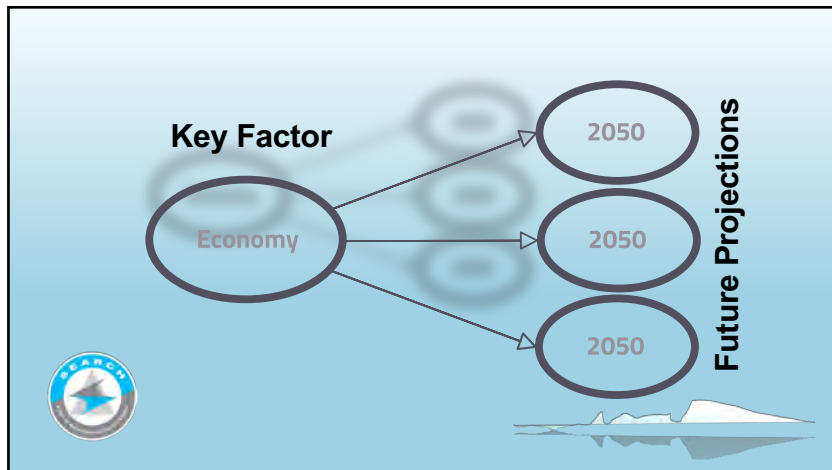
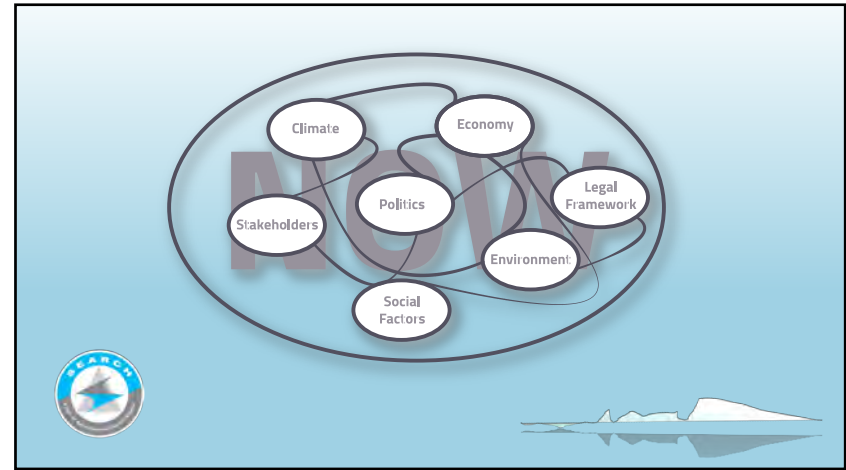
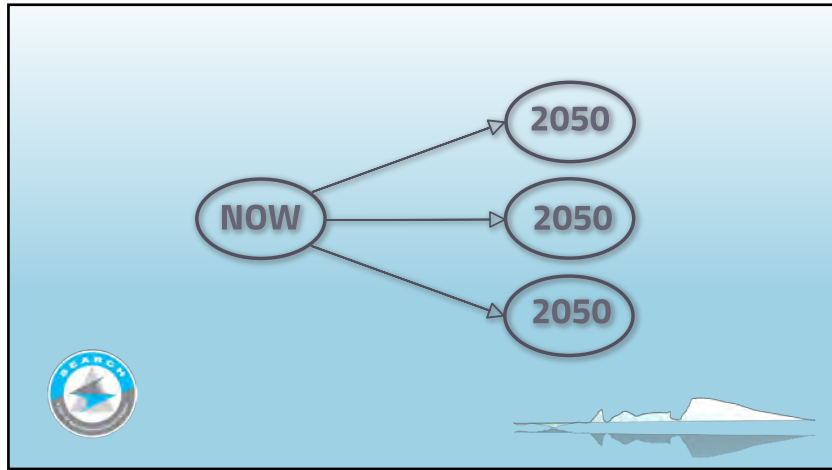
Under conditions of uncertainty we need nimble strategic thinking that does not lock us into investigation, policy processes, or goals that are likely to change as conditions in the Arctic change.

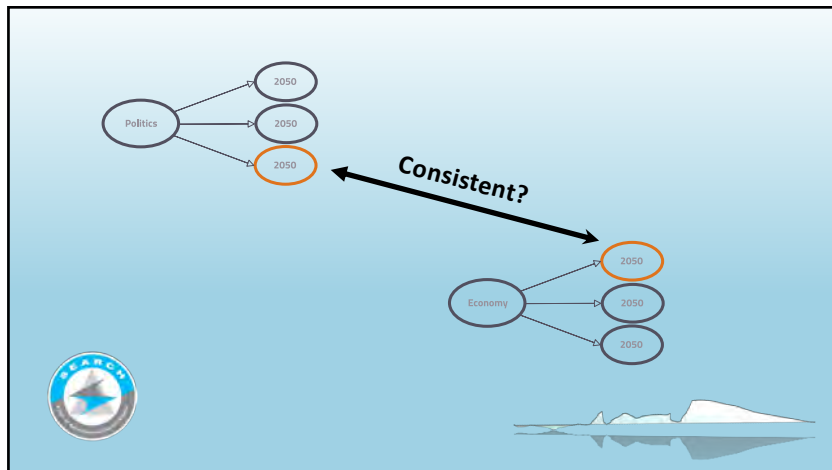
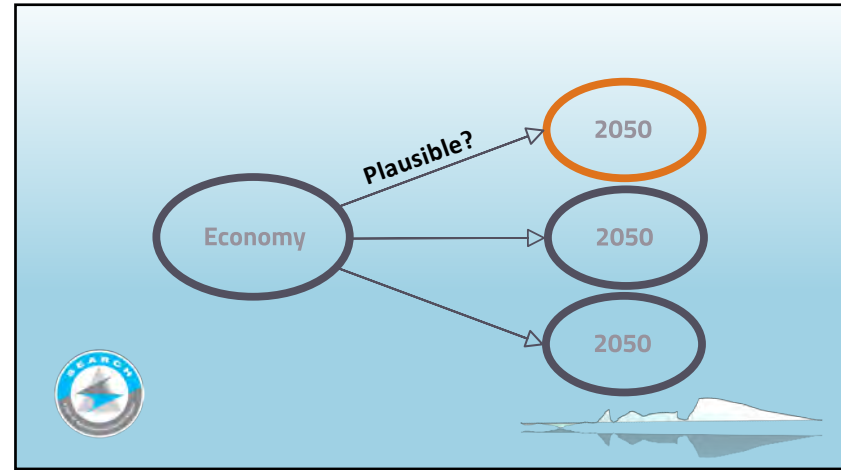
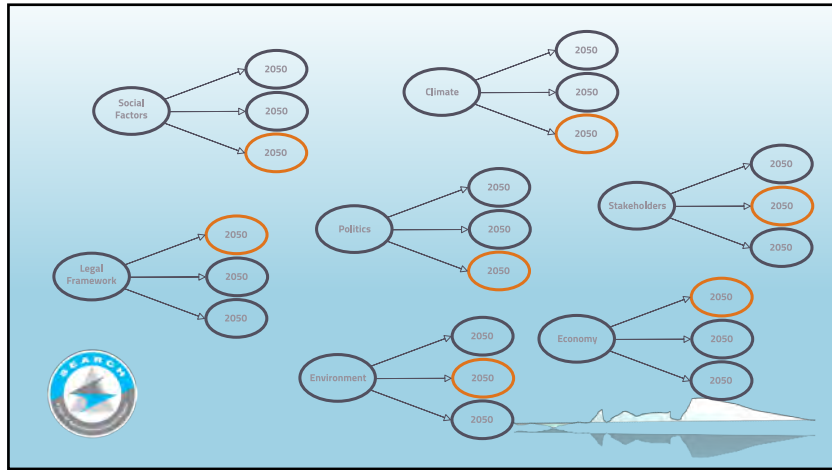
Scenarios are narratives of plausible future Arctics created by the evidence of experts.



# Robustness Analysis

Quantitative Scenario Development







**Robust = Plausible + Consistent**  
Multiple and very different scenarios can be robust.

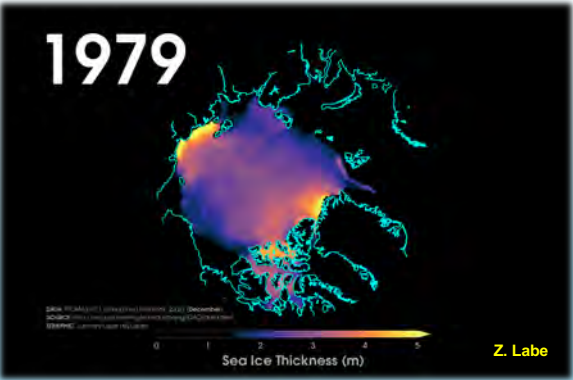
# SEARCH Action Teams

Sea Ice, Land Ice, and Permafrost





## Arctic sea ice is dwindling

# 1979

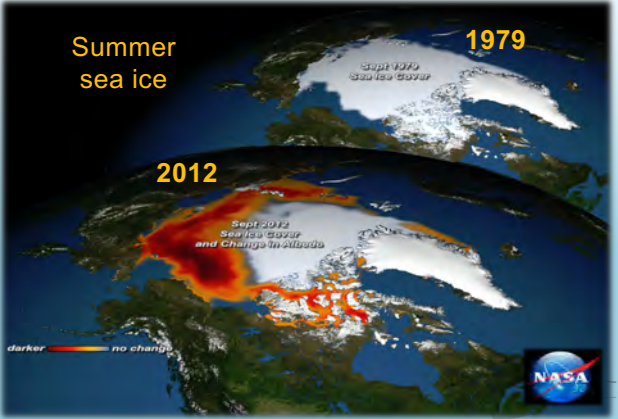


SEARCH logo




## The Arctic is darker now.

Summer sea ice

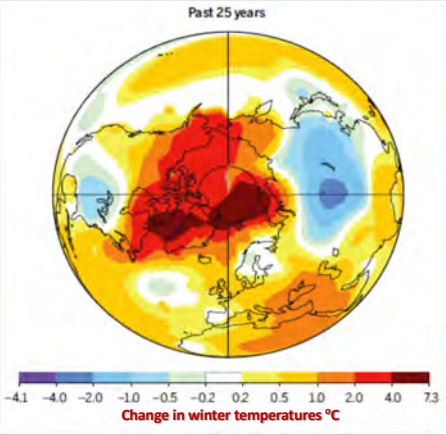


SEARCH logo



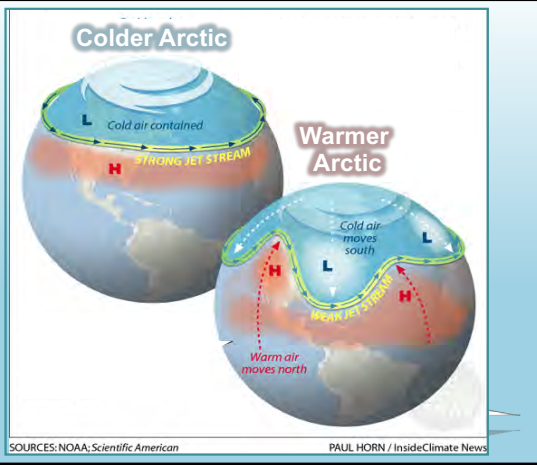
## Change in winter temperatures

Past 25 years



SEARCH logo

# The Jet Stream makes our weather



SOURCES: NOAA; Scientific American PAUL HORN / InsideClimate News



Jennifer Francis | [francis@imcs.rutgers.edu](mailto:francis@imcs.rutgers.edu) | [jenniferfrancis.com](http://jenniferfrancis.com)



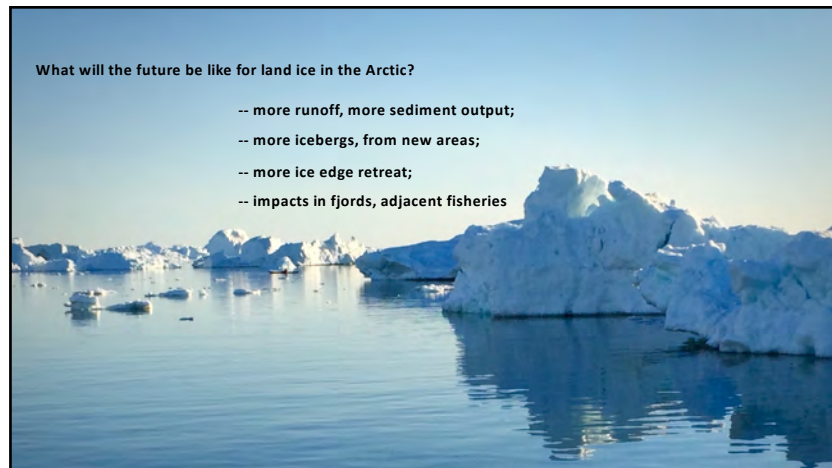
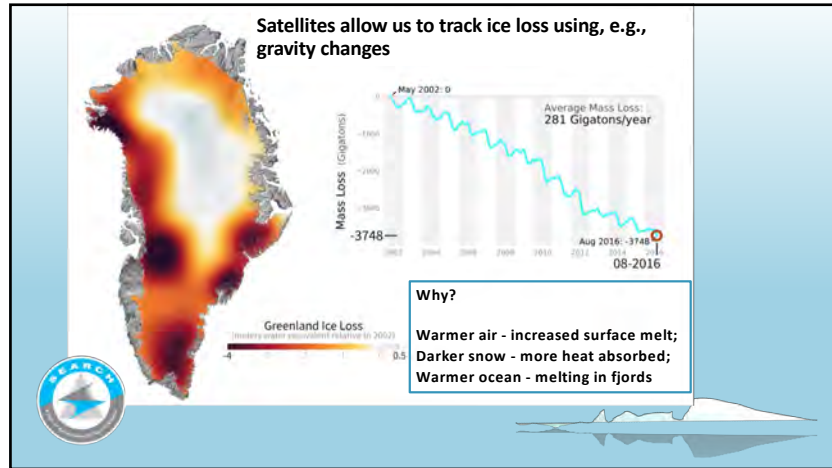
## Land ice in the Arctic is declining rapidly

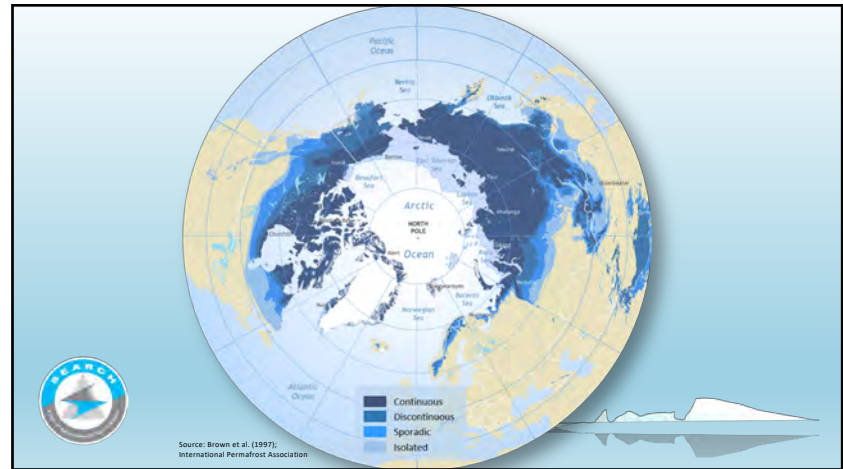


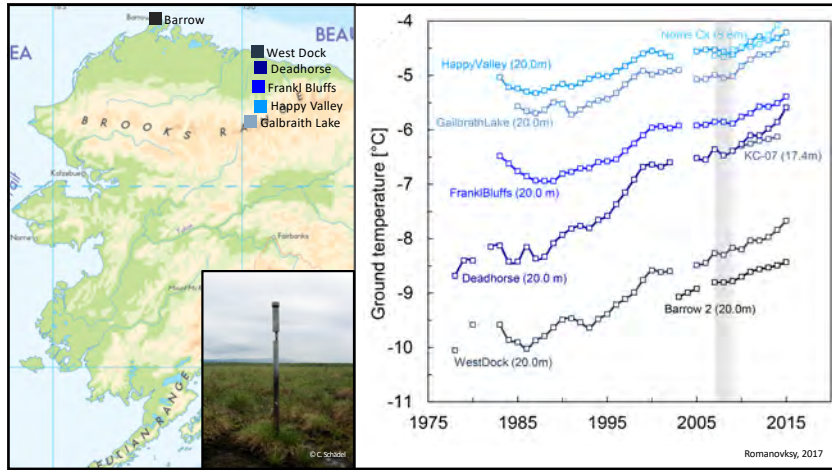
Ted Scambos [teds@nsidc.org](mailto:teds@nsidc.org)

- Greenland, Alaska, Canadian, and Russian ice caps; all are shrinking;
- Rapid ice loss in Greenland began in the early 2000s; it is now 22% of global sea level rise.
- In 1995 it was near-zero.









## Key Factors?

What factors will strongly influence the development of Arctic Futures by 2050?

The slide features the 'SEARCH' logo in the bottom left corner and a stylized graphic of an ice formation or snowdrift in the bottom right corner.

## Your turn

- What factors will strongly influence the development of Arctic Futures by 2050?
  - On a sticky note, write down **three** Key Factors (about 5 minutes)
  - Find a conversation partner you don't know.
  - Show your Key Factors to the conversation partner.
  - The conversation partner will select **one** Key Factor.
  - Spend **one** explaining why you selected this Key Factor.
  - The conversation partner then has **one** minute to provide **positive** feedback.
  - Repeat with roles reversed.
- On your way out, please leave your sticky notes with the three Key Factors with us.



- ❖ Be sure to post your Key Factor sticky notes here!
- ❖ Participants must fill out their surveys by tomorrow morning.
  - ❖ We meet tomorrow morning 8:00 in the Cove room.
- ❖ Brendan, Marc, and Amy will now remain here for questions.



**We thank you for sharing your time and expertise!**



Arctic Futures 2050 Website:  
[www.searcharcticsscience.org/arctic-2050](http://www.searcharcticsscience.org/arctic-2050)

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Marc Müller-Stoffels  
 marc@denamics.com



# Arctic Futures 2050

Scenarios as a Tool for Collaboration Among Scientists and Policymakers



## Ice breaker and introductions

- Find a conversation partner (some one you don't know)
- In **1 minute** introduce yourself and share your view of the Arctic's future
- The listener gives **1 minute** of **positive feedback**
- Repeat with reverse roles
- Reconvene, everyone introduces their conversation partner to the group (**30 seconds each**)



## What is a focal question?

The long-term time horizon associated with scenarios hints at their key utility. Scenarios are used to explore possible futures that lie beyond forecasts or predictions where there is a reasonable confidence about trajectories, outcomes, and uncertainties.

The further into the future we look the less reliable forecasts become. When your crystal ball goes dark...

Better a *what if* than an oops!



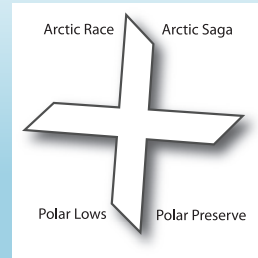
## What is our focal question?

What information is needed to successfully respond to changes in Arctic environments by 2050?



## Key Factors and mini-scenarios

- Group Exercise
  - 8 Groups
- As a group select **two** key factors
- Two mini-scenarios with these key factors
  - Best case
  - Worst case



## What information is needed to successfully respond to changes in Arctic environments by 2050?

We are now beginning to pare down and combining and reconsidering Key Factors.

We need between about 10 and 15 as a final number.

This is not the final decision!



## Importance and Uncertainty

- Key Factors can be ranked by:
  - **Importance:** important KF are more influential than others in driving future developments
  - **Uncertainty:** uncertain KF are those where it is very unclear how they may develop into the future, or where a lack of knowledge impedes further assessment
- In groups of three:
  - One person makes the case for the Key Factor they find **most important** (1 minute)
  - Other two give feedback (1 minute each).
  - Rotate through
  - Repeat for the Key Factor that is **most uncertain**



## Key Factor Ranking

- You have 10 green and blue sticky dots each:
  - Green : importance
  - Blue: uncertainty
- Distribute dots to Key Factors
  - You may give more than one dot to a Key Factor
  - You may give dots of each color to a Key Factor





# Arctic Futures 2050

Scenarios as a Tool for Collaboration Among Scientists and Policymakers






# Key Factor down-select

## Uncertainty and Wild Cards

- Uncertainty: lack of knowledge that may be remedied.
- Wild Card: unknowable disruptive changes that have a very high impact, yet a very small likelihood.
- In previous 8 groups:
  - Come up with a Wild Card that would severely disrupt the Best Case scenario
  - What/how does the future development change

## Wild Cards



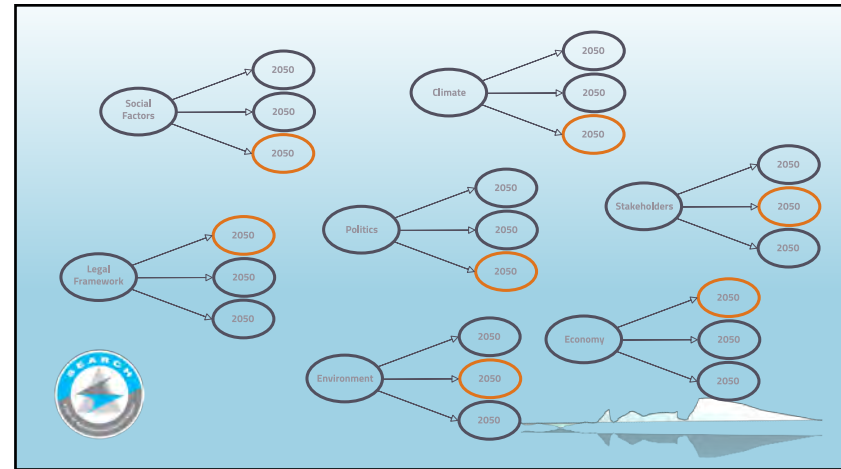
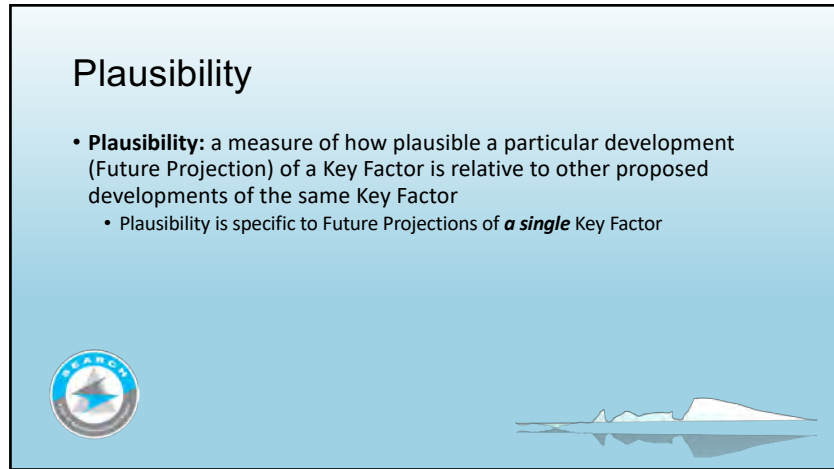
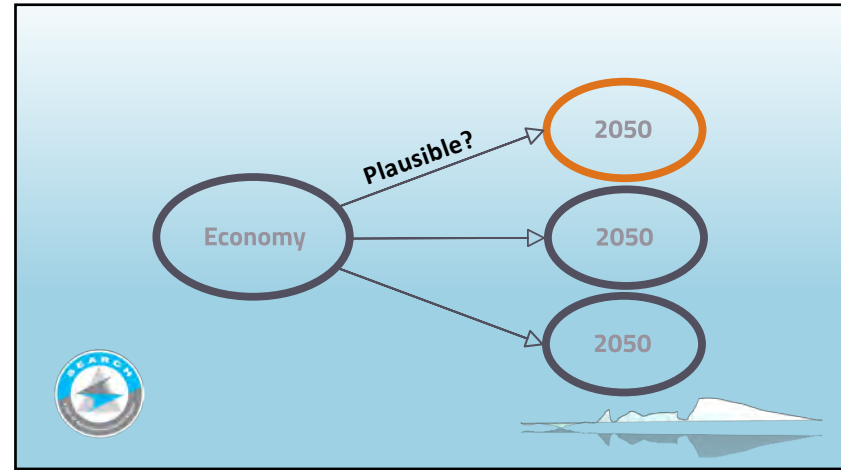
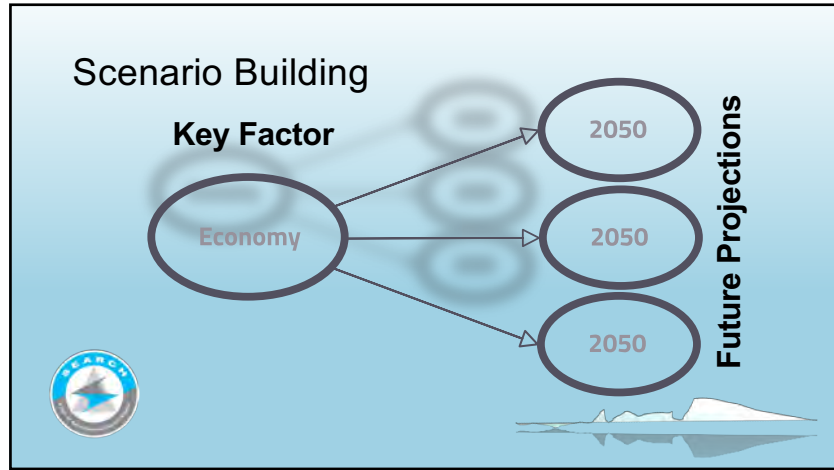
**1. The Lesson of the Black Swan**  
*rara avis in terris nigraque simillima cygno*  
 "a rare bird in the lands and very much like a black swan"



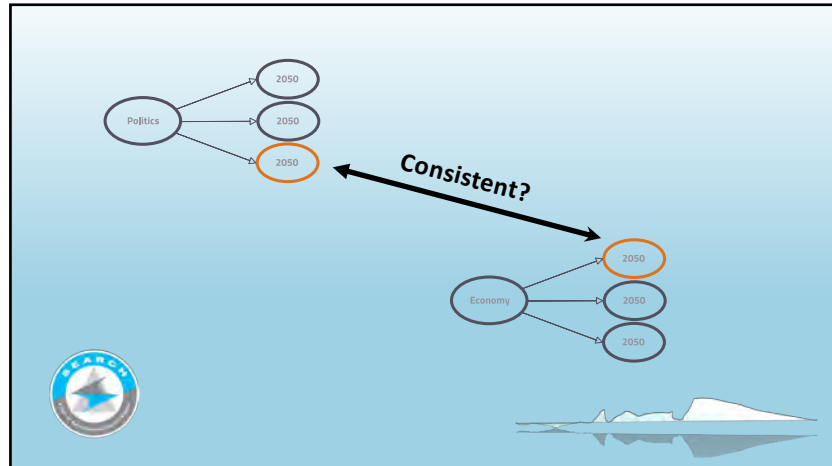
**2. Each group will briefly present its card to the group: what is it? How likely is it to happen? What sort of ways might we know if it happens?**









## Plausibility and Consistency

- **Plausibility:** a measure of how plausible a particular development (Future Projection) of a Key Factor is relative to other proposed developments of the same Key Factor
  - Plausibility is specific to Future Projections of *a single* Key Factor
- **Consistency:** a measure of how consistent two developments (Future Projections) of two *different* Key Factors are to appear in the same scenario.
  - Consistency measures involve Future Projections of *two different* Key Factors

## Plausible and consistent scenario

- Group Exercise:
  - Select two (somewhat orthogonal) Key Factors
  - Come up with a **plausible** Future Projection for each
  - The two Future Projections have to be **consistent to appear in the same scenario**
  - Develop a mini-scenario narrative with the two Future Projections

## Presentation of Group Scenario Work

Turn around and look at how far we have come since Friday at 11:00!



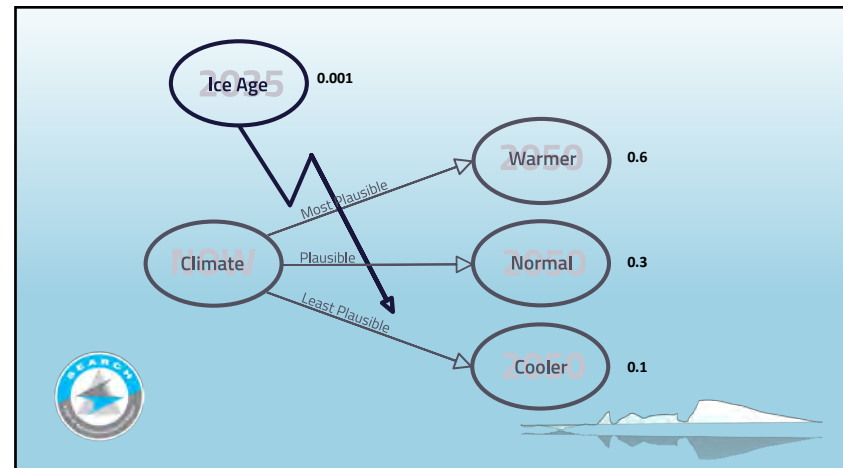
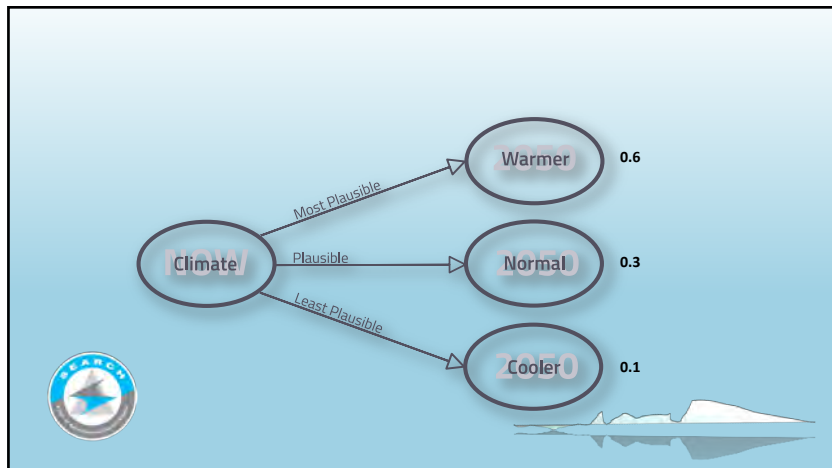
# Arctic Futures 2050

Scenarios as a Tool for Collaboration Among Scientists and Policymakers




## Future Projections, Plausibility and Consistency

- **Plausibility:** a measure of how plausible a particular development (Future Projection) of a Key Factor is relative to other proposed developments of the same Key Factor
  - Plausibility is specific to Future Projections of *a single* Key Factor
  - Value between 0 and 1
  - Sum of plausibility scores for all Future Projections of a Key Factor has to be 1
  - Very low plausibility scores -> consider turning this FP into a Wild Card or dropping it.

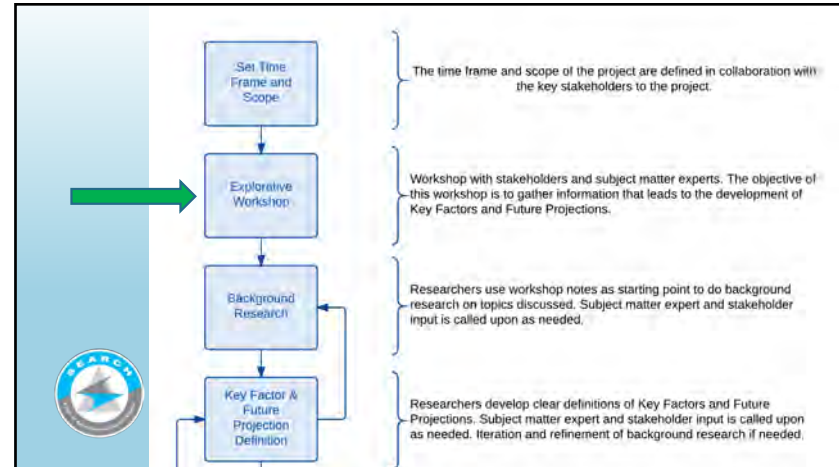
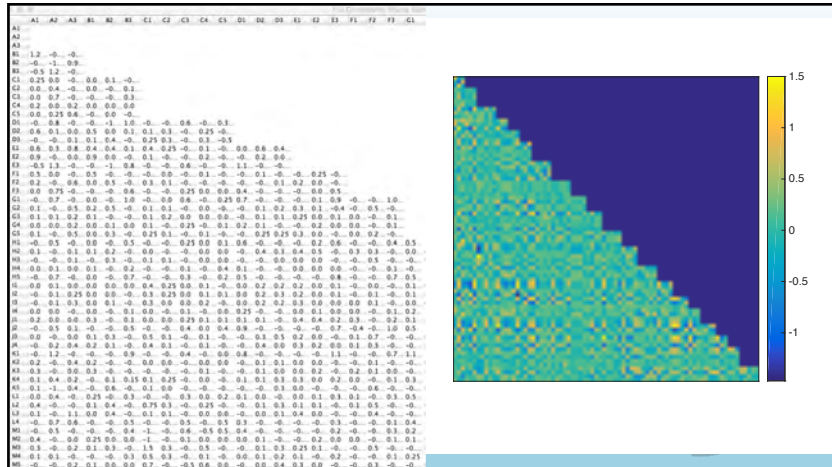




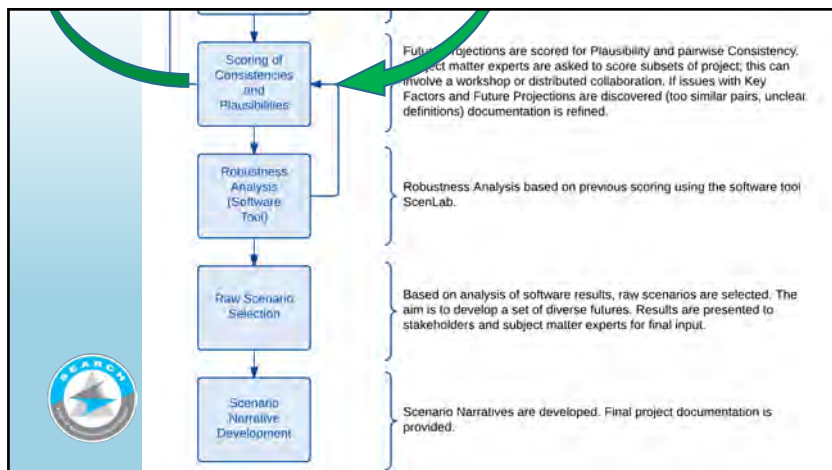
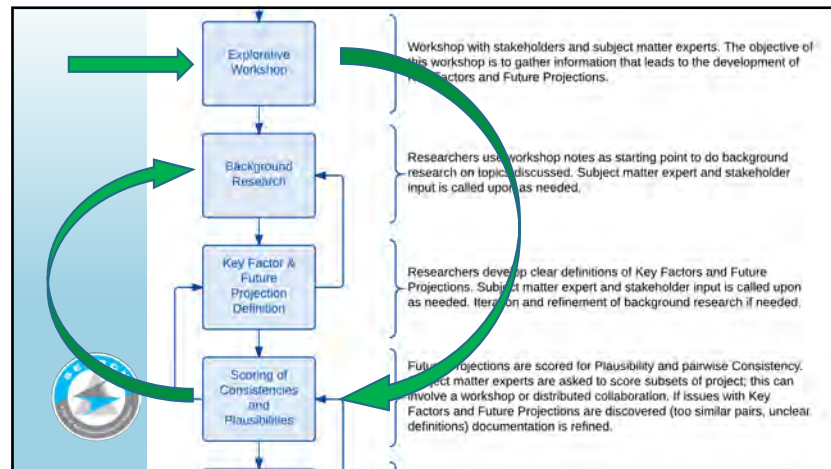
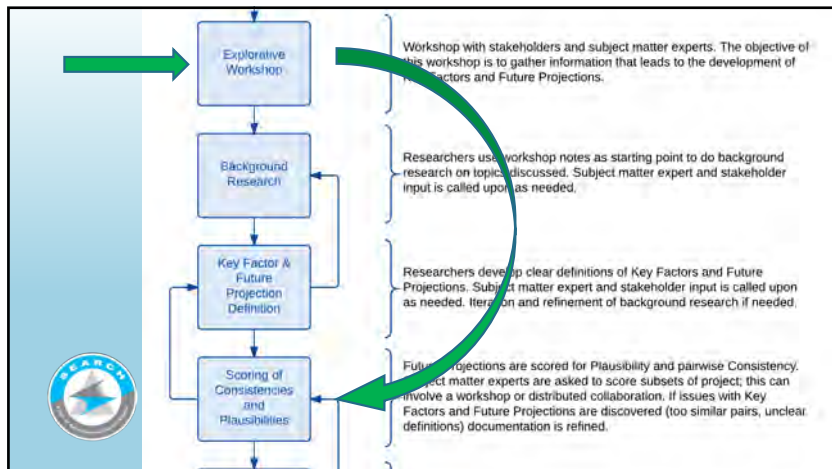
## Future Projections, Plausibility and Consistency

- **Consistency:** a measure of how consistent two developments (Future Projections) of two **different** Key Factors are to appear in the same scenario.
  - Consistency measures involve Future Projections of **two different** Key Factors
  - Scores between -2 and 2, from **totally inconsistent** (<-1.5), **partially inconsistent** (between -1.5 and -0.5), **neutral** (-0.5 to 0.5), **consistent** (>0.5)
  - Most scores should be fairly neutral.



		Employment Rate		
		Full Employment	Normal Employment	Low Employment
Economy	High growth	1.5	0.0	-0.5
	Moderate growth	-0.5	1.0	0.0
	Negative growth	-2.0	-0.5	1.0





# Arctic Futures 2050

Scenarios as a Tool for Collaboration Among Scientists and Policymakers

Arctic Futures 2050 Website:  
**[www.searcharcticsscience.org/arctic-2050](http://www.searcharcticsscience.org/arctic-2050)**

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Marc Müller-Stoffels  
marc@denamics.com



## Appendix C: Plausibility Scores

The following three pages show the combined individual plausibility scores and their analysis. Individual survey inputs are hidden.

Key Factor	Future Projections	Mean P-Score	P-Score Std. Dev	Min. P-Score	Max. P-Score	Delta Max-Min	Count Zeros
A. Climate Change - Cryosphere	1. Slowing the melt and thaw in the Arctic	1.045	0.21	1	2	1	0
	2. Gradual increase in cryosphere loss	3.045	1.13	1	5	4	0
	3. Rapid melt and thaw of the cryosphere	3.818	0.73	3	5	2	0
	4. The Vanishing Cryosphere	2.091	1.11	1	5	4	0
	Plausibility score check sum	10.000					
B. Climate Change - Atmosphere	1. Early decline in emissions	1.136	0.56	0	3	3	1
	2. Mid-century decline in emissions	3.000	0.98	1	4	3	0
	3. Late century decline in emissions	3.409	0.73	2	5	3	0
	4. Rising emissions throughout the century	2.455	0.96	1	4	3	0
	Plausibility score check sum	10.000					
C. Climate Change - Terrestrial Biosphere	1. Terrestrial biosphere stabilization	1.318	0.72	1	3	2	0
	2. Mid-century decline in emissions	2.773	0.97	1	4	3	0
	3. Late century decline in emissions	3.364	0.66	2	4	2	0
	4. Rising emissions throughout the century	2.545	1.14	1	5	4	0
	Plausibility score check sum	10.000					
D. Marine Systems Change	1. Early decline in emissions	1.273	0.63	1	3	2	0
	2. Mid-century decline in emissions	2.818	1.05	1	5	4	0
	3. Late century decline in emissions	3.455	0.74	2	5	3	0
	4. Rising emissions throughout the century	2.455	1.22	1	5	4	0
	Plausibility score check sum	10.000					
E. Arctic Regional Collaboration	1. Northern harmony	1.864	0.94	1	4	3	0
	2. Business as usual	3.864	1.08	1	5	4	0
	3. Divided Arctic	2.682	1.04	1	6	5	0
	4. Arctic for the Arctic	1.591	0.80	0	4	4	1
	Plausibility score check sum	10.000					

Key Factor	Future Projections	Mean P-Score	P-Score Std. Dev	Min. P-Score	Max. P-Score	Delta Max-Min	Count Zeros
F. Arctic Regional Security	1. Global Harmony	1.091	0.68	0	2	2	4
	2. Business as usual	3.182	0.96	1	5	4	0
	3. A dangerous world	2.273	0.88	1	4	3	0
	4. Fortress Arctic	1.500	0.80	0	3	3	2
	5. Arctic Insecurity	1.955	0.84	1	4	3	0
	Plausibility score check sum	10.000					
G. Global Policy	1. Status Quo	3.727	0.88	2	5	3	0
	2. Global policy globalizes arctic concerns	2.591	0.91	1	5	4	0
	3. The Arctic Council as government	1.318	0.48	1	2	1	0
	4. Breakdown of international cooperation	2.364	0.85	1	4	3	0
	Plausibility score check sum	10.000					
H. International Security	1. Global harmonization	1.545	0.91	0	4	4	1
	2. International security as a luxury	3.409	0.91	2	6	4	0
	3. A hot, dry, dangerous place	3.136	1.17	1	6	5	0
	4. Arctic security through isolation	1.909	0.81	1	4	3	0
	Plausibility score check sum	10.000					
I. Status of Arctic Indigenous Peoples	1. Autonomy for Indigenous governments	1.591	0.67	1	3	2	0
	2. Greater self-determination in the Arctic	2.636	0.90	1	4	3	0
	3. Arctic status quo	3.455	0.91	1	5	4	0
	4. Decline of Indigenous status in the arctic	2.318	1.17	1	5	4	0
	Plausibility score check sum	10.000					
J. Access to Markets	1. Arctic development boom	2.864	1.17	1	5	4	0
	2. Local planning for sustainable markets	2.136	0.64	1	4	3	0
	3. Market gloom	1.955	0.72	1	3	2	0
	4. Status quo	3.045	1.17	1	5	4	0
	Plausibility score check sum	10.000					



Key Factor	Future Projections	Mean P-Score	P-Score Std. Dev	Min. P-Score	Max. P-Score	Delta Max-Min	Count Zeros
K. Economic Development: Renewable Resources	1. Forgotten Arctic	2.864	1.13	1	6	5	0
	2. Resource and revenue extracted	4.364	1.00	3	6	3	0
	3. Arctic Development Bank	2.773	1.15	1	5	4	0
	Plausibility score check sum	10.000					
L. Economic Development: Non-renewable Resources	1. Cold, dark and expensive	2.818	1.18	1	6	5	0
	2. Collaboration, moderation and consultation	2.773	1.19	1	5	4	0
	3. Drill, dig and remove	4.409	1.30	2	8	6	0
	Plausibility score check sum	10.000					
M. Arctic Energy Systems	1. Energy independence	2.364	0.95	1	4	3	0
	2. Infrastructure offensive	2.182	0.80	1	4	3	0
	3. Unorganized diversity in a boom-bust economy	3.318	1.36	1	7	6	0
	4. Our fossil future	2.136	0.99	1	4	3	0
	Plausibility score check sum	10.000					
N. Public Health	1. Resilient arctic public health	2.000	0.93	1	4	3	0
	2. Public health for those who can pay for it	3.636	1.00	2	6	4	0
	3. Public health in decline	2.500	0.74	1	4	3	0
	4. The public health crisis	1.864	0.83	1	4	3	0
	Plausibility score check sum	10.000					
O. Community Sustainability	1. Arctic Adaptation Delivers Self-Reliance	2.227	1.02	1	4	3	0
	2. Workforce Development with Reactionary Mitigation	2.591	0.91	1	5	4	0
	3. Outmigration Outpaces Need for Adaptation	2.364	0.95	1	4	3	0
	4. Community-specific Pockets of Adaptation	2.818	1.18	1	6	5	0
	Plausibility score check sum	10.000					
P. Science Advancement and Communication	1. Scientist rekindle public trust	2.045	0.84	1	4	3	0
	2. Citizen-science revolution	1.955	0.95	0	3	3	1
	3. Scientists as global mechanics	1.773	0.97	1	4	3	0
	4. Corporatocracy declares war on science	1.909	0.97	0	4	4	1
	5. Knowledge co-production	2.318	1.13	0	5	5	1
	Plausibility score check sum	10.000					

## Appendix D: Consistency Matrix

The following 10 pages show the final consistency matrix. Total inconsistencies are highlighted in red.

	Climate Change - Cryosphere/Slowing the melt and thaw in the Arctic	Climate Change - Cryosphere/Gradual increase in cryosphere loss	Climate Change - Cryosphere/Rapid melt and thaw of the cryosphere	Climate Change - Cryosphere/The vanishing cryosphere	Climate Change - Atmosphere/Early decline in emissions	Climate Change - Atmosphere/Mid-century decline in emissions	Climate Change - Atmosphere/Late century decline in emissions	Climate Change - Atmosphere/Rising emissions throughout the century	Climate Change - Terrestrial Biosphere/Terrestrial biosphere stabilization	Climate Change - Terrestrial Biosphere/Mid-century decline in emissions	Climate Change - Terrestrial Biosphere/Late century decline in emissions	Climate Change - Terrestrial Biosphere/Rising emissions throughout the century
Climate Change - Cryosphere/Slowing the melt and thaw in the Arctic												
Climate Change - Cryosphere/Gradual increase in cryosphere loss												
Climate Change - Cryosphere/Rapid melt and thaw of the cryosphere												
Climate Change - Cryosphere/The vanishing cryosphere												
Climate Change - Atmosphere/Early decline in emissions	1.67	0.08	-1.00	-1.67								
Climate Change - Atmosphere/Mid-century decline in emissions	-0.33	1.83	-0.08	-0.83								
Climate Change - Atmosphere/Late century decline in emissions	-1.33	0.08	1.75	0.17								
Climate Change - Atmosphere/Rising emissions throughout the century	-2.00	-1.25	0.58	2.00								
Climate Change - Terrestrial Biosphere/Terrestrial biosphere stabilization	1.75	0.08	-1.00	-1.75	1.92	0.08	-1.00	-1.92				
Climate Change - Terrestrial Biosphere/Mid-century decline in emissions	0.08	1.50	0.08	-0.83	-0.08	1.92	0.08	-0.92				
Climate Change - Terrestrial Biosphere/Late century decline in emissions	-1.17	-0.17	1.67	0.25	-1.00	-0.08	1.92	0.17				
Climate Change - Terrestrial Biosphere/Rising emissions throughout the century	-2.00	-1.00	0.25	2.00	-2.00	-1.00	0.00	2.00				
Marine Systems Change/Early decline in emissions	1.92	0.25	-0.92	-1.92	1.92	0.08	-0.92	-1.92	2.00	0.00	-1.00	-2.00
Marine Systems Change/Mid-century decline in emissions	0.00	1.42	0.00	-0.67	0.00	1.92	0.00	-1.00	0.00	2.00	0.00	-1.00
Marine Systems Change/Late century decline in emissions	-1.08	0.00	1.50	0.25	-1.00	0.00	1.92	0.00	-1.00	0.00	2.00	0.00
Marine Systems Change/Rising emissions throughout the century	-2.00	-0.92	0.50	2.00	-2.00	-1.00	0.00	1.92	-2.00	-1.00	0.00	2.00
Arctic Regional Collaboration/Northern Harmony	0.58	0.00	-0.50	-0.50	0.50	0.00	-0.50	-0.50	0.50	0.00	-0.50	-0.50
Arctic Regional Collaboration/Business as usual	-0.33	0.17	0.42	0.33	-0.50	0.00	0.50	0.50	-0.50	0.00	0.50	0.50
Arctic Regional Collaboration/Divided Arctic	-0.50	-0.50	0.50	0.50	-0.50	-0.50	0.50	0.50	-0.50	-0.50	0.50	0.50
Arctic Regional Collaboration/Arctic for the Arctic	0.42	0.08	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Arctic Regional Security/Global harmony	0.42	0.08	-0.50	-0.50	0.50	0.00	-0.50	-0.50	0.50	0.00	-0.50	-0.50

Arctic Regional Security/Business as usual	-0.50	0.17	0.33	0.33	-0.50	0.00	0.50	0.50	-0.50	0.00	0.50	0.50
Arctic Regional Security/A dangerous world	-0.58	-0.33	0.50	0.50	-0.50	-0.50	0.50	0.50	-0.50	-0.50	0.50	0.50
Arctic Regional Security/Fortress Arctic	-0.17	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.08	-0.17
Arctic Regional Security/Arctic Insecurity	-0.50	-0.50	0.50	0.50	-0.50	-0.50	0.50	0.50	-0.50	-0.50	0.50	0.50
Global Policy/Status Quo	-0.67	-0.33	0.50	0.75	-0.92	-0.25	0.50	0.75	-0.75	-0.42	0.42	0.83
Global Policy/Global policy globalizes Arctic concerns	0.50	0.92	-0.08	-0.83	0.50	1.00	0.00	-1.00	0.50	0.83	0.00	-1.00
Global Policy/The Arctic Council as government	0.08	0.08	-0.08	-0.08	0.00	0.00	-0.08	-0.08	0.00	0.00	0.00	0.00
Global Policy/Breakdown of international cooperation	-0.50	-0.42	0.17	0.58	-0.50	-0.50	0.00	0.50	-0.50	-0.50	0.00	0.50
International Security/Global Harmonization	0.08	0.42	0.08	-0.08	0.08	0.50	-0.08	-0.17	0.08	0.42	-0.08	-0.17
International Security/International security as a luxury	-0.50	0.08	0.50	0.50	-0.50	0.00	0.50	0.50	-0.50	0.00	0.50	0.50
International Security/A hot, dry, dangerous place	-1.50	-0.50	0.08	1.00	-1.50	-0.50	0.00	1.00	-1.50	-0.50	0.00	1.00
International Security/Arctic security through isolation	-0.08	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Status of Arctic Indigenous Peoples/Autonomy for indigenous government	0.00	0.00	0.00	0.00	0.00	0.00	-0.08	-0.08	0.00	0.00	-0.08	-0.17
Status of Arctic Indigenous Peoples/Greater self-determination in the Arctic	0.08	0.17	-0.25	-0.33	0.00	0.00	-0.50	-0.50	0.00	0.00	-0.50	-0.50
Status of Arctic Indigenous Peoples/Arctic status quo	0.08	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Status of Arctic Indigenous Peoples/Decline of indigenous status in the Arctic	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.08	0.17
Access to Markets/Arctic Development Boom	-0.92	-0.50	0.58	1.08	-1.00	-0.50	0.50	1.00	-1.00	0.50	0.50	1.00
Access to Markets/Local planning for sustainable markets	0.08	0.08	-0.08	-0.08	0.00	0.00	-0.08	-0.17	0.00	0.00	0.00	0.00
Access to Markets/Market gloom	0.00	0.00	0.00	-0.08	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Access to Markets/Status quo	-0.50	0.00	0.42	0.42	-0.50	0.00	0.50	0.50	-0.50	0.00	0.50	0.50
Economic Development: Renewable Resource Extraction/Forgotten Arctic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.08	0.00	0.00	0.00
Economic Development: Renewable Resource Extraction/Resources and revenue	0.25	0.42	0.08	0.00	0.50	0.50	0.00	0.00	0.50	0.50	0.00	0.00
Economic Development: Renewable Resource Extraction/Arctic development	0.25	0.42	0.17	0.08	0.50	0.50	0.00	0.00	0.50	0.50	0.00	0.00
Economic Development: Non-renewable Resource Extraction/Cold, dark, and dangerous	1.00	0.50	-0.08	-0.25	1.00	0.50	0.00	0.00	1.00	0.50	0.00	0.00
Economic Development: Non-renewable Resource Extraction/Collaboration	-0.08	0.08	0.00	0.00	0.00	0.00	-0.08	-0.08	0.00	0.00	-0.08	-0.17
Economic Development: Non-renewable Resource Extraction/Drill, dig, and burn	-0.58	0.00	0.50	0.58	-0.50	0.00	0.50	0.50	-0.50	0.00	0.50	0.50
Arctic Energy Systems/Energy independence	-0.08	0.08	-0.08	0.00	0.00	0.00	0.00	0.00	-0.08	0.00	0.00	0.00
Arctic Energy Systems/Infrastructure offensive	-0.25	0.42	0.08	-0.17	0.00	0.50	0.00	-0.50	-0.08	0.50	0.08	-0.33
Arctic Energy Systems/Unorganized diversity in a boom-bust economy	-0.08	-0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08
Arctic Energy Systems/Our fossil future	0.67	0.58	-0.42	-0.58	0.67	0.33	-0.33	-0.67	0.83	0.42	-0.33	-0.75
Public Health/Resilient Arctic public health	0.50	0.00	-0.17	-0.50	0.50	0.00	-0.08	-0.58	0.50	0.00	0.00	-0.50
Public Health/Public health for those who can pay for it	0.00	0.33	0.33	0.00	0.00	0.50	0.50	0.00	0.00	0.50	0.50	0.00
Public Health/Public health in decline	-0.50	0.00	0.50	1.00	-0.50	0.00	0.50	1.00	-0.50	0.00	0.50	1.00
Public Health/The public health crisis	-0.50	0.00	0.50	1.00	-0.50	0.00	0.50	1.00	-0.50	0.00	0.50	1.00
Community Sustainability/Arctic adaptation delivers self-reliance	0.08	0.00	0.00	0.00	0.08	0.08	-0.08	-0.08	0.08	0.08	-0.08	-0.17
Community Sustainability/Workforce development with reactionary mitigation	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00	-0.08	0.08	0.08	0.00
Community Sustainability/Outmigrations outpaces need for adaptation	0.00	0.00	0.08	0.08	-0.08	0.08	0.17	0.17	0.00	0.00	0.17	0.17
Community Sustainability/Community-specific pockets of adaptation	0.00	0.00	0.50	0.50	-0.08	0.00	0.50	0.50	0.00	0.00	0.50	0.50
Science Advancement and Communication/Scientists rekindle public trust	0.50	0.42	0.00	-0.42	0.50	0.50	-0.17	-0.50	0.50	0.50	0.00	-0.50
Science Advancement and Communication/Citizen-science revolution	0.17	0.08	0.00	-0.08	0.08	0.08	0.00	0.00	0.08	0.08	0.00	-0.08
Science Advancement and Communication/Scientists as global mechanics	-0.08	0.00	0.08	0.17	-0.08	0.00	0.08	-0.08	-0.08	0.08	0.08	-0.08
Science Advancement and Communication/Corporatocracy declares war on science	-1.00	-0.50	0.50	0.83	-1.00	-0.50	0.50	1.00	-1.00	-0.50	0.50	1.00
Science Advancement and Communication/Knowledge co-production	0.08	0.00	0.00	-0.17	0.00	0.08	0.00	0.00	0.08	0.08	0.00	-0.08
<b>Column Average</b>	-0.15	0.06	0.15	0.09	-0.12	0.06	0.13	0.07	-0.10	0.06	0.13	0.09
<b>Total Average</b>	0.05											

Marine Systems Change/Early decline in emissions							
Marine Systems Change/Mid-century decline in emissions							
Marine Systems Change/Late century decline in emissions							
Marine Systems Change/Rising emissions throughout the century							
Arctic Regional Collaboration/Northern Harmony							
Arctic Regional Collaboration/Business as usual							
Arctic Regional Collaboration/Divided Arctic							
Arctic Regional Collaboration/Arctic for the Arctic							
Arctic Regional Security/Global harmony							
Arctic Regional Security/Business as usual							
Arctic Regional Security/A dangerous world							
Arctic Regional Security/ Fortress Arctic							
Arctic Regional Security/Arctic Insecurity							
Global Policy/Status Quo							
Global Policy/Global policy globalizes Arctic concerns							
Global Policy/The Arctic Council as government							
Global Policy/Breakdown of international cooperation							
0.50	0.00	-0.50	-0.50				
-0.50	0.00	0.50	0.50				
-0.50	-0.50	0.50	0.50				
0.50	0.00	0.00	0.00				
0.50	0.00	-0.50	-0.50	1.50	-0.50	-1.00	-1.50

-0.50	0.00	0.50	0.50	-0.50	1.50	-0.50	-1.00										
-0.50	-0.50	0.50	0.67	-1.00	-0.50	1.50	-0.50										
0.00	0.00	0.00	-0.08	-1.50	-1.00	-0.50	1.50										
-0.50	-0.50	0.50	0.50	-1.50	-0.42	1.00	-1.00										
-1.00	-0.50	0.50	1.00	0.50	1.50	0.50	-0.50	-0.42	1.50	0.50	0.00	-1.00					
0.50	1.00	0.00	-1.00	0.58	-0.50	-0.50	-0.50	0.08	-0.08	-0.50	-0.50	-0.50					
0.00	0.00	0.00	0.00	1.50	-0.50	-1.50	1.00	1.42	0.00	-0.58	1.00	-1.50					
-0.50	-0.50	0.00	0.50	-1.50	-1.00	1.50	-1.00	-1.50	-0.50	0.50	-0.50	1.50					
0.00	0.50	0.00	0.00	1.50	-0.50	-1.00	-1.50	1.50	-0.50	-1.00	-1.00	-1.50	0.00	1.00	-0.42	-1.00	
-0.50	0.00	0.50	0.50	-1.00	-0.50	1.00	0.42	-1.00	1.00	0.50	-0.50	-0.50	0.83	0.00	0.00	0.00	0.00
-1.50	-0.50	0.00	1.00	0.00	-1.00	-0.92	0.50	-1.50	0.00	1.50	-1.00	0.50	0.50	-0.50	-1.00	1.00	0.00
0.00	0.00	0.00	0.00	-1.50	-0.50	-1.00	1.00	-1.50	0.00	0.50	0.50	-1.00	-0.50	-1.00	1.00	1.00	0.00
0.00	0.00	0.00	0.00	0.50	-0.50	-1.00	1.00	0.92	0.00	-1.00	-0.42	-1.00	0.00	0.00	0.50	-0.50	0.00
0.00	0.00	-0.50	-0.50	1.08	0.00	-0.58	1.08	1.50	0.50	-1.00	-0.50	-1.00	0.00	0.50	1.00	-0.50	0.00
0.00	0.00	0.00	0.00	-0.08	1.00	0.00	-0.50	0.50	1.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	-0.67	0.50	1.00	-0.50	-1.00	0.00	0.58	0.00	0.50	0.00	-0.50	-0.50	0.50	0.00
-1.00	-0.50	0.50	1.00	0.50	0.08	0.42	0.50	1.00	0.00	1.00	-0.42	0.42	0.00	0.50	0.00	-0.50	0.00
0.00	0.00	0.00	0.00	0.00	0.00	-0.50	0.50	1.00	0.00	-0.50	0.00	-1.00	0.00	0.50	0.50	-0.50	0.00
0.00	0.00	0.00	0.00	-0.50	0.50	0.50	-0.50	0.00	0.00	0.50	0.50	0.50	0.00	-0.50	0.00	0.00	0.50
-0.50	0.00	0.50	0.50	0.00	0.58	0.00	0.00	-0.50	0.50	0.50	0.50	0.92	0.50	0.00	0.00	0.00	0.50
-0.08	0.00	0.00	0.00	-0.50	0.00	0.50	0.33	-0.50	0.00	0.50	0.50	-0.50	0.50	0.00	0.00	0.00	0.50
0.50	0.50	0.00	0.00	0.00	0.50	0.17	-0.50	0.00	0.50	1.00	0.00	1.00	0.00	0.50	0.00	0.00	0.50
0.50	0.50	0.00	0.00	0.50	-0.08	-1.00	0.50	1.00	0.50	-0.50	1.00	-1.00	0.00	0.00	1.00	-0.50	0.00
1.00	0.50	0.00	0.00	-0.50	0.00	-0.50	-0.50	-0.50	0.00	-0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.58	0.00	-0.50	0.58	0.50	0.00	-0.50	0.00	-0.50	0.00	0.50	0.50	-0.50	0.00
-0.50	0.00	0.50	0.50	-0.50	0.08	0.50	0.00	-0.50	0.00	0.50	0.00	0.50	0.00	-0.08	-0.50	0.50	0.00
0.00	0.00	0.00	0.00	0.08	-0.50	-0.50	0.08	0.50	0.00	-0.50	0.50	-1.00	-0.50	0.50	0.50	-0.50	0.00
-0.08	0.50	0.00	-0.50	0.50	0.00	-0.50	0.50	0.00	0.00	0.50	1.00	-0.50	0.00	0.50	0.50	0.50	-0.50
0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	-0.50	0.00	0.50	0.00	1.00	0.50	0.00	0.00	0.00	0.50
0.75	0.42	-0.50	-1.00	-0.08	0.00	0.00	0.00	0.50	0.00	-1.00	0.00	-0.50	0.00	0.50	0.00	-0.50	0.00
0.50	0.00	-0.08	-0.58	0.50	-0.08	-0.50	0.50	0.50	0.00	0.00	0.00	-0.50	0.00	0.08	0.50	-0.50	0.00
0.00	0.50	0.50	0.00	0.00	0.50	0.00	0.08	0.00	0.50	0.50	0.50	0.50	0.08	0.00	0.00	0.00	0.00
-0.50	0.00	0.50	1.00	-0.08	0.08	0.00	0.00	-0.50	0.00	0.50	0.50	0.50	0.08	0.00	-0.50	0.50	0.00
-0.50	0.00	0.50	1.00	-0.08	0.00	0.50	0.00	-1.00	-0.50	0.50	0.50	1.00	0.00	-0.50	-0.50	0.50	0.00
0.08	0.08	0.00	0.00	0.58	0.08	-0.50	0.08	0.50	0.00	-0.50	0.00	-0.50	0.00	0.50	0.50	-0.50	0.00
-0.08	0.00	0.00	0.08	-0.50	0.08	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00
0.00	0.00	0.00	0.00	-0.50	0.08	0.50	-0.08	-0.50	0.08	0.50	0.00	0.50	0.00	-0.08	-0.50	0.50	0.00
0.08	0.08	0.50	0.50	-0.08	0.08	0.50	0.50	0.00	0.08	0.50	0.50	0.50	0.08	-0.08	0.00	0.00	0.50
0.50	0.50	0.00	-0.50	0.17	0.00	-0.08	0.17	0.50	0.00	0.00	0.00	0.00	0.00	0.50	0.08	0.08	-0.50
0.08	0.08	0.00	0.00	0.08	0.00	-0.50	0.08	0.50	0.00	-0.50	0.00	-0.50	0.00	0.08	0.08	0.08	0.00
-0.08	0.08	0.08	0.00	0.00	0.00	-0.17	0.00	0.00	0.00	0.50	0.50	0.08	0.08	0.33	0.00	0.00	0.00
-1.00	-0.50	0.50	1.00	-0.08	0.08	0.50	0.00	-0.50	0.08	0.08	0.00	0.50	0.08	-0.08	-0.08	-0.08	0.58
0.08	0.08	0.00	-0.08	0.50	0.00	0.00	0.08	0.50	0.00	-0.50	0.00	-0.50	0.00	0.50	0.50	-0.50	0.00
-0.09	0.03	0.11	0.13	-0.03	-0.01	-0.05	0.02	0.03	0.13	0.08	0.09	-0.10	0.09	0.12	0.09	0.02	0.02

International Security/Global Harmonization

International Security/International security as a luxury

International Security/A hot, dry, dangerous place

International Security/Arctic security through isolation

Status of Arctic Indigenous Peoples/Autonomy for indigenous governments

Status of Arctic Indigenous Peoples/Greater self-determination in the Arctic

Status of Arctic Indigenous Peoples/Arctic status quo

Status of Arctic Indigenous Peoples/Decline of indigenous status in the Arctic

Access to Markets/Arctic Development Boom

Access to Markets/Local planning for sustainable markets

Access to Markets/Market gloom

Access to Markets/Status quo

Economic Development: Renewable Resource Extraction/Forgotten Arctic

Economic Development: Renewable Resource Extraction/Resources and reven

Economic Development: Renewable Resource Extraction/Arctic development I

Economic Development: Non-renewable Resource Extraction/Cold, dark, and ex

Economic Development: Non-renewable Resource Extraction/Collaboration, mc

0.50	0.00	-1.00	0.50														
1.00	0.00	-0.50	1.00														
0.00	0.50	0.00	0.00														
-0.50	0.00	0.50	-0.50														
0.00	0.50	-0.50	0.00	0.00	0.00	0.50	0.08										
0.50	0.00	-0.50	0.00	0.58	0.50	0.00	-0.50										
-0.50	0.00	0.50	0.50	-0.50	0.00	0.00	0.50										
0.00	0.50	0.00	0.00	-0.08	0.00	0.50	0.00										
0.00	0.00	-0.50	0.50	0.00	0.00	0.00	0.00	-1.50	-0.08	0.50	0.08						
0.00	0.08	0.50	-0.50	-0.08	0.00	0.50	0.08	0.50	-1.00	0.00	0.00						
0.50	0.00	-0.50	0.50	0.58	0.58	0.00	-0.58	1.00	1.50	-0.50	-0.50						
0.00	0.00	-0.50	0.50	0.00	0.00	0.00	0.00	-1.42	-0.08	1.00	0.08	0.50	-0.08	-0.50			
0.50	0.00	-0.50	0.00	0.50	0.50	0.00	-0.08	0.50	1.00	0.00	-0.50	-0.08	-0.50	0.50			
0.00	0.08	0.50	-0.50	-0.58	-0.08	0.08	0.50	1.00	-0.50	-0.50	0.50	-0.50	0.58	0.00			
0.17	-0.08	-0.50	-0.08	0.50	0.08	0.00	-0.50	0.50	1.00	-0.50	-0.08	-0.50	-0.50	1.50	-0.50	0.50	
0.50	0.50	0.00	-0.50	0.00	0.00	0.50	-0.50	1.00	0.50	-1.00	0.00	-0.50	0.00	1.00	-0.50	0.50	
0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.50	-0.33	-1.00	0.50	0.17	0.00	1.00	-0.50	0.00	-0.50	
0.50	0.00	-0.50	0.00	0.00	0.00	0.00	0.00	-0.50	-0.08	0.08	0.08	0.50	0.00	0.00	0.50	0.00	
0.50	0.00	-0.50	0.00	0.67	0.67	0.00	-0.58	0.00	0.50	-0.50	0.00	-0.08	-0.50	1.00	-0.50	0.50	
0.00	0.00	0.50	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.50	0.08	0.08	-0.08	0.00	-0.08	
0.00	0.00	0.50	0.00	-0.50	0.00	0.50	0.50	0.00	-0.50	0.50	0.00	0.50	0.50	-0.50	0.50	-0.50	
-0.50	0.00	0.50	-0.50	-1.00	-0.50	0.00	0.50	-0.50	-1.00	1.00	-0.50	0.50	0.00	-1.00	0.50	-0.50	
0.50	0.08	-0.50	0.50	1.50	1.00	-0.08	-1.00	0.08	1.00	-0.92	-0.50	-0.08	-0.08	1.00	-0.08	0.50	
0.00	0.08	0.00	0.00	0.00	0.50	0.50	-0.33	0.58	0.50	0.00	0.08	0.08	0.50	0.00	0.50	0.00	
-0.50	0.00	0.50	0.00	-1.00	-0.50	0.50	1.00	-0.50	-0.08	1.00	0.50	0.50	0.00	-0.50	0.50	-0.50	
0.00	0.50	0.50	0.08	0.00	0.08	0.08	0.42	-0.83	-0.92	1.00	0.50	0.50	0.50	-0.50	0.50	0.00	
0.50	0.00	-0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50	-0.50	0.00	0.00	0.00	0.50	0.00	0.50	
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	-0.08	0.08	-0.08	0.08	
0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.08	0.08	0.08	0.50	0.00	0.08	-0.08	
0.00	0.00	0.50	0.00	-0.50	-0.50	0.00	0.50	0.50	-0.50	0.50	0.08	0.08	0.58	-0.58	0.08	-0.50	
0.50	0.00	-0.50	-0.50	0.50	0.67	0.00	-0.50	-0.50	0.58	0.00	0.00	-0.08	-0.50	0.58	-0.08	0.50	
0.15	0.10	-0.06	0.03	0.02	0.13	0.15	0.02	0.00	0.08	0.08	0.03	0.08	0.10	0.10	0.08	0.02	



Economic Development: Non-renewable Resource Extraction/Drill, dig, and rene

Arctic Energy Systems/Energy independence

Arctic Energy Systems/Infrastructure offensive

Arctic Energy Systems/Unorganized diversity in a boom-bust economy

Arctic Energy Systems/Our fossil future

Public Health/Resilient Arctic public health

Public Health/Public health for those who can pay for it

Public Health/Public health in decline

Public Health/The public health crisis

Community Sustainability/Arctic adaptation delivers self-reliance

Community Sustainability/Workforce development with reactionary mitigation

Community Sustainability/Outmigrations outpaces need for adaptation

Community Sustainability/Community-specific pockets of adaptation

Science Advancement and Communication/Scientists rekindle public trust

Science Advancement and Communication/Citizen-science revolution

Science Advancement and Communication/Scientists as global mechanics

Science Advancement and Communication/Corporatocracy declares war on sc

-0.50													
0.50													
0.50													
-0.50													
-0.50	0.50	0.50	-0.50	-0.08									
0.50	0.00	0.08	0.50	0.00									
0.00	-0.08	0.17	0.50	0.08									
0.00	-0.50	0.08	0.08	0.08									
-0.50	0.58	0.00	-0.50	-0.50	1.00	0.00	-0.50	-1.00					
0.50	0.08	0.58	0.17	0.17	0.00	0.08	0.08	0.00					
0.00	-0.50	-0.50	0.50	0.08	-0.58	0.00	0.50	0.17					
0.50	-0.50	0.00	0.50	0.08	-0.50	0.50	0.50	0.50					
0.00	0.08	0.00	0.00	0.50	0.50	0.00	0.00	-0.50	0.50	0.00	0.00	0.00	0.00
-0.08	0.00	0.00	0.00	0.00	0.08	0.08	0.00	-0.50	0.08	0.00	-0.08	0.08	0.08
0.50	0.00	0.08	0.08	0.00	0.00	0.08	0.00	0.08	-0.08	0.08	0.00	0.00	0.00
0.50	0.00	0.08	0.50	0.08	-0.50	0.08	0.08	0.58	-0.08	0.08	0.08	0.08	0.00
-0.08	0.50	0.00	0.00	0.00	0.67	0.50	-0.08	-0.50	0.67	-0.08	-0.08	-0.08	0.08
0.08	0.01	0.08	0.14	0.04	0.07	0.15	0.06	-0.13	0.22	0.02	-0.02	0.03	0.03





# Climate Change - Cryosphere

## Key Factor A - Environment Theme

Importance	23.3	Uncertainty	17.0	Combined	40.3
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### Contributing Key Factors:

Pace of Greenland ice sheet and glacier melt	7	8	15
Lake ice	0	1	1
State of sea ice	10	4	14
Climate change	5.3	2.3	7.7
Climate	0.0	1.0	1.0
Environmental change- pace, severity & response	0.7	0.3	1.0
Environment	0.3	0.3	0.7

## Key Factor Description

The frozen parts of the earth system—the cryosphere—comprise sea ice, freshwater ice (including snow cover, lakes, rivers, glaciers, and ice sheets), and permafrost. The cryosphere is especially responsive to climate change as the difference between a solid and liquid state is determined by a small temperature change. Moreover, the change from frozen to unfrozen triggers substantial additional environmental changes, including magnification of climate warming. The high reflectivity of snow-covered sea ice—one of the most reflective natural materials—limits the sun’s heating of the Earth. Over the past 40 years, however, the area of the Arctic Ocean covered by seasonal sea ice has decreased by 50% and more sunlight is absorbed by the Arctic Ocean rather than being reflected back to space. The additional warming melts yet more sea ice, further reducing reflectivity, and bringing about even more warming. Largely due to this loss in reflectivity, temperatures in the Arctic are increasing at two to three times the rate of the globe as a whole. Global warming due to diminished reflectivity of the Arctic Ocean is equivalent to 25% of the warming due to increased greenhouse gas concentrations.

Warming temperatures and decreased reflectivity are also melting land ice at an accelerating rate. Reflectivity of the Greenland ice sheet has decreased by several percent in this century as soot, dust, and biologic material have collected on the surface and as the warming snow has become coarser. A 15% decrease in reflectivity will double the amount of solar energy absorbed. Additional melting is promoted by warming ocean waters and by warming air temperatures. Surface melt is becoming increasingly important for Greenland and other Arctic land ice areas. Though surface melt can vary substantially year to year, more of it is expected overall in the future. Currently, Arctic land ice contributes about 70% of the roughly 735 billion tons of glacial ice melting each year. That Arctic melt water raises sea level an additional 1.4 mm annually, contributing to coastal flooding and erosion, groundwater infiltration, and wetlands degradation. Since 2000, the rate of ice loss has increased five-fold from the Greenland ice sheet and nearly doubled from glaciers in the Gulf of Alaska region. With continued warming of the planet, roughly 1 meter of additional sea level rise due to Arctic land ice loss is probable by 2100. Climate warming also is accelerated by thawing permafrost, soil that remains frozen for at least two consecutive years. Nearly 25% of the northern hemisphere land mass is underlain by permafrost, but the extent and depth of permafrost are diminishing. As the frozen ground thaws, soil microbes become active and break down the remains of plants and animals releasing carbon dioxide and methane. Release of just a fraction of the 1,330-1,580 billion tons of permafrost carbon dioxide and methane (almost twice as much carbon as currently contained in the atmosphere) would significantly increase the rate of global climate warming and raise the possibility of surprises that would further accelerate climate impacts on sea-level rise, extreme weather, droughts, and agriculture. Eventually, carbon emitted from thawing permafrost will likely amplify warming caused by fossil fuel emissions.

## Future Projections

### FP1: Slowing the Melt and Thaw in the Arctic

An early decline in greenhouse gas emissions significantly slows melt of ice and thaw of permafrost. Changes in sea ice, land ice, and permafrost are driven primarily by temperature, which, even with the early decline in emissions is still expected to increase approximately 2-3°C (4-5°F) in the Arctic region by 2100. These projections are consistent with a Representative Concentration Pathway (RCP 2.6) in which greenhouse gas emissions peak between 2010-2020 and then decline substantially. Winter sea ice remains thinner than it was forty years ago, but continues to extend over much of the Arctic Ocean and marginal seas. While still significantly lower than the minima from previous millenia, summer sea ice stabilizes to cover well above 1 million km<sup>2</sup>, even at the summer minima. The sea ice ecosystem remains intact with minimal loss of species and continues to support subsistence harvests with modest changes. Reductions in land ice and permafrost, while still significant, remain below the worst case scenarios. Land ice volume in the Arctic continues to decline at rates consistent with a reduction by volume of 15% to 55% by 2100. The Arctic's contribution to sea level rise is slow

enough to allow effective mitigation globally. Permafrost declines at rates consistent with a 37% of area reduction by 2100. The rate of carbon emissions from thawing permafrost adds significantly to overall climate warming but does not result in surprises that further accelerate impacts on sea-level rise, extreme weather, droughts, and agriculture.

**Early indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 8%, with some sea ice cover remaining year-round
- Renewed international cooperation in reducing emissions.
- Emissions begin decreasing before 2030 and are untrack to reach zero by 2070

## FP2: Gradual Increase in Cryosphere Loss

These cryospheric changes are consistent with RCP 4.5 in which the global temperatures increase approximately 1.8°C (3.2°F) by 2100. Arctic temperatures, however, would increase even more, by approximately 7°C (12.6°F) in fall months and 3°C (5.4°F) in spring months. Sea ice thickness continues to decline dramatically, and reduced snow and ice cover further decrease reflectivity. Summer ice conditions are increasingly hard to predict posing hazards to hunters and ship traffic. Year-to-year variability in ice conditions increases limiting the utility of forecasts of ice conditions on time scales useful to shippers. Years of especially low ice select against ice-dependent species further threatening their persistence. Combined with diminishing ice cover, increased ocean temperatures precipitate ecosystem shifts changing the compositions and timing of subsistence and commercial harvests. Melt rates for Arctic land ice increase and, with them, overall rates of sea level rise also increase. Sea level rise is higher in low latitudes than in the Arctic as the decreased mass of land ice reduces gravitational pull on the surrounding ocean. Permafrost declines at rates expected to exceed a 37% reduction of area by 2100. The rate of carbon emissions from thawing permafrost adds significantly to overall climate warming, and it is increasingly possible that we will observe climate surprises that further accelerate impacts on sea-level rise, extreme weather, droughts, and agriculture.

**Early Indicators:**

- Increasing occurrence of September minimum sea ice cover below 1 million km<sup>2</sup>; by mid-century, 50% probability each year
- Gradual progress in international climate negotiations.

- Decreased emissions beginning in 2040.

### FP3: Rapid Melt and Thaw of the Cryosphere

Rapid increases in melt and thaw rates are consistent with RCP 6.0 in which greenhouse gas emissions peak around 2080, global temperatures increase approximately 2.2°C (4.0°F) by 2100, and Arctic temperatures increase more than 7°C (12.6°F) in fall months and 3°C (5.4°F) in spring months. Sea ice in winter is thin and nearly absent in summer in the Arctic Ocean leading to dramatic shifts in the ecosystem and food security. Populations dependent on sea ice are declining dramatically, and some are in danger of extinction. Species important to subsistence harvest are less available due to diminished populations and reduced access. Populations of some species dependent on sea ice are declining, and some are in danger of extinction. As those populations decline, they are less and less available for subsistence harvests. Rapid melting of Arctic land ice freshens waters around Greenland disrupting the marine ecosystem while opening up new land areas to mineral development and other economic opportunities. The Arctic contribution to sea level rise substantially impacts infrastructure, especially in lower latitudes. Rapidly thawing permafrost adds substantially to the atmosphere's greenhouse gas concentrations and planetary warming. Infrastructure over much of the Arctic landscape experiences expensive damage, and surface travel is greatly restricted.

#### **Early Indicators:**

- Year round ice loss with some possibility of September ice free summer conditions
- Late century progress in international climate negotiations.
- Increasing emissions through at least 2050.
- Large scale ecosystem changes in the Arctic.

### FP4: The Vanishing Cryosphere

Arctic temperatures, amplified by the loss of the reflectivity 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. Summers with less than 1 million km<sup>2</sup> of the Arctic Ocean covered by sea ice are the norm. Small glaciers are disappearing, and the Greenland Ice Sheet is melting rapidly. Overall, Arctic land ice is headed for a 35 to 85% reduction in its cryosphere by 2100. Ecological impacts of ocean freshening around Greenland are pronounced. For example, species availability and timing are dramatically affected. The rapidly warming region sees trade-offs. For example, economic gains from newly opened land and sea routes are offset to some extent by the costs of increased flooding and rapid disappearance of coastal regions. Landscapes are experiencing severe changes with much of the near-surface permafrost thawing and on track for a projected loss of over 81% of area by 2100. Infrastructure damage greatly increases the cost



of living in Arctic communities. Greenhouse gas emissions from northern soils substantially add to the warming attributed to fossil fuel emissions.

#### **Early Indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 48%
- Lack of progress in international climate negotiations.
- Increasing global emissions.
- Large scale ecosystem changes in the Arctic.

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# Climate Change - Atmosphere

## Key Factor B - Environment Theme

Importance	26.3	Uncertainty	14	Combined	40.3
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### Contributing Key Factors:

Black carbon	1	0	1
Storm activity	5	3	8
Pace of greenhouse gas emissions globally	11	5	16
Greenhouse gas emissions	2	2	4
Temperature	1	0	1
Climate change	5.3	2.3	7.7
Climate	0.0	1.0	1.0
Environmental change - pace, severity & response	0.7	0.3	1.0
Environment	0.3	0.3	0.7

## Key Factor Description

Greenhouse gases, including carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>) absorb then re-emit energy back to Earth, similar to the way heat is trapped by a blanket. Without atmospheric greenhouse gases, the Earth's temperatures would be too extreme to support life as we know it. Since the onset of the industrial revolution, however, emissions from the burning of fossil fuels increased concentrations of CO<sub>2</sub> by more than 40%—from 280 parts per million (ppm) to over 400 ppm—driving global warming at an unprecedented rate. A previous natural warming event 56,000,000 years ago occurred over a 100,000-year period and drove many extinctions. Today's warming is 10 times as rapid as that previous event. Approximately 0.7 Gigatons of CO<sub>2</sub> were emitted to the global atmosphere each year between 2005 and 2014, an annual increase of about 2%. Emissions decreased by about 0.16% in 2014-2015 and increased by about 0.34% in 2015-2016 period. Shifts from coal burning to other energy sources accounted for a decrease in CO<sub>2</sub> emissions in the United States, Japan, in Russia in 2016. India, on the other hand, increased its emissions in 2016, while emissions in China, the European Union, and other G20

countries stayed about the same. After CO<sub>2</sub>, CH<sub>4</sub> is the second greatest contribution to anthropogenic greenhouse gas emissions, with major sources being the burning of fossil fuels (25%), cattle (23%), and rice (10%).

Since 1880, the global temperature has risen about 1.7°F, with the fastest warming after 1970. This warming has not been uniform, however, and regional differences in atmospheric temperature are a major force in driving atmospheric circulations. In the Arctic, temperatures have been increasing at twice the rate of the global average. Contributing to this “Arctic amplification” is a reduction in reflectivity of solar energy, as the area covered by snow and ice diminishes. Ice loss also allows for additional evaporation from the ocean, which increases water vapor in the Arctic atmosphere – another greenhouse gas. Compounding Arctic amplification are decreasing summer and increasing winter cloudiness as well as heat escaping from the newly sea-ice free ocean into the atmosphere.

The strength of the westerly winds of the polar jet stream is proportional to the temperature difference between the atmosphere in the Arctic and in mid-latitudes. Because the Arctic is warming at more than twice the global average rate, the temperature difference is decreasing and, in turn, slowing the jet stream. As it slows, the jet stream tends to take a more meandering path, giving rise to increasingly persistent and unusual weather around the northern hemisphere. As warming temperatures melt sea ice, more of the Arctic Ocean is exposed to solar warming in summer. In the autumn, some of that heat is released back into the atmosphere, further decreasing the latitudinal temperature difference and magnifying the meanders of the jet stream. Large north-south jetstream waves contributed to a recent prolonged drought in California and to southward flow of Arctic cold in to the eastern United States in recent winters. A similar ridge over eastern Europe – intensified by sea-ice loss in the Barents/Kara sea – contributed to cold winters in central and eastern Asia.

The warmer atmosphere tends to increase the intensity of storms. Much of the increased heat trapped by greenhouse gases is absorbed by the ocean. The warmer ocean intensifies both tropical and extra-tropical storms by supplying additional heat and moisture. Diminishing Arctic sea ice contributes further to storm intensity by replacing the bright surface of ice—which reflects most of the sun’s energy to space—with a darker surface of liquid water, which absorbs most of the sun’s energy. The loss of reflective sea ice increases the warming caused by greenhouse gases by an additional 25%.

Combustion of fossil fuels and biomass also produces black carbon (soot), which absorbs additional solar energy in the atmosphere and darkens snow and ice, both of which exacerbate warming. In part because black carbon is spread widely in the atmosphere, its contribution to global warming is second in strength to CO<sub>2</sub> emissions. In high-altitude areas, e.g., the Himalayas, black carbon may contribute as much to melting snow and glaciers as does CO<sub>2</sub>-induced warming.

# Future Projections

## FP1: Early Decline in Emissions

Strong international cooperation leads to a 70% reduction in greenhouse gas emissions by 2050, and the increased heating associated with greenhouse gases relative to the pre-industrial climate in 2100 equals +2.6 watts/meter<sup>2</sup> (Representative Concentration Pathway 2.6). 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), triggering substantial ecological, economic, and social impacts.

### **Early indicators:**

- Renewed international cooperation in reducing emissions.
- Emissions begin decreasing before 2030 and approach zero by 2070.
- Reduced losses from extreme weather events.

## FP2: Mid-Century Decline in Emissions

International action begins to reduce emissions only after 2040, and the amount of heat trapped by greenhouse gases in 2100 equals +4.5 watts/meter<sup>2</sup> (relative to pre-industrial levels, RCP 4.5). Global temperatures increase approximately 1.8°C (3.2°F) by 2100, and mitigation is managed at substantial cost. Arctic temperatures increase approximately 7°C (12.6°F) in fall months and 3°C (5.4°F) in spring months. Sea ice volume continues to decline dramatically, and reduced snow and ice cover further decreases reflectivity. Increased ocean temperatures precipitate ecosystem changes with impacts on subsistence and commercial harvests.

### **Early Indicators:**

- Gradual progress in international climate negotiations.
- CO<sub>2</sub> emissions below current levels by 2070 and are about twice pre-industrial levels by 2100.
- Reduced losses from extreme weather events.

## FP3: Late Century Decline in Emissions

International action to reduce emissions is delayed until 2080, and the amount of heat trapped by greenhouse gases in 2100 equals +6.0 watts/meter<sup>2</sup> (relative to pre-industrial levels, RCP 6.0). Global temperatures increase approximately 2.2°C (4.0°F) by 2100, and efforts to mitigate the impacts of warming challenge most economies. Arctic temperatures increase more than 7°C (12.6°F) in fall months and 3°C (5.4°F) in spring months. Sea ice in winter is thin and nearly absent in summer in the Arctic Ocean, leading to dramatic shifts in the ecosystem and uncertainties in food security.

### Early Indicators:

- Late century progress in international climate negotiations.
- Increasing emissions through at least 2050.
- Large scale ecosystem changes in the Arctic.

## FP4: Rising Emissions Throughout the Century

International climate negotiations fail to arrest the rise in emissions, and the amount of heat trapped by greenhouse gases in 2100 equals +8.5 watts/meter<sup>2</sup> (relative to pre-industrial levels, RCP 8.5). Global temperatures increase approximately 3.7°C (6.7°F) by 2100, and large-scale ecological, economic, and social disruption challenges societies around the globe. Arctic temperatures increase 13°C (23.4°F) in fall months and 5°C (9.0°F) in spring months. Arctic ecosystems and economies undergo profound shifts to new states with substantial social disruption.

### Early Indicators:

- Lack of progress in international climate negotiations.
- Steadily increasing global emissions.
- Large-scale ecosystem changes in the Arctic.

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# Climate Change - Terrestrial Biosphere

## Key Factor C - Environment Theme

Importance	25.3	Uncertainty	50	Combined	75.3
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### Contributing Key Factors:

Ecosystem	0	5	5
Forest fires	1	0	1
Food chain	2	13	15
Fire	2	0	2
Species migrations	5	16	21
Ecosystem change	4	11	15
Coastal erosion/processes	5	1	6
Climate change	5.3	2.3	7.7
Climate	0.0	1.0	1.0
Environmental change- pace, severity & response	0.7	0.3	1.0
Environment	0.3	0.3	0.7

## Key Factor Description

Fewer species inhabit the Arctic than lower latitudes as a consequence of low temperatures and other environmental extremes. As the Arctic climate warms, biodiversity in the Arctic may increase, but particular changes in species are hard to predict. Species that could be favored as the Arctic environment changes depends on the combination of their tolerance for seasonal temperatures, thawing permafrost, extent and timing of snowmelt, moisture regimes, and fires. Interactions between organisms, including predation, competition, disease, and parasitism, will further determine the composition of future Arctic terrestrial communities. Longer growing seasons may favor reproduction and growth of some species currently limited by season length. Those species adapted to current seasonality may be disadvantaged. While the physical environment will influence the composition of the biological community, the converse also is

expected. For example, the northward advance of treeline will enhance warming by reducing surface reflectivity. The long-term balance of factors favoring and disfavoring productivity are unclear. Extreme events also impact animal populations. For example, snow events that decrease rodent populations can impact populations of their bird and mammal predators.

As Arctic environments become more hospitable, new species of hosts and parasites are extending their range to the Arctic bringing new diseases. Arctic species—including muskoxen, reindeer, Dall's sheep, moose, snowshoe hares, and Arctic foxes—have been impacted by novel parasites or increases in existing parasites.

Wildfires drive ecosystem change in boreal forests and likely will become important drivers in the tundra as the climate warms. Model simulations forecast that the size and frequency of wildfires will increase with warming air temperatures and favor shrub tundra over grass-dominated tundra and—to a lesser extent—favor forest expansion in this century. Those ecological changes will impact animals as well as plants in the Arctic. For example, lichens—important in the winter diet of caribou—require five or more decades to recover from wildfires. Models of future Arctic fires suggest increases in area burned in Arctic Alaska as much as 30% by mid century and over 50% by late century. Such fires could diminish winter range for caribou by 30% in coming decades. In addition to decrease nutritional forage, the fires could favor moose in competition with caribou. Such species substitution can lead to cascading impacts on other species and impact patterns of subsistence harvesting. Boreal and tundra wildfires also promote carbon release to the atmosphere and degradation of permafrost. Tundra fires may cause the ground to collapse in permafrost regions in the decade following the fires. A study of tundra fires in Alaska reported such ground collapse for 34% of burned areas but less than 1% of unburned tundra.

## Future Projections

### FP1: Terrestrial Biosphere Stabilization

An early decline in greenhouse gas emissions slows the rapid pace of terrestrial change. Plant biomass increases with rising temperature and atmospheric CO<sub>2</sub> are partially offset by increasing wildfires. Permafrost thaw alters habitats changing the species composition and releasing stored contaminants such as mercury. Atmospheric warming and seasonal shifts in rain and snow lead to increased shrubs and the movement north of species including landscape engineers such as beaver. Food security is threatened by decreased access to preferred game. The biome changes are largely driven by increasing temperatures expected under RCP 2.6 including global temperature increases of approximately 1 °C (1.8 °F) by 2100. Over the same period, Arctic temperatures increase approximately 2-3 °C (4-5 °F).

**Early indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 8%
- Renewed international cooperation in reducing emissions
- Emissions begin decreasing before 2030 and approach zero by 2070
- Increasing frequency and size of wildfires

## FP2: Mid-Century Decline in Emissions

Shifts in species composition and increased temperatures and atmospheric CO<sub>2</sub> lead to more frequent wildfires counteracting increases in plant biomass. Shrubs continue to expand in tundra, and treeline advances northward. The changing composition of species require Arctic people to change patterns of hunting and gathering. The biome changes are largely driven by increasing temperatures expected under RCP4.5 including global temperature increases of approximately 1.8 °C (3.2 °F) by 2100 and Arctic temperatures increases of approximately 7 °C (12.6 °F) in fall months and 3 °C (5.4 °F) in spring months.

**Early Indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 26%
- Gradual progress in international climate negotiations
- Decreased emissions beginning in 2040
- CO<sub>2</sub> emissions below current levels by 2070 and are about twice pre-industrial levels by 2100
- Increasing frequency and size of wildfires

## FP3: Late Century Decline in Emissions

Plant productivity adjacent to areas of diminished sea ice increases due to longer periods in which soils are thawed and longer plant growing seasons. Earlier plant green-up does not correspond with the timing of calving and nursing by caribou decreasing their populations in some areas. In other areas, diminished winter snow cover increases food for caribou boosting survival rates. Shrubs continue to increase in tundra. The corresponding increase in carbon uptake is counteracted by increased fires and methane emissions.

Reduced snow cover leads threatens populations of rodents and carnivores that depend on snow cover for insulation and protection from predators.

These biome changes, largely driven by temperature changes and enhanced by diminishing sea ice and permafrost are consistent with RCP 6.0 under which global temperatures increase approximately 2.2°C (4.0°F) by 2100, and Arctic temperatures increase more than 7°C (12.6°F) in fall months and 3°C (5.4°F) in spring months.

**Early Indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 32%
- Late century progress in international climate negotiations.
- Increasing emissions through at least 2050.
- Large scale ecosystem changes in the Arctic.
- Increasing frequency and size of wildfires.

## FP4: Rising Emissions Throughout the Century

Major shifts in the species composition of the terrestrial ecosystem, now dominated by frequent and large wildfires. Preferred subsistence foods in Arctic communities substantially less available. In addition to internal restructuring, the Arctic terrestrial ecosystems connections with the marine ecosystem also shift as runoff takes more terrestrial carbon into marine environments. Fjords and other marine systems see locally increased productivity.

These biome changes are driven by changes consistent with RCP8.5. Global temperatures increase approximately 3.7°C (6.7°F) by 2100, and Arctic temperatures increase 13°C (23.4°F) in fall months and 5°C (9.0°F) in spring months.

**Early Indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 48%
- Lack of progress in international climate negotiations.
- Increasing global emissions.
- Large scale ecosystem changes in the Arctic.
- Increasing frequency and size of wildfires.

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# Marine Systems Change

## Key Factor D - Environment Theme

Importance	20	Uncertainty	19	Combined	39
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### Contributing Key Factors:

Rate of ocean warming	2	3	5
Marine ecosystems	12	6	18
Coastal erosion/processes	5	1	6
Northern migration of fisheries	1	9	10

## Key Factor Description

The central Arctic Ocean has been seasonally ice covered for the past 5 million years with modern sea ice limits established 2.6 million years ago. Since then, the extent of Arctic sea ice has varied, but over the past 40 years the area covered by Arctic sea ice has diminished at an unprecedented rate with the greatest declines—more than 10% per decade—in September. Since 2011, the per decade rate of loss has exceeded 13%. In the same period, the ice has thinned and over 60% of the ice volume also was lost. Absent substantial reduction in the burning of fossil fuels, the Arctic Ocean is likely to have less than 1 million km<sup>2</sup> of sea ice during summers before 2050.

Warming air and sea temperatures are diminishing Arctic sea ice. Globally, ocean temperatures changed little before 1980 but subsequently rose steadily. Since 1990, the warming has penetrated increasingly the ocean's deeper layers. The Arctic Ocean is warming significantly. August sea surface temperatures were +4°C warmer in 2015 than the 1982-2010 mean in eastern Baffin Bay and the Kara Sea and increasing at ~0.5°C/decade in the Chukchi Sea. Many organisms of the Arctic marine ecosystem depend on ice and snow and, therefore, are vulnerable to the rapid pace of warming in the region. The biodiversity of ice-dependent species is likely to diminish with the extent of ice cover. Changes in abundance, distribution, and behavior of Arctic marine species are impacting the Arctic peoples who depend on them. Changing ice conditions have already diminished indigenous hunters' access to fish, seabirds, and marine mammals in many regions of the Arctic.

Most of the Arctic Ocean's primary producers are algae and phytoplankton that grow on or under sea ice. As ice diminishes, so will these primary producers along with the organisms that consume them. Other species of phytoplankton may increase as more light penetrates through thinner ice and diminished snow cover and during an increasing open-water season. A massive phytoplankton bloom observed under ice in the Chukchi Sea in 2011 appeared to be enhanced by thinning ice. Increased under-ice phytoplankton may contribute to further ice melt by trapping more heat in the upper portion of the ocean. Phytoplankton growth depends on nutrients as well as light. Nutrients may decrease in surface waters as those waters become freshened by sea ice melt and river run-off. Conversely, reduced sea ice cover has increased mixing bringing carbon, nutrients, and trace metals out of continental shelf sediments. Modelling studies seek to forecast the combined effects on primary production of shifting nutrient availability and increased temperature and light penetration.

Carbon dioxide absorbed in water increases acidity, and the cold waters of the Arctic Ocean have a higher capacity to absorb carbon. As sea ice diminishes, the rate of carbon absorption is increasing in the Arctic Ocean. Important prey items (e.g., pteropods and echinoderms) for many Arctic marine organisms are impaired by ocean acidification. The simple food webs of the Arctic Ocean magnify the impact of acidification on key species. The well being of people who rely on marine organisms in the Arctic for fishing and harvesting may be challenged by increasing acidification.

As the physical environment of the Arctic Ocean changes, some species will be favored and some challenged. Some sub-Arctic species will shift their ranges northward into Arctic waters while some current Arctic species will be displaced by these new migrants through competition or predation. For example, Arctic cod—a key species in the diet of many Arctic fish, birds, and marine mammals—is adapted to sea ice habitats and, as ice diminishes, is being displaced by an Atlantic Ocean cod forcing predators to switch to less nutrient-rich species. Ice-dependent mammals, including seals, polar bears, and walruses, are increasingly challenged by diminished habitats (particularly snow and ice) and altered food availability. Large numbers of female walruses that used to rest and nurse their young on sea ice in summer are now forced to come on land in large aggregations where they and their calves are vulnerable to predation and trampling. Declining ice and, especially, snow cover are projected to reduce the birthing habitat for ringed seals by 70% by 2100. On the other hand, more southerly species of seabirds and marine mammals, such as shearwaters, humpback whales, and killer whales are expanding northward during summer months as ice diminishes and their prey (zooplankton and fish) become seasonally more abundant and accessible in the Arctic.

Temperate species will move northward and become less accessible to fisheries based in the southern Bering Sea. Boreal fish species may be challenged to survive in the northernmost Bering Sea and Arctic Ocean where cold, salty brine generated by sea ice creates bottom waters that are too cold for most fish species to survive. Reduced seasonal ice cover is creating

greater opportunities for increased human activity—including commercial and military ship traffic, mineral extraction, and fishing—in the Arctic Ocean. The increased activity raises prospects of increased economic prosperity, shifts in geopolitical balance, and challenges to the ecosystem, including pollution and exploitation.

Much of the Arctic's 100,000 km of coastline comprises permafrost, and the warming ocean is accelerating coastal erosion. Coastal permafrost is thawed by the warming ocean and the increased severity of wave action that has resulted from diminished sea ice cover. The rates of coastal erosion in northern Alaska have doubled since the middle of the twentieth century, and increasing erosion has been observed across the entire Arctic threatening indigenous, industrial, scientific, and military infrastructure.

## Future Projections

### FP1: Early Decline in Emissions

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 driving ecosystem changes and coastal erosion. Coastal erosion increases as warmer sea temperature accelerate permafrost thaw and diminish sea ice results in large waves. Food security is threatened by decreased access to marine foods as harvesting from sea ice and from boats becomes more precarious.

These changes in the Arctic Ocean are consistent with RCP 2.6 in which global temperatures increase approximately 1°C (1.8°F) by 2100, and Arctic temperatures increase approximately 2-3°C (4-5°F).

#### **Early indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 8%, with some ice cover remaining year-round
- Renewed international cooperation in reducing emissions.
- Emissions begin decreasing before 2030 and approach zero by 2070

### FP2: Mid-Century Decline in Emissions

Coastal erosion is worsening as protective sea ice cover further declines. Increased ocean temperatures precipitate ecosystem changes, as endemic populations are challenged by influxes of new predators, competitors, and parasites. The changing species composition requires shifts in subsistence and commercial harvests.

Diminished sea ice cover increases marine shipping and requires increased logistic support and safety patrols. The increased ship traffic also increases the frequency of accidents including oil spills.

These ecological and economic changes ultimately are driven by global temperatures increase approximately 1.8°C (3.2°F) by 2100, and Arctic temperature increases of approximately 7°C (12.6°F) in fall months and 3°C (5.4°F) in spring months as described in RCP4.5.

**Early Indicators:**

- Frequency of September ice coverage below 1 million km<sup>2</sup> increasing and, by mid century, as likely as not
- Gradual progress in international climate negotiations.
- Decreased emissions beginning in 2040.
- CO<sub>2</sub> emissions below current levels by 2070 and are about twice pre-industrial levels by 2100

### FP3: Late Century Decline in Emissions

Sea ice in winter is thin and nearly absent in summer in the Arctic Ocean leading to dramatic shifts in the ecosystem, decreased food security, and expensive efforts to maintain and/or relocate coastal infrastructure. Ice-dependent species are threatened by diminished habitat, and cold-adapted species are threatened by the appearance of more warm-water species. The reduced ice cover and increasingly rough sea states combine with species changes to make traditional harvest more difficult and dangerous. Coastal communities as well as military, industrial, and research installations must be relocated or protected by expensive additions.

These changed conditions are driven largely by global temperatures increases (forecast under RCP 6.0) of approximately 2.2 °C (4.0 °F) by 2100, and Arctic temperatures increase of more than 7 °C (12.6 °F) in fall months and 3 °C (5.4 °F) in spring months.

**Early Indicators:**

- Year round ice loss with some possibility of September ice free summer conditions
- Late century progress in international climate negotiations.
- Increasing emissions at least through 2050.
- Large scale ecosystem changes in the Arctic.

## FP4: Rising Emissions Throughout the Century

Sea ice is almost entirely absent in summer accelerating warming by reducing reflectivity. The resulting warmer water favors new species of fish and marine mammals. Killer whales increasingly prey on belugas, narwhals, and other marine mammals deprived of sea ice refuges. Harbor seals compete with ringed seals whose productivity declines as snow covered ice necessary for rearing young has largely disappeared. Bowhead whales diminish in the face of competition from humpback whales. Arctic species diminish in number with some extinctions.

Indigenous communities adapt to harvesting new species, but access to those marine resources is diminished by thin ice in winter and spring and rough seas in summer and fall.

Coast erosion rates are in excess of 100 feet/year in some areas, and armoring of shorelines and relocation of communities and other installations severely burdens the economies of Arctic states.

Arctic shipping is more reliable in summer and supports mineral and hydrocarbon development. Law enforcement, emergency response, and military vessels further increase ship traffic.

These changes in the Arctic marine system are driven primarily by global temperature increases of approximately 3.7 °C (6.7 °F) by 2100, and Arctic temperatures increases of 13 °C (23.4 °F) in fall months and 5 °C (9.0 °F) in spring months consistent with RCP8.5.

### **Early Indicators:**

- Decadal mean decreases in Arctic sea ice cover approaching 48%
- Lack of progress in international climate negotiations.
- Increasing global emissions.
- Large scale ecosystem changes in the Arctic.

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# Arctic Regional Collaboration

## Key Factor E - Politics and Policy Theme

Importance	23.5	Uncertainty	20.25	Combined	43.75
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### Contributing Key Factors:

Northern sea route & international collaboration in the Arctic	1	0.75	1.75
Cross-Arctic transportation	0.5	3	3.5
Collaboration between gov and nations and sub-national groups	1.5	1	2.5
Government funding, attention & resources given to Arctic	4	2.5	6.5
Political acknowledgement and support	0	0.5	0.5
Transboundary collaboration	1	0	1
Plans of action	1	1	2
Border designation	0	0.5	0.5
Circumpolar management	1	1	2
Inter/intragovernment policy	0	3	3
Energy policy	3	0.5	3.5
Visionary governance & policy making	9.5	1	10.5

Global motivation/drive and local leadership	0	0.5	0.5
Impactful and cost-effective policies developed	1	0	1
Politics	0	3.75	3.75
Regulation-law, policy, & industry changes	0	1.25	1.25

## Key Factor Description

Arctic regional collaboration describes the degree to which arctic nation-states, Arctic peoples, and stakeholders cooperate around political, economic, social, and environmental issues in the region. The eight arctic nations play the key role in pan-Arctic collaboration, but other entities are influential too, such as the Permanent Participants at the Arctic Council (representing indigenous interests), and certain corporations, non-government organizations, and non-arctic states. In addition, the collaboration is helped or hindered by international agreements as well as national plans related to the Arctic. These may be from the eight Arctic Council members and be multi- or bilateral, but they may also come from outside the region, such as China’s recent white paper explaining its interests. In short collaboration in the Arctic, to work well, will need both horizontal and vertical communication and integration. The former among the eight nation-states and their Indigenous peoples as well as non-arctic nation-states and the latter in terms of designing pathways of governance and communication from the Arctic Council down to local scale governments - and back up.

## Future Projections

### FP1: Northern Harmony

Highly collaborative international partnerships exist between Arctic and non-Arctic nations that share responsibility for sustainable development, environmental protection and **arctic regional security**. All nations have ratified United Nations Convention on the Law of the Sea (UNCLOS) and there are no territorial boundary disputes. Indigenous interests are well-represented as the Arctic Council acts to strengthen ties among Arctic peoples, but also across stakeholders to ensure that wealth from increasing resource development activities compensates for impacts affecting Indigenous and mixed-Indigenous communities. There are joint regional infrastructure projects for example for electricity or gas delivery. Decades of coordinated scientific research in the Arctic, facilitated, for example, by the International Arctic Science Committee and the Arctic



Science Ministerials, help to improve system-level understanding of climate and other drivers of change which facilitates resource management partnerships across jurisdictional boundaries.

**Early Indicators:**

- New agreements, treaties, and other forms of coordination among the Arctic nations are developed and ratified by national legislatures.
- Growing recognition among the Arctic Eight of the role of the University of the Arctic in advancing intra-Arctic collaboration in STEM education, research and mobility.

## FP2: Business as Usual

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. Non-Arctic states retain an Observer status in the Arctic Council and are not formally influential in Arctic activities, yet many of them have industrial development projects within the region, or are backing such projects with large investments. Indigenous interests are considered important but large-scale organizations and many governments do not accurately understand indigenous concerns. Implementation of Arctic national strategies differ and do not uniformly align with Arctic Council recommendations. States, NGOs and others continue to pursue the goal of collaborative research that will support sustainable communities, development and environment. There are some territorial disputes, but these have not escalated to conflict because there is no rush for resources.

**Early Indicators:**

- The U.S. has still not ratified UNCLOS

## FP3: Divided Arctic

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 with collaborative science, humanitarian, and cultural projects greatly reduced while states consider the need for greater military presence.. Non-Arctic states significantly influence Arctic development and marine transportation activity through economic development but without strong pan-Arctic regulatory systems. Territorial disputes occur. Significant Russian investment in Arctic infrastructure leaves other arctic nations lagging behind in infrastructure and military presence. The Chinese become dominant in mega-mining projects in several arctic locations. A lack of cooperation over responses to climate change impacts and environmental disasters increases distrust among nations. Indigenous interests come second to national security and a rush for greater development. The Arctic Council is not effective at improving international collaboration as nations scramble to protect their boundaries and compete for investments to extract wealth from places newly accessible due to diminishing sea ice.

**Early Indicators:**

- Reduction in cooperative Arctic agreements
- Reduction in collaborative funding of multinational projects

## FP4: Arctic for the Arctic

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, although there is increasing global pressure to gain access to Arctic resources. In addition, there is a flourishing of agreements among arctic actors granting benefits related to education, mobility, jobs and investments, and even some governmental services. The Arctic Council nations and the Permanent Participants are effective at ensuring that Indigenous interests are strongly represented resulting in a slow pace of development with an emphasis on 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.

**Early Indicators:**

- The U.S. invests in buying 2 new icebreakers from Finland.
- An increase in international environmental agreements co-developed with and supported by Arctic Indigenous peoples
- The U.S. recognizes the Northwest Passage as an integral part of Canada's internal waters.

## Resources

[http://europa.eu/rapid/press-release\\_IP-16-1539\\_en.htm](http://europa.eu/rapid/press-release_IP-16-1539_en.htm)

<https://arcticconsult.files.wordpress.com/2018/01/2018-01-chinas-arctic-policy-chinas-arctic-white-paper.pdf>

# Arctic Regional Security

## Key Factor F - Politics and Policy Theme

Importance	18.5	Uncertainty	20	Combined	38.5
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### Contributing Key Factors:

Northern sea route & international collaboration in the Arctic	1	0.75	1.75
Security- food, water, defense	14	4	18
Cross-Arctic transportation	0.5	3	3.5
Plans of action	1	1	2
Circumpolar management	1	1	2
Politics	0	3.75	3.75
Conflict	1	6.5	7.5

## Key Factor Description

During the years of the Cold War, the Arctic, which had previously been largely ignored as a geopolitical theatre by its resident countries, became significantly militarized. While attention to the region increased and some infrastructure developed, the regular expansive and thick annual cycle of sea ice formed a physical regional barrier. The 1990s, in contrast, saw confrontation diminish, with the Arctic becoming viewed as a peaceful, relatively secure region. The inauguration of the Arctic Council demonstrated this security and a focus on environmental sustainability. The more recent “opening of the Arctic” - primarily correlated with regional warming and shrinking sea ice, but also the development of communication and other technologies - has seen tensions rising once again. Arctic regional security, in contrast to **Arctic regional collaboration**, refers to the physical security of the territories (including ecosystems and their inhabitants), peoples, economies, and infrastructure of the Arctic. In addition, this includes the political capacity of the Arctic nations to set their own agendas and defend their own territories in the region in a world of nations. Arctic regional security, for example, encompasses issues of rights to resources; control of Arctic shipping and other

transportation routes; regional in and out migration of people, organisms, and things; and the influence of non-Arctic nations in affairs internal to the Arctic.

## Future Projections

### FP1: Global Harmony

Highly collaborative international partnerships exist between Arctic and non-Arctic nations that share responsibility for sustainable development, environmental protection, and Arctic regional collaboration. Arctic countries feel strongly secure in the region and non-arctic nations feel they have dependable and fair relationships across the region for example for economic pursuits, travel, and research. All nations have ratified United Nations Convention on the Law of the Sea (UNCLOS) and there are no territorial boundary disputes. Indigenous interests are well-represented as the Arctic Council works to strengthen ties among Arctic peoples as well as across stakeholders. 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 (e.g., infrastructure, economic access, education) from the local to global scales.

#### **Early Indicators:**

- UNCLOS ratified by all and actually consulted for conflict resolution
- Strong commitment to multilateralism in Arctic matters
- Moves towards 'nation status' for (multinational) representatives of Arctic Indigenous peoples on the Arctic Council
- No proxy wars between Arctic nations in other locations, though there are some manageable disagreements

### FP2: Business as Usual

The Arctic Council helps to facilitate continued cooperation in the Arctic, but national interests and political actions outside of the Arctic result in strained relationships among Arctic states in different sectors such as fishing, seafloor resources, mining, and tourism. 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. Implementation of Arctic national strategies differ and do not uniformly align with Arctic Council recommendations. The US has still not ratified UNCLOS and there are some territorial disputes, such as Canada claiming the Northwest Passage as part of its internal waters, but these have not escalated to conflict because of either generally friendly relations among nations, a lack of significant economic gain in disputed regions, or environmental factors.

**Early Indicators:**

- Weak multilateralism in the Arctic Council, diluted by bilateral side agreements
- No uniform pan-Arctic status for Indigenous peoples

## FP3: A Dangerous World

Arctic nations focus on their own national policies with an emphasis on resource development and national security. This happens in a world that is “resource hungry” with non-Arctic nations eager to move beyond Arctic Council observer status and become decision-makers, or at least major actors, in the region. Nations withdraw into domestic agendas and exhibit reduced international engagement. For example, Russia reestablishes Cold War military bases, Alaska’s military infrastructure is reinforced, and Canada militarizes the Northwest Passage. Scientific research across borders lessens as does travel and tourism due to cumbersome, and enforced, rules related to mobility. Indigenous interests come second to national security and a rush for greater development focused on producing wealth to securitize territory. Seabed and Arctic Ocean conflicts, along with other disagreements, strain Arctic Council cooperation - funding for it and pan-Arctic collaboration drops. Arctic locations are used for military posturing but only violent rhetoric results.

**Early Indicators:**

- Increase of military hardware, spending, and troops in the Arctic
- Stagnant tourism and shipping numbers in spite of longer seasonally ice-free periods
- China conducts freedom of navigation/right of innocent passage exercises by sending warships through the Bering Strait into the Arctic Ocean, and long-range aircraft into the Arctic
- China claims that one of its submarines surfaced at the North Pole

## FP4: Fortress Arctic

The Arctic becomes a secured region in a dangerous world. Strong governmental coordination 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, although there is increasing global pressure to gain access to Arctic resources. Disputes within the Arctic remain but are de-escalated as poaching, piracy, economic “warfare”, and technology attacks from non-Arctic actors further create a sense that the Arctic is for the Arctic. The Arctic Council is effective at ensuring that Indigenous interests are strongly represented and the different countries use

these peoples as national symbols of “Arcticness” to be protected. Multiple multilateral treaties are created in the region to promote good relations across the eight nations.

**Early Indicators:**

- Removal of Observer nations from Arctic Council
- Political pressures on smaller Arctic nations, e.g., Greenland, not to work with non-Arctic partners on resource development
- The Russian Federation and U.S.A. create a joint force to police the Bering Strait and inspect all vessels going north and south through the strait

## FP5: Arctic Insecurity

The 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 Asian nations and multinational companies exploit internal divisions and promise wealth to different Arctic countries, subgovernments, and peoples. The U.S. and Russia drain resources fighting proxy wars, Canada is unable to secure its northern borders and the European nations, including Iceland, continue to experience a weakening of the European Union through some nations leaving and others desiring a weaker central government. Bi- and multilateral treaties are discarded or revised for national interests. Distrust among Arctic nations escalates and conflicts arise due to a lack of cooperation over responses to climate change impacts and environmental disasters. Borders on land and sea are locations of military posturing and low-level violence erupts between fishing boats, at border crossings, and on international scientific expeditions. The Arctic Council is a battleground of interests rather than an agent of cooperation, it remains funded, but only as a location of competition and the press reports fears it may be dissolved.

**Early Indicators:**

- Influx of non-Arctic investment for access to resources
- Return to bilateralism, increasingly strained relations
- Use of minor border disputes for populist purposes

## References

The information presented here was drawn from multiple pages on the Arctic Council’s website, which can be accessed from: <http://www.arctic-council.org/index.php/en/>.

# Global Policy

## Key Factor G - Politics and Policy Theme

Importance	26.3	Uncertainty	14	Combined	40.3
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### Contributing Key Factors:

Northern sea route & international collaboration in the Arctic	1	0.75	1.75
Collaboration between gov and nations and sub-national groups	1.5	1	2.5
Government funding, attention & resources given to Arctic	4	2.5	6.5
Political acknowledgement and support	0	0.5	0.5
Role of Arctic basin geopolitically/economically	1	8	9
Border designation	0	0.5	0.5
State of US-Russia relations	2.5	2.5	5
Actions of Russia & China	1.5	6.5	8
International relations	0.5	0.5	1
Collaboration at global geopolitical level	5	7	12
US rejoining Paris Agreement on climate change	2	1	3

Energy policy	3	0.5	3.5
Visionary governance & policy making	9.5	1	10.5
Global motivation/drive and local leadership	0	0.5	0.5
Politics	0	3.75	3.75
Global policies on energy development	3	9	12
Regulation-law, policy, & industry changes	0	1.25	1.25

## Key Factor Description

The Global Policy key factor focuses on the drivers of international relations both in the Arctic and across the rest of the globe. It can consist of trends, for example in marketplaces and social thinking, but also formal agreements and organizations that are themselves global, such as the United Nations. The phrase “policy” indicates this key factor addresses how courses of action by governments are created and implemented. “Global” pushes the level of government to the realm of national actors in communication over world-wide concerns.

## Future Projections

### FP1: Status Quo

The governance of the world remains organizationally driven by nation-states and some multinational companies. Each arctic nation remains considered its own entity and Westphalian sovereignty is the principle used in international law. It affirms that each nation-state has control over its territory and domestic affairs, to the exclusion of all external powers. In addition, the principle of non-interference in another country's domestic affairs is promoted, and each state, regardless of size, is equal in international law. The United Nations still exists as does the Arctic Council. Each has continued to operate as organizations promoting communication and cooperation producing research and offering agreement and treaty options. The Arctic continues to change demographically and environmentally. This is globally recognized and sometimes it influences global policy. However, the same debates over conservation and development remain and are largely decided at the national or subnational level.

### Early Indicators:



- Accords on climate change mitigation and environmental protection remain non-binding
- Comprehensive structural planning for the Arctic does not proceed beyond the discussion phase

## FP2: Global Policy Globalizes Arctic Concerns

The governance of the world remains organizationally driven by nation-states and some multinational companies. Each Arctic nation is considered its own entity and Westphalian sovereignty principles apply. In this future the vital nature of the Arctic in relation to the mid-latitudes and global South has been recognized. Strong measures to mitigate climate change measures have been put in place after hundreds of thousands of deaths from flooding, heat waves, ecosystem degradation, and other climate-driven events have occurred and have been empirically directly connected human activities (e.g. greenhouse gas emissions, short-term forcings such as black carbon). See **Climate Change Atmosphere, Cryosphere, Terrestrial and Marine System Change**. To the displeasure of some Arctic nations, there is a global policy promulgated by the U.N. that limits activities in the arctic and holds other nations firmly responsible for implementing policies to stabilize global climate processes. Nearly every country signs and most ratify it in light of the global environmental system processes now recognized as in danger of failing to provide ecosystem services across the globe.

### Early Indicators:

- Agreements on climate change mitigation are binding; failure to meet benchmarks has direct monetary consequences
- Direct or indirect (through tariffs, and other incentives) bans on fossil fuel extraction are put in place

## FP3: The Arctic Council as Government

The governance of the world remains organizationally driven by nation-states and some multinational companies. Each Arctic nation is considered its own entity and Westphalian sovereignty principles apply. In this future the vital nature of the Arctic in relation to the mid-latitudes and global South has been recognized but there is little will across the world to act. In a vacuum of United Nations' ability to recognize the Arctic region as a location of special importance, the Arctic Council's nations have decided to make the council a governing body over a suite of, primarily, environmental but also social protections. The eight nations create a multilateral treaty to encourage pan-Arctic cooperation and to make costly to non-Arctic nations extractive activities in the Arctic. There is an eight-nation fund created to remediate externalities of economic progress and to conserve species and territories, particularly from non-Arctic nations. This fund is also accessible by Permanent Participants, who's role as part of Arctic

governance bodies has further increased in recognition and importance. Intra-Arctic collaboration for adaptation rises, but puts these nations and their peoples at odds with the priorities of the global South and Asian countries increasing tension where interests conflict.

#### **Early Indicators:**

- Implementation on Arctic-wide hurdles to do business for non-Arctic nations and businesses

## **FP4: Breakdown of International Cooperation**

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 dealt significant blows to the Westphalian system. Cyber warfare and other encroachments on the decisions of nations by other nations occurs routinely and depending on location many northern citizens do not feel a sense of **Arctic regional security**. The larger nations of Russia, the U.S., China, and surprisingly Brazil have developed imperialist goals to, if not formally, then informally, capture and govern smaller nations. Where their interests in territory overlap this leads to posturing, hostility, and armed proxy-conflicts. The Arctic Council is largely abandoned by governments, and their funding, but remains an entity of limited communication and research in the North. People talk about the “Arctic fad” of the early 2000s as over and the region is no longer viewed as a shared location but simply another area of national boundaries.

#### **Early Indicators:**

- Increasingly hostile rhetoric, territorial disputes, and devaluation/weakening of former fora to resolve differences.
- The United States leaves the U.N. Human Rights Council

## **Resources and References**

Powell, R.C. and K. Dodds. “Polar geopolitics” In Powell, R.C. and K. Dodds. 2014. *Polar Geopolitics? Knowledges, resources, and legal regimes*. Edward Elgar, Northampton, MA. pp3-18.

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# International Security

## Key Factor H - Politics and Policy Theme

Importance	26.3	Uncertainty	14	Combined	40.3
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### Contributing Key Factors:

Northern sea route & international collaboration in the Arctic	1	0.75	1.75
Role of Arctic basin geopolitically/economically	1	8	9
State of US-Russia relations	2.5	2.5	5
Actions of Russia & China	1.5	6.5	8
International relations	0.5	0.5	1
Politics	0	3.75	3.75
Conflict	1	6.5	7.5

## Key Factor Description

International security, in contrast to Arctic regional security, refers to the physical security of nation-states (including ecosystems and their inhabitants), peoples, economies, and infrastructure. In addition, this includes the political capacity of nations to set their own agendas and defend their own territories in the region in a world of nations as the Westphalian doctrine suggests. International security, for example, encompasses issues of rights to resources; control of shipping and other transportation routes, as well as communications technology; global mobility of people, organisms, and things; the influence of corporations and other non-state actors; and in a more and more politically fragmented landscape, the ability to provide effective countermeasures to terrorism and cyber warfare by nation and non-nation actors.

# Future Projections

## FP1: Global Harmonization

Highly collaborative international partnerships exist between Arctic and non-Arctic nations and globally among all nations as they share responsibility for sustainable development, environmental protection, and human rights. The Arctic countries feel strongly secure in the region and non-Arctic nations feel they have dependable and fair relationships across the region because strong multilateral institutions and mechanisms such as the Arctic Council and UNCLOS guarantee stability and dependability. For example, collaborative economic pursuits, travel, and research can be planned years in advance. Indigenous interests are well-represented in nations. A general environment of collaboration around common goals and interests internationally has fostered strong mechanisms to resolve disputes peacefully and fairly. New climate and environmental pollution have been curtailed significantly, and international mechanisms are in place to ensure that those affected severely by the effects of climate and ecosystem change receive the necessary support. The collaboration and its positive impact on the economic and military powerhouse countries has led to an abatement of radical tendencies everywhere, and a significant reduction of international terrorism.

### Early Indicators:

- A rise in multilateral treaties
- The U.N.'s recommendations are actively considered if not always used in the Arctic
- Fewer sub-national disputes and a reduction in domestic and international terrorism.

## FP2: International Security as a Luxury

National interests and political actions outside of the Arctic result in strained relationships among Arctic states in governance and in different economic sectors such as fishing, seafloor resources, mining, and tourism. Global boom and bust cycles across economic sectors affect the Arctic along with other nations. Climate changes producing desertification across the African continent affect the near Middle East further pressing immigration from South to North. Implementation of Arctic national strategies differ and do not uniformly align with Arctic Council recommendations. There is weak international security at the global scale but in the rich nations of the world security, outside of domestic terrorism, is still fairly high and this continues to include the Arctic. However, the significant security concerns around terrorism and cyber attacks and warfare perpetuate a general climate of distrust that strains relationships and makes continued long-term collaboration difficult, but rather lends itself to ever shifting alliances.

### Early Indicators:

- Wealthy countries, including the Arctic 8, continue to see stable or rising GDP while poorer countries generally are doing worse
- Stronger border controls among the Arctic 8 with respect to non-Arctic citizens or “undesirable” immigrants

### FP3: A Hot, Dry, Dangerous Place

Global instability in governance is the norm in this future where the pressures of terrorism, immigration, subnational resistance and independence movements occur on a warmer planet with far less predictable weather. 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. This happens in a world that is “resource hungry” with non-Arctic nations eager to move beyond Arctic Council Observer status and become decision-makers, or at least major actors, in the region. Nations withdraw into domestic agendas and exhibit reduced international engagement. For example, Russia reestablishes Cold War military bases, Alaska’s military infrastructure is reinforced, and Canada militarizes the Northwest Passage. This retrenchment of nationalist goals causes global concern from smaller nations as well as minorities in these and other nations. The United Nations operates but under multi-polar tensions driven by China, U.S., and Russian conflicts related to **global policy**. Scientific research across borders lessens as does travel and tourism due to fears of significant government entanglements outside of one’s home country. Indigenous interests come a distant second to national security and a rush for greater development focused on producing wealth to securitize territory. Seabed and Arctic Ocean conflicts, along with other disagreements, strain Arctic Council cooperation but the general global insecurity forces the U.S. and Russia to generally cooperate on Arctic-specific concerns.

#### Early Indicators:

- Uncertainty across multiple economic sectors indicates nations and corporations are hesitant to invest far into the future
- Shrinking of comparative science studies

### FP4: Arctic Security Through Isolation

Isolation is the internationally generally accepted approach to improve all aspects of security - resource, economic, and defense. An additional driver of isolation is the attempted migration from South to North that could not be resolved or mitigated through international negotiations and aid. Thus, borders are generally closed off to goods, and to people where practicable, and

communications networks are severely restricted to avoid real or perceived influence by outside players.

International collaboration is limited to very limited scope and practical issues of common interest. For example, Arctic nation corporations related to significant economic sectors of shipping, mining, oil and gas, and fisheries are developed to shut out Asian and other regional actors' access to Arctic resources. Arctic nation passports are issued and the region as a whole grows hostile to what it perceives as a hostile international security situation.

#### **Early Indicators:**

- The Arctic Council is effective at ensuring that Indigenous interests are strongly represented and the different countries use these peoples as national symbols of "Arcticness" to be protected. Multiple multilateral treaties are created in the region to promote good relations across the eight nations.

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# Status of Arctic Indigenous Peoples

## Key Factor I - Cross-cutting: Society, and Politics and Policy, and Environment Themes

Importance	64	Uncertainty	27	Combined	91
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### Contributing Key Factors:

Cultural input & engagement	3	1	4
Hunting	4	1	5
Iñupiaq culture and speaking tradition	3	0	3
Local or Indigenous Knowledge and needs**	17	0	17
Arctic peoples	6	0	6
Buy-in/cooperation	2	6	8
Issues of national sovereignty	2	1	3
Food security	6	7	13
Language vitality	2	5	7
Indigenous persons' sovereignty in decision-making	19	6	25

\*\*We note here that both the participants and the team leaders recognize that local and traditional and Indigenous knowledge are different types of systems of knowing. Initially we had as a *contributing key factor* “Local/Indigenous knowledge and needs” drawn from the process of reviewing these initial participants inputs, but feedback indicated this signaled a lack of understanding that there are differences. To avoid confusion we have added the “or.” Please note that below in our description of the Status of Arctic Indigenous Peoples that we only reference Indigenous Knowledge (IK) and we do not seek to explicitly define it as the Indigenous peoples of the Arctic will develop and are developing their own definitions. Nonetheless its importance in relation to status requires its reference and inclusion.

## Key Factor Description

The suite of relationships that shape the status of Indigenous peoples across the Arctic can be evaluated by six indicators at any level of government. The greater the self-determination of Indigenous peoples to define and manage these relationships, the stronger one would argue their status is.

Firstly, *self governance*. This refers to the traditionally organized decision-making structures within the Indigenous groups in the Arctic from families to regions. It includes a self-determined process of selecting leaders and coming to consensus on decisions. The concept of tribal governance is broader than simply a government for a single tribe and reflects a need for equally situated levels of governance to recognize the authority of one another - Indigenous and non-Indigenous.

Secondly, *territorial management and ownership* refers to the entities that own or control the terrestrial and marine areas of the Arctic and make many of the economic, legal, and environmental decisions that occur there. These may be public (municipal, state, federal) or private (individual, corporate, tribal). With the various layers of government, jurisdictions may overlap.

Thirdly, *food sovereignty* refers to the power of those directly engaged with marine and terrestrial natural resources to determine and enforce the regulations that shape human interactions with nature, generally with the intent of sustaining a resource while allowing sufficient access for cultural, economic, and social needs. This includes decisions about hunting and gathering in terms of timing, harvest levels, methods, accessibility, and sanctions for rule violations.

Fourthly, *participation that includes two-way exchanges in governance processes from local to global* refers to activities at the individual, community, and higher levels of government where regulations or rules aimed at balancing individual liberties against the common good are debated and created. Subnational and national regulations are often critical factors controlling subsistence activities or high-impact endeavors such as resource exploration and development.

Fifthly, *the transmission and recognition of Indigenous Knowledge (IK)*. Indigenous Knowledge is a system of knowledge that is passed between, and co-created through, the shared intergenerational life experiences of a closely connected group of people who are themselves Indigenous. Transmission should be understood to have multiple possibilities including the transference between knowledge holders and others who may be Indigenous or not, who may be living in rural and indigenous communities or not. Recognition is also twofold. On the one hand it means acceptance of this form of knowledge as existing and containing truth, for example resource managers understanding there is traditional knowledge related to animal



migrations. On the other hand it means creating pathways so that traditional knowledge itself can be recognized, for example through language skills a young person may have to learn through traditional knowledge from an Elder. In the last three centuries cultural trauma created by western colonialism has fractured Indigenous transmission processes and altered the form and content of current knowledge creation. However, the evolution and adaptation, and even the meaning of Indigenous knowledge will rest primarily with the Arctic Council Permanent Participants and their own choices in relation to IK.

Lastly, embedded in IK is *language proficiency*. This implies the ability to use an acquired language in everyday settings and in a fluent manner that is easily understood between communicators. Exactly what defines “proficiency” is debated. However, it is certain that real language proficiency involves competency in applying the language to a variety of environmental and social settings. Maintaining or revitalizing language proficiency requires intergenerational communication and the transmission of traditional knowledge. It entails much more than utilizing a few key phrases and words in another more dominant language. The understanding of complex concepts from different worldviews inherently requires some language proficiency.

## Future Projections

### FP1: Autonomy for Indigenous Governments

There is a trend toward Arctic nation-states returning the governance over specific territory to the Indigenous peoples of the region. This development is enshrined in the creation of Autonomous Indigenous Territories (AITs) with relationships to their colonial countries (the Arctic Council nations, except Iceland) as sovereign nations. The AITs would assume responsibility for their own formation of governments, political processes, legal guarantees, enforcement capacity for these guarantees, and funding mechanisms. Each AIT will have discretion over creation of relationships with other AITs and other nations. These agreements may be related to Non-Indigenous peoples remaining in the territory, languages accepted for business and governance, management of shared resources (e.g. ecosystems that cross jurisdictional boundaries), educational mobility, and other concerns of nations. The Permanent Participants in the Arctic Council gain status as nations.

#### **Early Indicators:**

- Move toward elevating Permanent Participant status at the Arctic Council
- Greenland becomes an independent nation
- Evidence in language, the Press, and legal documents that Indigenous peoples are gaining more self-determination in the six key areas of the Key Factor

- New partnerships grow among business sectors, Indigenous governments/organizations (not yet autonomous governments), scientists, and social and educational allies that recognize the value of IK, practices and worldviews

## FP2: Greater Self-Determination in the Arctic

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 to the role of Indigenous peoples in the Arctic. This has resulted in the Arctic Council pressing for “the Arctic nations to advance sovereignty for the Indigenous peoples within their borders as appropriate for the social contexts of each nation.” While some countries do less, for example permitting more tribal governance over natural resources or authorizing some lands to be returned, others do more. For example, languages indigenous to the Arctic are taught in Northern schools alongside the dominant national language(s) and there is greater work and educational flexibility for subsistence practices. There is more communication and organizational alignment among the Permanent Participants that provides fiscal and intellectual capacity for them to engage in national politics to protect subsistence security and affect regulatory regimes.

### **Early Indicators:**

- Evidence in language, the Press, and legal documents that Indigenous peoples are gaining more self-determination in the six key areas of the Key Factor
- K-12 and university schooling becomes more flexible to allow for subsistence and other cultural pathways (e.g. festivals, pasture rotations, seasonal hunting and gathering, skill development) to exist with the western system
- More governance institutions (e.g. co-management) are put into place that require Indigenous input; these also grow in social services and other areas of daily life
- Chinese corporations form joint ventures with Alaska Native corporations, Indigenous peoples governments, and country governments.

## FP3: Arctic Status Quo

The general treatment and characterization of Arctic Indigenous peoples remains similar to the early 2000s but with national differences in policies. Some countries may move towards self-determination and others have done little or nothing to enable Indigenous access to governance. There is pan-Arctic recognition of the value of Indigenous peoples but few concrete national or circumpolar efforts to revitalize languages, require co-management or recognition of IK, and “self-determination” is a phrase viewed with suspicion by governments. In this future the progress occurs largely at the local level where there are communities of Indigenous peoples

and their allies practicing 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 without any defined organizational strategy and little political power. The Arctic Council recognized the existence of Indigenous peoples and the Permanent Participants remain active.

**Early Indicators:**

- Evidence in language, the Press, and legal documents that Indigenous peoples are making little progress in the six key areas of the Key Factor
- Similar to above, there remain strong debates over “who is Indigenous” and what this means in relation to national citizenship and roles and responsibilities in management

## FP4: Decline of Indigenous Status in the Arctic

Some nations remove the suite of rights of Indigenous peoples altogether and view them as another racial category, able to access affirmative action programs for minorities but not related to as governments. The Arctic Council firmly keeps Permanent Participants outside of high level, or decision-making, fora unless formally charged to include them. Indigenous peoples and their demands for territory, management authority, and IK and language recognition are viewed as barriers to economic progress in the Arctic. Across the Arctic nations, where possible, numerous lawsuits from different parties have been in the court systems for many years to either gain or remove recognition of Indigenous peoples’ rights. There is resistance, hot rhetoric, and low level violence over grazing pastures, fishing areas, marine mammals, educational rights, and other aspects of Indigenous status as funding and rights are incrementally removed by colonial governments. This does create a stronger role for pan-Arctic Indigenous cooperation as well as efforts to communicate and work with non-Arctic Indigenous peoples. However, several languages die, and there is a social turn to view Indigenous people as “obstructionist” and “anti-progress” that results in poor statistics in their well-being.

**Early Indicators:**

- Increasing populist rhetoric questioning Indigenous peoples status and actions to affirm their roles in governance
- Weakening of the rules requiring co-management and other institutions to work with Indigenous peoples
- A rise in court cases that have Indigenous and non-Indigenous peoples pitted against one another over issues such as land and water rights, animal migration, language and cultural concerns

- Changes in legal structures of nations that reduce the legitimacy of Indigenous peoples to hold rights that may differ from other citizens
- Movement toward reversal of recognition of Alaskan tribes by the Federal government

## Resources and References

<https://arctic-council.org/index.php/en/about-us/permanent-participants>

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See also websites for the Inuit Circumpolar Council:

Canada - <http://www.inuitcircumpolar.com/>

Alaska - <http://iccalaska.org/>

Greenland - <http://www.inuit.org/>

And the websites that are hosted for the other Permanent Participants by the Arctic Council:

<https://www.arctic-council.org/index.php/en/about-us/permanent-participants>

# Access to Markets

## Key Factor J - Economy Theme

Importance	7.3	Uncertainty	13	Combined	20.3
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### Contributing Key Factors:

Extent of development of Arctic shipping/ecotourism	3.5	6.0	9.5
Tourism development	0.5	1.0	1.5
Mobility/activity within the Arctic	0.3	0.3	0.7
Marine port development	1.0	1.0	2.0
Outside investment into Arctic	2.0	2.0	4.0
Economy	0.0	2.7	2.7

## Key Factor Description

Communities in the high North often lack efficient access to modern marketplace economics due to their remoteness and related to costs of living, internet/technology capacity, housing, local access to education for college, career and livelihood readiness. Market access differs across arctic nations. The nature of communities across the Arctic are diverse, for example some are large and have had established ports on the Arctic Ocean since the medieval era such as Arkhangelsk, Russia. But many people, in particular in North America and Greenland, live in small settlements, often with a majority of Indigenous residents, and primarily rely on subsistence fishing, hunting, and gathering for food, material goods, and cultural continuity. These “mixed subsistence” locations also differ in terms of “hub” communities (approximately 2,000-6,000 people) where there is greater access to markets for both buying and selling goods, and smaller villages of a few hundred or less. This contrast in livelihoods and place-based experiences means any efforts to evaluate and facilitate access to markets must be sensitive to scale and local conditions when evaluating the role and development of further connectivity.

In addition, regulatory restrictions tied to subsistence practices as well as local-scale participation in the regulatory process can depress the growth of small businesses that could take advantage of global markets. Across the Arctic there are different national rules, for example, related to polar bear and whale hunting in relation to economic possibilities. Or, consider the less contentious possible expansion of a market for reindeer products. Market access in arctic communities can enable competition of vendors and can lower costs of goods, it also means goods produced in the Arctic may be able to make it to markets elsewhere in the U.S. and abroad. Market access can stimulate community development, for example, simply building up broadband and other communication resources, in combination with postal services, can create new opportunities; but it can also bring influences that may be unwelcome to communities. Such problematic influences may be related to infrastructure development, demographic shifts, or black market goods (many arctic communities ban alcohol along with marijuana or other drugs).

In many areas, Arctic communities do not have diversified economies, but rather depend on a single large source of revenue, e.g., oil and gas extraction, mining, or fishing. To increase economic diversity and sustainability of livelihoods there are two major aspects of the North that are important to understand, First, as Goldsmith, an Alaskan economist, explains “money doesn’t stick.” The cash generated in remote regions generally doesn’t stay there. This is because of the money generated the bulk of it goes into producer profits, governmental taxes and royalties. Of greater concern is that many resident households and businesses cannot or will not purchase locally. In other words, money that does come into the region goes out when people spend elsewhere. And likewise many extractive industries “fly-in” and “fly-out” their workers who do not reside in the region. Changes in the economies of the Arctic that can increase access to market flows will be related to a suite of government and private drivers. Of largest concern is government spending, as it slows it affects many jobs directly, or indirectly (e.g., government contracts) dependent upon it. New jobs not tied to extractive industries are likely to be in the “information sector” which carries the advantage of having remote workers, but these will require advanced educational training. There are many small-scale business opportunities related to tourism and the arts, food production, and other local businesses that arctic communities need have potential to grow with investment.

## Future Projections

### FP1: Arctic Development Boom

There is a boom in oil and gas production in northern coastal regions. This produces a new deepwater port in Nome, Alaska and a smaller port in Chukotka to manage increased shipping traffic. Additionally, mining of rare earths and other globally desirable minerals promotes road projects to and from ports and mining sites creating infrastructure 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. Little is done however in terms of diversification of economies, which remain heavily reliant on the fortunes of a local anchor industry.

**Early Indicators:**

- Large-scale mining projects move into the implementation phase
- Investments into heavy extraction industry-enabling infrastructure are made

## FP2: Local Planning for Sustainable Markets

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. There is 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). There is conscious attention to the boom-bust cycle and planning to ameliorate the negative externalities of both. 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 native startups in product develop, attracting investment, and developing markets achieve great success rates.

**Early Indicators:**

- There is heavy lobbying to change laws to permit management and sale of harvested animals and plants.
- Comprehensive long-term sustainable development plans are put in place and executed

## FP3: Market Gloom

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. There is out-migration from these areas to cities or other countries.

**Early Indicators:**

- Sustained net out migration from Arctic settlements, disproportionately larger in smaller settlements
- Continued decline of per capita investment in infrastructure and development programs
- Further widening of the gap in broadband speed between Arctic and lower latitudes



## FP4: Status Quo

The boom and bust cycle tied to non-renewable extractive industries remains. 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. Little anticipatory planning happens in governments, meaning investments in reaching and extracting resources during booms doesn't spill over into features of community sustainability such as educational, cultural, or location-appropriate infrastructure.

### **Early Indicators:**

- Lack of long-term planning or periodic significant changes to the fundamentals of long-term sustainable development plans.

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# Economic Development: Renewable Resource Extraction

Key Factor K - Cross-cutting: Economy, and Politics and Policy Theme

Importance	9.8	Uncertainty	21.5	Combined	31.3
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## Contributing Key Factors:

Extent of development of Arctic shipping/ecotourism	3.5	6.0	9.5
Tourism development	0.5	1.0	1.5
Mobility/activity within the Arctic	0.3	0.3	0.7
Marine port development	1.0	1.0	2.0
Economic development	2.5	1.0	3.5
Economy	0.0	2.7	2.7
Resource extraction	1.0	1.5	2.5
Regulations for Arctic resource development	1.0	2.5	3.5
How the tension between resource development and environmental protection will be balanced	0.0	5.5	5.5

## Key Factor Description

There are vast renewable resources available in the Arctic, ranging from the land- and seascape itself, via marine and land flora and fauna, to the products of craft and creativity of Arctic peoples. Consumption of these products can range from people from outside of the Arctic coming to see them in place, e.g., eco-tourism, to large export industries into global economy, e.g., the fishing industry in the Bering Strait and the Gulf of Alaska. Much of the exports from the Arctic, as well as the large tourism operations, are controlled by entities outside of the Arctic region, which often means that much of the 'value-add', i.e., the refinement of a product for a higher-end market, may not happen in the Arctic and thus does only feedback a diminished economic benefit to the region. Similarly, vast natural resources may be economically stranded in the Arctic region as they are not accessible for efficient exploitation and delivery to existing markets. This is true, for example, for much of the wind energy production potential in the Arctic region, as well as for vast freshwater sources. While other resources, such as timber and certain fish species, have been over-harvested at times.

Thus, there are three aspects to renewable resource extraction that are key to keeping resources renewable, i.e., ensuring continued availability through natural replenishment, or avoidance of destructive activity. The first aspect is to ensure accessibility for economic exploitation via development of sufficient infrastructure. The second aspect is the careful management of accessibility and use of resources. The third aspect is access to investments to develop diverse renewable resource-based economies sustainably, which will require national and international efforts. An additional consideration is the careful management of competing interest in a given resource. For example, fishing industry and subsistence lifestyle would compete for coastal waters as a resource and basis of livelihood. An additional aspect here can be the 'non-extraction' of resources as a global interest and, thus, a product, the Arctic may have to offer. For example, the continued sequestration of carbon in Arctic fauna could be a marketable service.

## Future Projections

### FP1: Forgotten Arctic

The Arctic region remains economically isolated and economic 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. Where demand, or supply, wanes sustaining markets and market share is difficult. Arctic tourism remains a cottage industry aside from a few very well accessible 'hot spots'.

#### **Early Indicators:**

- Little, or negative economic growth

## FP2: Resource and Revenue Extracted

The renewable resources of the Arctic region are extracted at intensifying rates driven by significant private investment from outside the region. However, stakeholders from the region have difficulty accessing capital markets. The result is that not only the resources are extracted by those outside the Arctic, but also that much of their total economic value leaves 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.

### **Early Indicators:**

- Early termination of fishing moratorium in the Central Arctic Ocean
- Divergent development of industrial infrastructure and local standard of living

## FP3: Arctic Development Bank

Major regional entities are collaborating on targeted sustainable economic development through a multilateral Arctic Development Bank. This bank was given the charter to fund sustainable development in the Arctic consistent with the UN Sustainable Development Goals. Through its lending practices, requiring rigorous project parameters regarding sustainability and long-term benefit to the Arctic region, the membership of the bank develops and shapes Arctic policy. Large infrastructure projects and boutique industries alike, if to the benefit of the Arctic peoples and their sustained life in the North, gain access to international capital markets.

### **Early Indicators:**

- Sustained and increased multilateral economic and policy collaboration
- Large 'locally owned' developments in sustainable energy and industry
- Steady increase in quantity and quality of infrastructure and local standard of living.

## Resources and References

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# Economic Development: Non-Renewable Resource Extraction

Key Factor L - Cross-cutting: Economy, and Politics and Policy Theme

Importance	7.8	Uncertainty	18.5	Combined	26.3
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## Contributing Key Factors:

Mobility/activity within the Arctic	0.3	0.3	0.7
Marine port development	1.0	1.0	2.0
Outside investment into Arctic	2.0	2.0	4.0
Economy	0.0	2.7	2.7
Economic development	2.5	1.0	3.5
Resource extraction	1.0	1.5	2.5
Regulations for Arctic resource development	1.0	2.5	3.5
How the tension between resource development and environmental protection will be balanced	0.0	5.5	5.5
Oil/coal	0	2	2

## Key Factor Description

The Arctic is, by some estimates, home to more than 10% of the world's remaining liquid fossil fuel resources, large amounts of gas, and coal, significant deposits of metals, rare earth elements, and diamonds. However, much of these resources are locked up due to accessibility issues and local commodity prices that make extraction non-competitive. In addition,

environmental risks of resource extraction in the volatile Arctic ecosystems have led to cautious development, even where access and cost are favorable. Any economy powered with renewable or fossil energy will require the resources available in the Arctic for strategic and economic reasons. A fossil fuel powered economy will have to tap the existing reserves, and Arctic nations generally strive for a maximum degree of independence from world market constraints. Similarly, a renewable energy powered economy will rely on copper, zinc, iron, gold, lithium, graphite, aluminium, etc. to build the wind turbines, power systems, solar panels, and energy storage systems required for it to function. Regardless of which direction the transportation sector swings - internal combustion engine, or battery electric - the requirements for fossil or mineral resources will remain.

Currently, it is difficult to transport large quantities of extracted resources, even if locally accessible, out of the Arctic region for refinement. Furthermore, extracted resources are rarely refined in the Arctic, even though, large, untapped energy resources in strategic (i.e., close to resources, and customers) locations could make this a revenue generating possibility. Here as in the resource extraction itself, existence of basic infrastructure, such as deep-water ports, large-scale power generation, rail lines, or roads seem a limiting factor. Development of over-land transportation can result in fragmentation of landscape productivity and increased wildfire risk. Development of ocean and waterway transportation can result in pollution. Tension exists between land and ocean use objectives (e.g., hunting vs. offshore drilling), and risks to the livelihood of Arctic peoples and the environment, as well as tensions about rights to the resources themselves.

## Future Projections

### FP1: Cold, Dark, and Expensive

The Arctic region, albeit containing vast resources, remains unattractive to extensive development of non-renewable resource extraction due to cost, policy, and/or climate uncertainty. Investments in the necessary infrastructure for accessing and removing resources have not been made by the public and remain too risky for private investment. Where resources are developed, operators are very aggressive to capture the opportunity of return on investment, which leads to significant localized tensions between various users of a given area or watershed.

#### **Early Indicators:**

- Level or declining resource exports
- Low investment and exploration/prospecting activity

## FP2: Collaboration, Moderation, and Consultation

With the confidence that the Arctic region controls sufficient resources to influence world markets at will, 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 necessary infrastructure development on land, waterways, and the ocean to reach this point has proven an excellent investment for resource extraction companies and some communities. Because this was only possible by creating long-term certainty for development, the necessary policies for shared use of the Arctic region have been developed with buy-in by all stakeholders, but this does not mean all inhabitants of Arctic nations receive the same, if any, benefits. While not without localized conflicts, resource management, collaboration and consultation provide for stable and diverse economies and life-styles.

### **Early Indicators:**

- Multilateral resource extraction planning and pan-Arctic resource management regulatory framework
- Targeted investments into enabling infrastructure

## FP3: Drill, Dig, and Remove

Pressure on world resource markets due to political uncertainty about other large deposits has driven commodity prices to sustained high levels. This has made expansion of resource extraction in the Arctic quite attractive to large international companies. So much so, that infrastructure investments are made, albeit with the limited scope of access to resources. Most of the new economic activity is driven by outside players with little interest in the Arctic itself, but with the ability to leverage their size and clout to play Arctic governments against each other, preventing a cohesive policy response that could establish the framework for sustained growth, collaborative land use, and long-term planning. As a result there is significant disagreement among governments (local to national scales) about how to regulate extractive industries and tensions over development are high.

### **Early Indicators:**

- High private investment into resource extraction specific infrastructure
- Conflict between local people and resource extractors
- Chinese corporations form joint ventures with Alaska Native corporations

## Resources and References

[Canadian Arctic Map Brings Metals Mining in the Arctic One Step Closer - Steel, Aluminum, Copper, Stainless, Rare Earth, Metal Prices, Forecasting | MetalMiner](#)



[USGS Identifies Areas with Critical Mineral Resource Potential in North-Central Alaska](#)  
[Profit from the scramble for the Arctic - MoneyWeek](#)  
[Arctic review logistics and mining – Future Watch report](#)  
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[The Cold War and the Arctic OPEC — The Pub](#)  
[Russia's Evolving Arctic Capabilities](#)

# Arctic Energy Systems

Key Factor M - Cross-cutting: Economy, Science and Engineering, and Society Themes

Importance	27	Uncertainty	11	Combined	38
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## Contributing Key Factors:

Price of oil & gas	6	6	12
Energy technology	1	5	6
Energy needs	4	0	4
Energy availability/solutions	8	0	8
Energy development/usage	8	0	8

## Key Factor Description

Life at high latitudes is very energy intensive in various ways. Basic life-support, such as heating, production of clean water and sanitation, and provision of electric power consume significant amounts of, often imported, energy. In addition, transportation of goods and people over vast distances and/or by relatively inefficient means contributes to high per-capita energy consumption. The way this energy is supplied varies widely across the Arctic region from large area power grids and pipeline systems in Scandinavia and parts of Russia, to mostly spatially disjointed regional grids or microgrids and long and discontinuous supply lines for fuels in North America. Paradoxically, the Arctic also is a region of vast energy exports, mostly in the form of unrefined fossil fuels, such as crude oil, natural gas, and coal. Further vast fossil fuel resources are suspected to be located in the Arctic region. However, little is known about the actual size, location and quality of these reservoirs, and exploration and extraction are hamstrung by economic, infrastructure, and cost-competitiveness challenges. Furthermore, even where energy extractive industry exists, this rarely translates into an energy abundance in adjacent communities due to the fact that small-scale refinement rarely is cost-competitive with importing fuels from large refineries further south. Conversely, large scale infrastructure investment without a sufficiently large customer base fails to meet necessary economic benchmarks.

Thus, faced with the question of energy supply, particularly during times of crude oil price volatility, often returns to what can be produced at reasonable cost, quality and sustainability locally or regionally. Local options often also depend on resource availability, such as an economically viable wind regime, or sufficient annual sunshine hours. Regionally, the availability of climatic conditions and geological features lending themselves to the production of hydropower can make a significant difference. However, all these solutions are fraught with some serious challenges. Technology trends in the energy area that are of interest for the Arctic region are the development of ability to perform energy resource extraction and refinement at small scales cost competitively. The development of effective ways to store and dispatch excess capacity of renewable energy resources, this could be battery storage systems, but also systems that can produce diesel-like liquid fuels, or combustible gases from surplus energy locally. And lastly, development of small modular nuclear reactors for heat, power and (potentially) liquid fuel generation might be of interest.

## Future Projections

### FP1: Energy Independence

Driven by technological advancements in renewable energy systems, energy management and storage, and small modular nuclear reactor systems essentially all settlements in the Arctic have the option to achieve energy independence. Independence from annual energy imports, that is. Larger projects are investor driven, smaller require external fiscal support. The transformation of the technology landscape has driven the development of a vibrant regional service industry for systems maintenance and repairs. And while energy cost remains high compared to more populous regions at lower latitudes, the increased energy surety and reliable long-term pricing has provided planning security for local industry.

#### **Early indicators:**

- Deployment of experimental SMR systems.
- `Oversized` wind power systems in islanded microgrids, coupling to heat and transportation sectors.
- Slow-down of diesel generator sales in the North.

### FP2: Infrastructure Offensive

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 via modern ultra-high voltage direct current (UHVDC) grids.

**Early Indicators:**

- 'Oversized' (exceeding required capacity for the region) energy projects are considered, e.g., large hydropower, wind farms, and gas power plants.

### FP3: Unorganized Diversity in a Boom-Bust Economy

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. This leads to high per unit costs, as investments cannot be distributed over the initially assumed time-scales. A great diversity of systems exists, from traditional diesel to highly integrated renewable energy systems, driven by local and regional back-and-forth regarding energy policy, but costs remain extremely high across the board, due to a lack of uniformity and long-term planning.

**Early Indicators:**

- Clear 'boom and bust' cycles for various regional energy technology suppliers

### FP4: Our Fossil Future

The populous regions of mid latitudes have abandoned fossil fuels for clean air reasons, particularly the use of diesel fuel for terrestrial transportation has been banned. 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. Even the acquisition of diesel generators is cheap as emissions rules have been scaled back for remaining legal sales. The downside is significant uncertainty as the energy fortunes of most Arctic settlements are now tied to a dying industry.

**Early Indicators:**

- Major countries signing on to bans of combustion engines by 20XX
- Lack of recovery of diesel engine sales in Europe
- Steep increase in EV (including heavy transport)
- Decline of diesel prices relative to oil price

## Resources

<http://worldmap.harvard.edu/maps/6718>

[http://www.rao-ees.ru/en/business/report2001/4\\_1-1.jpg](http://www.rao-ees.ru/en/business/report2001/4_1-1.jpg)

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# Public Health

## Key Factor N - Cross-cutting: Society, and Environment Themes

Importance	25.5	Uncertainty	16.5	Combined	42
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### Contributing Key Factors:

Public health	1	6	7
Water availability/quality	7	7	14
Resilience of communities	9.5	3.5	13
Residents-food/health	8	0	8

## Key Factor Description

As a concept, public health is both a process and a goal. Public health is a suite of institutional arrangements, scientific processes, events in the real world related to disease and injury, and perceptions of well-being that are a part of the lives of people and their communities. Overall, public health is concerned with protecting the mental and physical health of entire populations. This includes behavioral and biological health. These populations can be as small as a local neighborhood, or as big as an entire country or region of the world. Specific to the Arctic region public health entails, in the most general terms, promoting healthy lifestyles; research on disease and injury prevention; and the detection, prevention and appropriate responses to infectious diseases.

## Future Projections

### FP1: Resilient Arctic Public Health

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 concept of well-being across most educational sectors and government programs is one that is holistic and considers multiple medical and mental health traditions legitimate. The changing nature of the Arctic, both social and ecological, is taken into account when governments make decisions related to public health (e.g. immigration, animal diseases, fragmented ecosystems). Disease spread and

behavioral health concerns are managed well, for example suicides have begun to drop across the Arctic and there are not large outbreaks of tick-borne diseases.

**Early Indicators:**

- More access to (and more infrastructure for) Indigenous health care
- Better funding and coordination of public health lines of action and research such as vaccines, evaluations of health in remote areas, research in the linkages between mental and physical distress; in particular studies in generational trauma
- More accessible and affordable health care for Arctic populations in general.
- Publically available and understandable materials on changes in disease and other changes due to climatic shifts.
- Major suite of studies coming from the Arctic Council that explain and value public health from multiple traditions and press for holistic physical-mental health programs.

## FP2: Public Health for Those Who Can Pay for It

A public-private health care system that remains complicated and often difficult to access. Healthcare remains largely disjointed with mental, physical, and environmental health remaining separate. The system for providing health care and monitoring disease has moved to a more private company and consultancy model. More people have moved North and brought with them tick-borne and other other diseases that thrive in a generally warmer climate. People with wealth 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.

**Early Indicators:**

- Health care that is uncoordinated across any one person's concerns
- Expensive healthcare
- Healthcare loopholes or opportunities for the wealthy

## FP3: Public Health in Decline

There is a slow degradation of health services across the Arctic along with climate sensitive diseases breaking out in multiple arctic locations from permafrost degradation and migratory animals; these are largely resistant to treatment, but tend to only be fatal in animals. There is significant reindeer and caribou die-off from climate sensitive diseases that have migrated from lower latitudes. Those better off in society are more likely to be informed about key ways to

avoid illness and they can afford treatment. The marginalized suffer in a public health system that has few institutional buffers to assist the poor, or those in remote and rural areas.

#### **Early Indicators:**

- Lack of success of circumpolar programs such as One Health in university settings and results being cited by agencies and office holders
- Less funding for cross-health sector projects and programs (e.g. disease control that works with stakeholders and ecosystem parameters)
- Government documents and policies related to health remain siloed.

### **FP4: The Public Health Crisis**

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. The annual bird migration vector over the Arctic brings a new type of “bird flu” (Avian influenza) to the shores of coastal communities in Alaska and the Canadian North. In addition ungulate diseases as well as diseases affecting canines and marine mammals have begun to rapidly spread north. While only the flu is easily transmittable across people, and is 5% lethal, initial mischaracterization of the disease due to poor public health in the North American Arctic means the disease spreads quickly across the circumpolar North as people travel. In addition, in locales with poor health care and poor veterinarian coverage due to cost or lack of infrastructure many ill people and ill animals remain unknown to the health system. The animal diseases in species humans eat are also climate sensitive and because multiple affected species see an increase in disease around the same time it makes “substitution foods” difficult so people resort to store-bought foods.

#### **Early Indicators**

- Farmers, hunters, fishers, and those reliant on subsistence begin to log increasing animal illnesses and death.
- There are some deaths from the flu that were unexpected (younger healthy people)
- An increase in ticks and insects, along with their diseases, in the middle and high North.
- Transference of disease from animal to animal (e.g. moose to cow or sheep to reindeer) and animal to humans indicate new diseases or older ones morphing into new threats.



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# Community Sustainability

## Key Factor O - Cross-cutting: Society, Economy, and Politics and Policy Themes

Importance	25.5	Uncertainty	34.5	Combined	60
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### Contributing Key Factors:

Dynamic education systems	1	0	1
Resilience of communities	9.5	3.5	13
Investment in local capacity	1	6	7
Social/cultural adaptations of local communities	1	13	14
K-12 STEM education	11	1	12
Climate refugees/changes in dynamics	2	11	13

## Key Factor Description

Community sustainability is nested in the capacity of a social-environmental system (scaled to size) to provide education and other investment towards the resilience of a place and its people. In addition, community sustainability includes finding ways to create regulatory alignment and political will that can address communities without features of resilience and susceptible to abandonment. Currently, national and state policy-makers continue to skirt the high price tags of relocation but out-migration (e.g. leaving a community due to ecosystem collapse) and in-migration (e.g. refugees and others seeking better lives) throughout the North are issues that cannot be ignored. Education in various forms is key to sustaining communities. It must be locally accessible and should provide a suite of skills that will prepare people to enter college, vocational and skill-based programs, and to learn livelihoods. In this context it also is important that the right knowledge-holders within the community are connected with teaching the right skills in the appropriate context. Education efforts can come from different post-secondary learning institutions for academic degrees and vocational skill sets, but also include situations such as one-on-one learning (mentorship), and socio-cultural activities (e.g. sewing, sled-making) that prepare people for independent livelihoods. Direct cross-generational and intersectional conveyance of knowledge is an important component of fostering community cohesiveness and is the hallmark of a functioning community. This process begins during K12 school years and continues through post-secondary learning institutions and

community-sourced options. K-12 STEM and Indigenous Knowledge are embedded into a holistic approach to education and will be key in developing adaptations that are appropriate for different local communities but also can be shared across arctic regions. Related to this resilience at a regional level is cohesiveness across not just place-based communities, but communities of interests - for example networks of scientists who may work in many different locations but focus on, say Kivalina.

## Future Projections

### FP1: Arctic Adaptation Delivers Self-Reliance

Local higher education options in the Arctic, for example, Ilisagvik College in Utqiagvik, Alaska or the Sami University College in Kautekeino, develop into 4-year universities offering degrees in locally necessary career fields, especially related to Arctic studies. The majority of the Arctic has relatively high bandwidth to enable distance learning, organizing, and sharing. Education in the Arctic becomes an important driver of regional economics. Indigenous peoples revisit, develop, and integrate pedagogical methods that incorporate the old ways of teaching and anticipate the new through general circumpolar acceptance of traditional local and Indigenous knowledge as sources of adaptation information. These multiple adaptation pathways/approaches to climate and societal change in Arctic communities lead to Innovation Collaboratives through which Arctic communities lead and model adaptations for local communities through change.

#### **Early Indicators:**

- Increase in local Arctic university enrollment
- Increase in diversity of Arctic specific topics of local offerings
- Increase in collaboration amongst Arctic universities
- Increase in expert Indigenous Knowledge holders as professors
- More regionally located educational institutions
- Growing recognition among the Arctic Eight of the role of the University of the Arctic in advancing intra-Arctic collaboration in STEM education, research, mobility and community sustainability

## FP2: Workforce Development with Reactionary Mitigation Strategies

K-12 STEM education in the Arctic never quite reaches its potential in the small of hub communities. Students must still leave their communities to seek access to higher education opportunities and this destabilizes the necessary intersectional relationships resilient communities need. Villages shrink but northern hubs grow. Traditional Indigenous skills development occurs informally in the community. Subsistence skills are still highly valued but other skills tied to living on the land/ocean dwindle in importance and die out over time. Constant flux in community populations renders strategic major adaptations to climate change difficult. Investment and capacity remain mostly at the wait-and-see approach utilizing stop-gap mitigation strategies as just-in-time reactions to crises. Internet bandwidth still remains elusive, which limits the capacity for a full suite of distance learning opportunities around adaptation, capacity-building and cooperation and collaboration within Arctic regions or with those outside.

### Early Indicators:

- Much population movement in and out of rural Arctic communities, outmigration still outpaces migration into rural Arctic communities.
- Increase in average population age in Arctic communities due to reduce birth rates, increased life expectancy, and/or outmigration of younger people.
- Lack of technological development and support, Internet and system-wide
- Insufficient funding levels for high quality education efforts

## FP3: Outmigration Outpaces Need for Adaptation

Investment, education, and therefore community capacity for sustainability are considerably under-realized in Arctic communities. By the time institutions and policy-makers react to the out-migration trend from the villages and eventually the hubs, the potential to turn this trend around has passed. Populations in the high Arctic dwindle, more so in the villages than the hubs, although both see their adaptation plans seriously compromised as a result. Most congregations of populations, and many not native to the lands, are only around what resources can be extracted in terms of industry. The vibrancy of the Arctic's Indigenous cultures and languages fades as their places depopulate and relationships are fractured. Adaptation becomes concentrated mainly in urban Arctic enclaves.

### Early Indicators:

- Number of rural Arctic villages decreases with each passing year.
- Populations now center around resource extraction nodes.

- Reduction and/or elimination of funding for smaller schools.

## FP4: Community-specific Pockets of Adaptation

National and subnational governments move to decrease the costs of maintaining Arctic populations. Arctic peoples give up on governance structures to yield possible throughways to community sustainability. For defense purposes, large bandwidth access is universal and affordable across most Arctic communities. Arctic residents develop their own personalized adaptation plans per community and for some even per household. Some pockets of resilience remain and thrive, while others shrink to non-existence. Out of the demise sprouts an Arctic based consultancy industry of adaptation advisement that is done on a distance-delivered basis. Traditional Indigenous skills related to self-reliance experience a revival as some communities seek out ways to remain in existence while adapting to a new suite of climate changes and general government neglect.

### **Early Indicators:**

- Increased bandwidth development across the Arctic.
- Some pockets of resilience and other pockets of societal disarray based in a lack of foresight and adaptation to climate and societal changes. These pockets are typically marked with a shuttering of villages.

## Resources and References

The State of Northern Knowledge in Canada-

[http://www.polarcom.gc.ca/sites/default/files/snk\\_report\\_english.pdf](http://www.polarcom.gc.ca/sites/default/files/snk_report_english.pdf)

# Science Advancement and Communication

## Key Factor P - Cross-cutting: Society, and Science and Engineering Themes

Importance	37	Uncertainty	24	Combined	61
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### Contributing Key Factors:

Science communications	6	0	6
Research- need to increase	3	1	4
Human behavior-willingness to act	4	12	16
Understanding scientific data	3	4	7
Communication/knowledge	4	2	6
Knowledge exchange	8	0	8
Public opinion- need to increase trust & awareness in science	9	5	14

## Key Factor Description

Science advancement and communication represents the interface of science, engineering and research with the subsequent successful dissemination of knowledge from the interdisciplinary processes creating it. The dissemination is successful if it can be broadly understood and data used to potentially form responses through policy, proactive human behavior, or other social response. Science advancement and communication embraces the co-production of knowledge approach in the Arctic with both science and Indigenous Knowledge creating new knowledge that helps inform how the transmission of scientific knowledge affects regulations, funding mechanisms, social-environmental relationships, and further research. Because of this, the ability across sectors to acquire, understand, and use (mobilize) such information is important. For science advancement, as well as communication, scientists and researchers partner with Indigenous and local knowledge holders to develop more comprehensive and inclusive data sets that inform the public and policy. Circumpolar knowledge exchange development across sectors and diverse audiences is a goal and for science to advance in the arctic there needs to be an equitable recognition of the value of IK.

# Future Projections

## FP1: Scientists Rekindle Public Trust

Effective science communication, that serves the public's needs, is achieved through concise and approachable communication of science research and findings. Science communication continues as a rapid growth field, so much so that a) science communication specialists are a career field and b) all science education from high school through PhD levels incorporates robust strands of science communication theory and practice. As the field matures and becomes fully integrated, new fields and experts are identified in science communication that are specific to particular audiences and/or fields of science. One example of these specialized science communicators, is climate science interpreter who bridges the gap between climate scientists and researchers and those of the public sphere who utilize climate science data. As a consequence, the communication of science to decision-makers and stakeholders is much improved and includes implications and robust adaptation strategies. Information disseminated is precise without being overly technical, and thus can much more easily be utilized without resulting in vaguery or misinterpretation. There is a general turn back to science as "having the answers" and a growth in technocrats as decision-makers.

### **Early Indicators:**

- More scientific results published across popular media platforms with data that is robust and easy-to-understand reporting.
- An increased number of full time jobs for science communication
- Increase in co-production of knowledge approaches
- Growing public trust in science, reduction of dissemination of false information at the political level

## FP2: Citizen-Science Revolution

Science survives numerous budget reductions and mistrust from antagonistic state, and other governmental actors, and derogatory propaganda in the press through a grass-roots revolution. Scientists not only bring the messages and findings to the people, they empower them to conduct their own science within their local social-ecological systems. Democratic norms and equity of access to data storage and analysis as well as dissemination and publication yield a bevy of citizen scientists who openly and avidly discuss projects and results to improve living conditions for more folks across the globe. Multiple, user-friendly internet programs exist for citizens to track, study, share, and ask questions about social-environmental events, anomalies, or concerns. These receive keen attention from scientists who not only interface with them but also perform research often with the help of citizen-science.

**Early Indicators:**

- Increase in the proliferation of citizen science groups, projects, and membership rolls

## FP3: Scientists as Global Mechanics

Geoengineering gains a large foothold in the area of fixing the planet's problems. Profits are to be made and state budgets to be secured, which dovetails nicely into the United States' and other nations' pursuit of continued economic growth and return to investors. The geoengineering solutions route pits some scientists versus activists, non-geoengineering scientists are left in the middle without leadership or direction. Conservative policy makers emboldened by the disarray and dwindling support for further scientific research slash research budgets. Scientists are now the out-migrants from the U.S. (primarily) to Europe, Russia, and developing economies as they seek locations that value scientific expertise (as a career track). Because of the lack of jobs science education is negatively impacted as well, students are reluctant to pursue science careers with such slim possibilities for future employment. Without the concerted direction of U.S. science agencies and its global scientific leadership, arctic research gains are small and the public trust, belief and understanding of the remaining scientific pursuits renders the impact of science on policy or human behavior minimal. Most global economic growth around scientific innovation occurs outside the U.S. Public science production diminishes while privately funded scientists are hired in increasing numbers in order to meet regulatory and legislative demands but from governments that fund very little science.

**Early Indicators:**

- Outmigration of scientists from the U.S.
- Increased funding for research that is also approved by corporate boards

## FP4: Corporatocracy Declares War on Science

Wealth and power continues to concentrate within the top 1-2% of global wealth holders. Through manipulation of the press and elected officials, both which impact funding opportunities, science is portrayed as a means to produce wealth rather than global progress. This focus erodes the democratic foundations of capitalism, growth and politics in support of singular agenda largely unrepresentative of common Arctic needs. The G7/8 governments maintain, "We have all the answers we need currently. We will reallocate funding towards defense and further resource exploitation to remain competitive." Corporations wield control over science in ways that continue economic growth at the expense of verifiable data generated from science that includes findings counter to growth or state priorities. 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.



Eventually, public funding reduced to the point of disciplinary collapse. Scientists are labeled as misguided liberals in the way of continued growth and progress, retreating to enclaves in developing countries or becoming employees of private corporations.

#### **Early Indicators:**

- Major funding decreases
- Top 1-2% continue to garner most of profit or potential wage increases across economic systems, but do not value science.
- Change of regulations and policy to reduced science requirements, e.g., for environmental impact statements.
- More scientists working for private companies and private universities

## **FP5: Knowledge Co-Production**

There is a radical shift in the modes of knowledge acquisition and dissemination across the Arctic nations to directly include local and traditional knowledges in educational processes, formation of regulatory mechanisms and environmental management, and Arctic Council agendas and reports. In order to make routine use of Indigenous knowledge acceptable to diverse parties in the Arctic “local” and “traditional” knowledges that may stem from empirical observations not related to ethnic and cultural identities are also included. There are new funding opportunities devoted to local-scale knowledge from diverse sources and scientists of all types are working to find ways to co-produce and integrate different evidence into their studies. Diverse actors base their political claims on more types of knowledge than ever before, but different regulatory regimes in different locales may or may not use LK, TK, and IK - that is decided on a nation by nation basis.

## **Resources and References**

<https://www.amacad.org/content/publications/pubContent.aspx?d=1101>

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See ARCUS video link at bottom of article webpage

<https://www.nap.edu/catalog/13430/a-national-strategy-for-advancing-climate-modeling> Chapter

12

## Appendix F: Raw Scenario Bundle Images

The following pages provide larger copies of the [Raw Scenario Bundles](#). They are provided here in the following order:

- Most plausible
- Most consistent
- Most robust
- Highly robust
- Highly consistent
- RCP 2.6
- RCP 4.5 More consistent
- RCP 4.5 More plausible

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboration	Arctic Regional Security	Global Policy	International Security	Status of Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewal Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communicat
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determin in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scient revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a bipolar economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community-s pockets of adaptation	Corporatocrat declares war on science
					Arctic Insecurity										Knowledge co-producer

Most plausible

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboration	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development: Renewable Resource Extraction	Economic Development: Non-renewal Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communicat
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determin in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scient revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status of the Arctic	Status quo			Our fossil future	The public health crisis	Community-si pockets of adaptation	Corporatocrat declares war on science
				Arctic Insecurity											Knowledge co-producer

Most consistent

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboration	Arctic Regional Security	Global Policy	International Security	Status of Indigenous Peoples	Access to Markets	Economic Development: Renewable Resource Extraction	Economic Development: Non-renewal Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communicat
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determination in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it with reactionary mitigation strategies	Workforce development with reactionary mitigation strategies	Citizen-scient revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Devel, dig, and remove	Unorganized diversity of a boom-bust economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community-s pockets of adaptation	Corporatocrac declares war on science
				Arctic Insecurity											Knowledge co-production

Most robust

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboration	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development: Renewable Resource Extraction	Economic Development: Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determination in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-science revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Dig, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community-specific pockets of adaptation	Corporatocracy declares war on science
					Arctic Insecurity										Knowledge co-production

Highly Robust

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaboration	Arctic Regional Security	Global Policy	International Security	Status of Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communicat
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independence	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determin in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scient revolution
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigrations outpaces need for adaptation	Scientists as global mechanics
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community-s pockets of adaptation	Corporatocrac declares war on science
				Arctic Insecurity											Knowledge co-production

Highly consistent

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaborative	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication	RCP2.6 Fixed
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independent	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust	Wild Card
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determination in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-science revolution	No Wild Card
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigration outpaces need for adaptation	Scientists as global mechanics	
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community--: pockets of adaptation	Corporatocra declares way on science	
					Arctic Insecurity										Knowledge co-product	

Fixed RCP 2.6



Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaborative	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Developer Renewable Resource Extraction	Economic Development Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication	RCP4.5
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independent	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust	Wild Card
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determination in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-scientist revolution	No Wild Card
Rapid melt and thaw of the cryosphere	Late century decline in emissions	Late century decline in emissions	Late century decline in emissions	Divided Arctic	A dangerous world	The Arctic Council as government	A hot, dry, dangerous place	Arctic status quo	Market gloom	Arctic development and bank	Drill, dig, and remove	Unorganized diversity in a boom-bust economy	Public health in decline	Outmigration outpaces need for adaptation	Scientists as global mechanics	
The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community pockets of adaptation	Corporations declares war on science	
															Arctic Insecurity	Knowledge co-product

Fixed RCP 4.5 - More consistent

Climate Change - Cryosphere	Climate Change - Atmosphere	Climate Change - Terrestrial Biosphere	Marine Systems Change	Arctic Regional Collaborative Security	Arctic Regional Security	Global Policy	International Security	Status of Arctic Indigenous Peoples	Access to Markets	Economic Development Renewable Resource Extraction	Economic Development Non-renewable Resource Extraction	Arctic Energy Systems	Public Health	Community Sustainability	Science Advancement and Communication	RCP4.5 Fixed
Slowing the melt and thaw in the Arctic	Early decline in emissions	Terrestrial biosphere stabilization	Early decline in emissions	Northern Harmony	Global harmony	Status Quo	Global Harmonization	Autonomy for indigenous governments	Arctic Development Boom	Forgotten Arctic	Cold, dark, and expensive	Energy independent	Resilient Arctic public health	Arctic adaptation delivers self-reliance	Scientists rekindle public trust	Wild Card
Gradual increase in cryosphere loss	Mid-century decline in emissions	Mid-century decline in emissions	Mid-century decline in emissions	Business as usual	Business as usual	Global policy globalizes Arctic concerns	International security as a luxury	Greater self-determination in the Arctic	Local planning for sustainable markets	Resources and revenue extracted	Collaboration, moderation, and consultation	Infrastructure offensive	Public health for those who can pay for it	Workforce development with reactionary mitigation strategies	Citizen-science revolution	No Wild Card
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The vanishing cryosphere	Rising emissions throughout the century	Rising emissions throughout the century	Rising emissions throughout the century	Arctic for the Arctic	Fortress Arctic	Breakdown of international cooperation	Arctic security through isolation	Decline of indigenous status in the Arctic	Status quo			Our fossil future	The public health crisis	Community pockets of adaptation	Corporatocracy declares war on science	
				Arctic Insecurity											Knowledge co-product	

Fixed RCP 4.5 - More plausible