Building an Arctic Urban Sustainability Index

A Reference to Aid in the Selection of Indicators

By Luis Suter and Robert Orttung

Abstract: This paper provides guidance for Arctic PIRE participants on how to construct an Arctic Urban Sustainability Index (AUSI). It reviews several earlier projects and defines guidelines for moving forward.

Basic Requirements

The study of cities and urban sustainability has taken on a new significance since the turn of the century, as more than half the global population now lives in urban centers.[1] Although cities make up only 3 percent of the world's landmass, the World Health Organization estimates that in 2014 urban populations accounted for 54 percent of the global population, with that number set to rise (National Research Council, 2014).[2] The growth of the world's cities has led to growing concerns about urban sustainability and invigorated efforts to define and measure this concept (Science for Environment Policy, 2015).

The Arctic region has also seen urban growth in resource-rich areas even as the population in other parts of the region shrinks (Heleniak, 2013). Urban growth has numerous impacts on the landscapes that support the expanding cities, which provide housing, jobs, and education for human populations but also impart negative effects such as pollution, encroachments on open land and contributions to climate change. The Arctic region is particularly sensitive as average temperatures there rose at almost twice the global rate over the past 100 years.[3] These concerns have spurred an interest in measuring the state of the Arctic urban centers, their promotion of sustainability, and the efficacy of such projects. It is imperative to properly assess the challenges these cities will face and the policies they implement. The Arctic PIRE Grant seeks to study the accelerated pace of change in the Arctic, both environmentally as well as socio-economically, and will yield valuable lessons to serve other cities around the globe as they will inevitably face and need to adapt to the effects of climate change.

The purpose of this paper is to inform researchers working on the Arctic PIRE Grant project about general practices in selecting indicators to populate the Arctic Urban Sustainability Index (AUSI) framework. Indicators are "collections of data, simplified and processed into measures of the performance of some organizational unit (Stone, 2012, p. 281)." The following analysis will review some globally accepted and easy-to-adapt frameworks as well as other urban sustainability tools that have been published in the past several years. These tools serve three basic functions for urban areas:

- determining the current baseline,

---

[1] We would like to thank the National Science Foundation for funding our Program for International Research and Education project: Promoting Urban Sustainability in the Arctic (Award 1545913).

[2] http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

[3] Intergovernmental Panel on Climate Change, Climate Change 2007 Synthesis Report, https://www.ipcc.ch/publications_and_data/ar4/syr/en/mains1.html

- measuring performance across geographies
- and informing policy going forward.

The Arctic PIRE project will create a synergetic tool, measuring Arctic urban sustainability across economic, social, environmental, governance, and planning dimensions. Creating such an index will require compiling a diverse set of indicators that take into account the unique nature of the challenges facing the Arctic region, utilizing data that is universally collectable in the cities of interest, and ensuring that the resulting analysis is understandable to policy makers in a position to act on the findings.

Preparing the Index of Arctic Urban Sustainability will require focusing on three tasks:

- defining indicators and determining the proper weight to give each one
- collecting data that is comparable across different cities in order to measure progress along the indicators
- balancing the complexity of the index to provide accurate measurements with the need to present finding in a clear and concise manner so that policy-makers can implement recommendations coming out of the research.

Developing a Theory of Sustainability

In a 2015 survey of ranking systems, Jack Snyder and Alexander Cooley concluded that

> the foregoing chapters portray public policy rankings as often incoherently defined, anchored in confused and untested theories, measured idiosyncratically, and subject to manipulation by both the raters and the rated, leading to unintended, unwanted consequences. … A root problem linking many of the shortcomings that our contributors describe is the raters' failure to conceptualize coherently what is being rated - in our volume, democracy, state failure, corruption, press freedom, and investment quality. Raters commonly identify a mixed bag of attributes and processes that encompass a syndrome of desired (or undesired) elements that seem to go together in emblematic cases of success (or failure). Rather than using theory to sort out which things in the grab bag are causes, which are consequences, and which relationships are variable or conditional, raters assign arbitrary weights to elements that are assumed to be additive, when in fact they are interactive in complex ways. Since the interesting cases for public policy are often ones in which the elements do not fit tidily into coherent syndromes, the result may be an index that obscures the very distinctions that are most important for policy evaluation. (Snyder & Alexander, 2015, p. 179)

In order to avoid repeating such mistakes, we will need to develop a theory of urban sustainability which makes explicit what processes we see as increasing or decreasing sustainability and what causes these processes to move forward. The current assumption in the model that we proposed to the NSF was that the main advances can be seen in the social, economic, and environmental sphere and that the main drivers are in the policy-making and planning spheres. At a minimum, we should discuss these assumptions and make sure that there is general agreement around them. There is a lot to do because, as the 2016 Worldwatch Institute *State of the World* report pointed out, “no mature models of urban sustainability are available today, anywhere on the planet. And even at the definitional level, there is little agreement about what constitutes a sustainable city (Gardner, 2016, p. 3)."

Considerations in Selecting Indicators: Weighting, Standardization, Communication

Definitions of sustainability constructed by scholars and practitioners generally include the major pillars of environment, economy, society, governance and planning, which are all covered in the AUSI framework laid out in the proposal for this project. Major differences among indexes are found in how these categories are weighted relative to each other, thereby determining their significance to the overall "score" of a city. The weighting of categories therefore requires careful (and defensible) reasoning. The over- or under-representation of variables could lead to criticisms that the resulting index is an environmental or socio-economic assessment rather than a comprehensive tool to measure the state of sustainability and the progress of sustainable development. Many indexes developed in the past have been accused of not truly capturing the complex nature of sustainability and the interconnectedness of its "pillars." Concerns that previous work does not fully take account the world's complexity and level of interactions have led universities to encourage increased multi-disciplinary analysis, caused funding agencies like the National Science Foundation to fund research on "nexus" issues that exist at the interfaces of several systems (eg the food-energy-water nexus[4]), and encouraged the National Academy of Sciences to study ways to promote team science (Cooke & Hilton, 2015). The balancing of weights between the five pillars of sustainability is further complicated in the Arctic region by the breadth of political systems in the region. The environmental impacts to urban centers in the Arctic are universal, but the social and political systems controlling the cities vary starkly. This difference is most apparent when comparing Russian Arctic cities to the rest of the circumpolar Arctic, both in terms of governance and scale.

The Arctic region is composed of eight states and many of these states have at least one significant urban center within the Arctic. The biggest challenge will be choosing a relatively standard set of indicators to properly assess all these unique cities. In fact, the countries even have different definitions for what constitutes an urban area (Rasmussen, 2011). We will also have to balance concerns of accessibility and the standardization of data for different cities (and countries) in the region. Different governments collect different data and the data that is collected might not be comparable across countries. Collecting data from a wide variety of sources takes time and effort and must be considered when selecting indicators. The remote nature of many Arctic cities must also be considered when selecting indicators, for data collection methods must be economically and logistically feasible. The more complex the indicators become, the harder they will be to reproduce for the entire Arctic community.

Finally, it is vital that the index be able to properly communicate its assessments in a way that informs policy-makers. In recent years, there has been explosive growth in the numbers of indicators created and these new tools have "the potential to alter the forms, the exercise, and perhaps even the distributions of power in certain spheres of global governance (Davis, Kingsbury, & Merry, 2012)." The importance of the policy implications is another reason to consider the complexity of data being used to illustrate urban sustainability. The index must be scientifically sound, yet also be accessible to policy makers and the public. It has been found that indicator sets with broad political support, actively involving those who will create policies and those who will be affected, improve the success of an index (Steward & Kuska, 2011). One

[4] http://www.nsf.gov/pubs/2016/nsf16524/nsf16524.htm

scholar working on the development of indicators in the developing world argues for designing them "from the bottom up" since they will have greater legitimacy (Stone, 2012, p. 283). A general lack of knowledge on Arctic policy issues will increase the challenge of making the index accessible and implementing its results.

The selection of indicators and the construction of the AUSI framework will be a project undertaken over the first year following the launch of the Arctic PIRE Grant in April 2016. This paper seeks to give some global context on how such indexes are designed and what makes them successful. At the center of the analysis is the weighting of categories, availability and standardization of data, and accessibility of outputs, all factors that are complicated by the unique characteristics of the Arctic region. The development of this regionally focused policy and assessment tool will allow us to track the accelerated pace of climate change on urban centers and the ability of each of the cities to respond.

A History of Sustainability Indexes

The concept of sustainability and sustainable development in an international context grew out of the 1972 United Nations Conference on the Human Environment, where leaders from various countries met to discuss the environmental and developmental challenges facing the globe (United Nations Environment Programme, 1972). In 1987, the Brundtland report coined the most widely used definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987)." This formulation presented a good ideal to strive for, but the world still lacked a way to quantify sustainability. The Rio Earth Summit of 1992 began to address this lack of assessment capacity by publishing Agenda 21, which called for the development of sustainability indicators (United Nations Conference on Environment & Development, 1992). Subsequently a plethora of indexes appeared, ranging in scope and scale, but many with a strong focus on the assessment of environmental or social conditions within urban centers. In the 2000s, there was a gradual shift in focus from assessment to action, driven by the desire to create a more inclusive sustainability strategy involving policy makers and the societies most affected by sustainability policies. The 2012 Rio+20 Earth Summit was focused on practical measures for implementing sustainable development, specifically "the building of a green economy" and the international support for policies that support developing countries to "find a green path towards development." The December 2015 COP21 meeting in Paris was even more focused on the actual implementation of policies, with each member country submitting individual plans on how to promote country-level sustainability goals. Looking forward, the 17 UN Sustainable Development Goals, adopted in 2015 with a target of 2030 in mind, provide general guideposts across a wide range of topics.[5] Sustainable Communities and Cities is Goal 11 of this ambitious development plan, calling for improvements in environmental stewardship, the building of a more inclusive society, and long-term planning to continue economic growth without adversely affecting our planet or disadvantaged peoples.

The development of sustainability indicator sets has followed a similar pattern, from a focus on largely environmental assessments to a more multi-faceted approach that considers social, economic, and political factors as well. One of the earliest, and most widely used indicator sets was the Organization for Economic Co-Operation and Development (OECD) Core Set of Indicators for Environmental Performance Reviews published in 1993. As the name

[5] https://sustainabledevelopment.un.org/sdgs

implies, this index was almost entirely focused on environmental issues. The OECD used the Pressure-State-Response (PSR) framework to measure how “human activities exert pressures on the environment and change [the] quality and the quantity of natural resources,” the “state” of the environment (Organization for Economic Cooperation and Development, 1993). The actions and policies that society and governments take to adapt to these changes are the “response” part of the cycle and feedback into the “pressure” on the environment. Pressure-indicators included population growth and waste management while State-indicators included air and water quality. The European Union developed a similar set of indicators in 1998 (Mega & Pedersen, 1998). However, the OECD cited a lack of well-developed indicators to represent societal responses, “both conceptually and in terms of data.” Measuring qualitative components of sustainability, such as population well-being, in a quantitative fashion remained a challenge in the early stages of sustainability science.

Following the 1993 OECD Report, the UN Commission on Sustainable Development (CSD) published a list of 140 indicators, covering four pillars of sustainability in 2001. This approach was intended for application at a national level, but it also represented a movement to create “theme-based” frameworks. Theme-based frameworks are a “more flexible conceptual structure that organizes indicators according to four dimensions of sustainability (environment, economy, society, and institutions) and around key themes or issues of policy relevance (Huang, Wu, & Yan, 2015, p. 1180).” This shift from the early PSR systems to theme-based frameworks reflected the general mood of the sustainability movement, from pure assessment to informed action. Theme-based frameworks are easily scalable and have been used to develop indicator sets that range from countries to urban regions or individual cities. This freedom to create an index designed around a locally appropriate framework allowed for a strong regional focus and local accuracy, with indexes being designed by individual cities or municipalities to fit their local context (Huang et al., 2015). The UN CSD report was refined in 2007 to include 14 themes, 44 subthemes, and 50 core indicators (United Nations, 2007).

Perhaps the most well-known and broadly used urban sustainability indexes is the Global City Indicators Facility (GCIF) which includes over 255 cities across 82 countries. The World Bank set up the project in 2007 and it is now housed at the University of Toronto. The GCIF indicators formed the basis for ISO 37120, the first international standard on city metrics, according to the Global Cities Institute website.[6] The GCIF framework is composed of 115 indicators organized into 20 themes.[7] The project organizers condensed this large breadth of indicators into 31 “core” indicators, which all cities had to report, alongside supplementary indicators to be reported when available (see appendix for the list). The core indicators are required to fulfill the requirements of: being reported annually, comparable, relevant to public policy making, cost effective to collect, understandable, and not overly complex.[8] The publically available data is warehoused at: http://www.dataforcities.org/. One criticism of this approach is that “while this framework seems to be providing member cities with a good, standardized system of collecting and reporting vital statistics, the results of the data system do not seem to reveal inherently and interdependently the comprehensive sustainability profile of any one single community (Steward & Kuska, 2011, p. 54).”

[6] http://www.globalcitiesinstitute.org/

[7] http://www.cityindicators.org/

[8] http://www.cityindicators.org/themes.aspx

The Scope and Number of Indicators in Successful Indexes

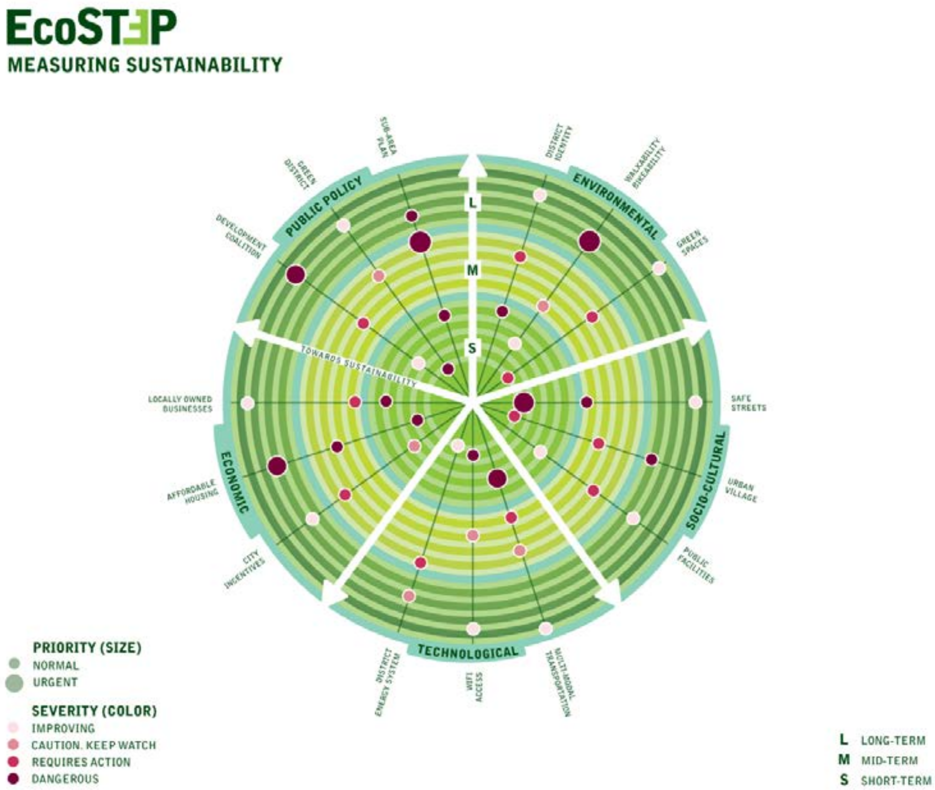
Numerous groups focused on urban sustainability quickly adopted the use of thematic frameworks. The adaptability, scalability, and freedom this framework design provided was appealing to city planners who could select indicators to support their needs and design indexes to underpin their own policy goals. Each of these actors could develop an index that showed their efforts were successful. But how can you really declare success and exceptional sustainable development practices without any comparative evidence?

In 2009, a group of University of Quebec researchers led by Georges A. Tanguay analyzed the use of sustainable development indicators in seventeen urban settings, and found a wide diversity in frameworks and indicator selection (Tanguay, Rajaonson, Lefebvre, & Lanoie, 2009). This diversity made it hard to compare across municipalities with the aim of identifying good practices and supporting bilateral-learning to enhance local-decision making processes. This breadth in indicator selection was a result of a broad definition of sustainability (and equally broad interpretations), the lack of universal classification methods, and constraints due to data availability (Tanguay et al., 2009, p. 24). The researchers analyzed the 118 indicators used in the seventeen urban centers and reduced the number of indicators to an "optimum level," with 29 indicators retained, which reflected the same distribution in the data as the original 118. This process was dubbed the Survey-Based Selection Strategy for SDI (SuBSelec), with indicators selected based on their: number of citations across the urban areas, ability to cover the sustainability categories, and ease of data collection.

However, these researchers agreed with Niemeijer and De Groot's study that the selection of indicators is "invariably subject to arbitrary decisions at one stage of the process or another (2008, p. 24)." The researchers concluded that the best way to find a compromise between a desire to standardize for comparative purposes and retain local relevance is the inclusion of "consensus" indicators across all the individual frameworks. The Tanguay study showed that there was a strong correlation between the number of indicators in an index and the type of actors driving the creation of the index. Studies endorsed by municipal leaders tended to favor a "structure comprising fewer indicators, intended to achieve simple and quantifiable objectives, [while] scientists prefer[ed] a minimum of aggregation and, if possible, simplification, in order to be faithful to the concepts (Tanguay et al., 2009, p. 14)."

In defining the number of indicators for the AUSI, there is a clear tradeoff between accuracy and accessibility. On one hand, the number of cities or institutions that adopt an index testify to its usefulness as a tool to compare global sustainable development policies. However, in order to make cities comparable one also has to aggregate the large number of indicators that comprise the breadth of the pillars of sustainability into a relatively few "core" indicators. This simplification reduces accuracy. Moreover, global indicators might not appeal to local or municipal policy makers who would like an index to support their own policy goals. The solution lies in selecting a set of indictors that can fulfill both the global comparative need while remaining locally relevant. Mediating between these two requirements of urban sustainability indexes remains a pressing issue.

One popular solution is to pick a core indicator for the key themes which can be supplemented by additional indicators that provide greater depth of analysis. For example, a 1998 Urban Sustainability Indicator framework developed by the European Foundation selected a single indicator for each policy theme and kept the data as simple as possible to encourage comparison and accessibility to policy-makers. However, the researchers also included "a 'Unique Sustainability' category, which endeavors to quantify certain sustainable practices or features that are unique to a specific cit[ies] (Science for Environment Policy, 2015). The Sustainometrics approach has five key themes (environment, socio-cultural, technology, economic, and public policy), but researchers can chose the key indicators to measure over the short, medium, and long term (pictured below) (Steward & Kuska, 2011). The World Bank/University of Toronto GCIF project picks core indicators and has a variety of additional indicators to flesh out the overall picture that it paints. The City Resilience Index has four dimensions, 12 goals, and 54 indicators.



Source: http://www.ecospheres.com/images/ecostep1_large.png

To date, there has not been a breakthrough to develop a universally used or standardized set of urban sustainability indicators. However, the research of the past decades has provided us baselines for global indicators, such as the 31 GCIF core-indicators. It has also provided us methods to aggregate a multitude of indicators into a representative set of fewer indicators, such as the Survey-Based Selection Strategy for SDI (SuBSelec) described by Tanguay. A successful index should be able to be deployed broadly across the target region, using the smallest possible number of indicators without sacrificing scientific accuracy. This minimalist approach to designing index frameworks, using globally accepted indicators from established sustainability indexes when possible, allows for the simple communication of information and easy justification of advice in a way that is accessible to policy makers and the public.

Types of Indicators

Following decisions on the number of indicators and scope of an index, it is important to start considering the desired characteristics of the indicators being selected. The character of an indicator is governed by two main functions:

- whether the indicator is measuring “weak” or “strong” sustainability and
- whether it quantifies outcome measures or policy-formation-to-produce-these-outcomes measures.

Weak and Strong Sustainability

Urban sustainability frameworks and their indicators approach the study and measurement of sustainability in two fundamentally different ways. “Weak sustainability” assumes an unlimited capacity to replace lost natural capital (biodiversity, resources, etc.) with human capital (urban infrastructure, higher education, etc.) (Pearce & Atkinson, 1993). This assumption implies that there is no loss, or decrease, in sustainability as long as environmental impacts are offset by improvements in the economic and social sphere. Rapid economic growth could make up for declining environmental quality. On the other hand, “strong sustainability” contends that these two forms of capital are not interchangeable, and this view means that there is a finite amount of damage that can be done to the environment before a system breaks down. Most theme-based frameworks assume weak sustainability, as they give higher weights to the economic and social aspects of sustainability. Meanwhile the PSR based frameworks tend to be more measures of strong sustainability, focused on assessing changes in the environment that result from anthropogenic activities. To truly capture the full scope of the interaction between the pillars, it is necessary to include both strong and weak measures of sustainability in any analysis. Any theme-based framework should include at least one measure for strong sustainability, which implies a finite ability to compensate for environmental losses through human gains. This strong sustainability indicator could be used to indicate a “red-line” of environmental degradation and actively encourage programs that encourage cities to improve their environments. As the Arctic environment is particularly fragile, with local economies largely based on resource extraction, it would be prudent to consider several measures of strong sustainability, so that social and economic gains do not overshadow environmental degradation, and the index can measure the interactions between the two.

Outcome and Policy Measures

As defined in the project proposal, the AUSI contains two types of indicators: outcome measures and policy measures. In reviewing many of the existing indexes, Kent E. Portney argues that the existing indexes tend to mix policy and outcome measures without explicitly explaining the difference between them (Portney, 2013, p. 41). While outcome measures are relatively straightforward (eg amount of greenhouse gases produced), the policy measures are much harder to quantify since they seek to gage how “seriously” cities take sustainability. The problem is that there still is not enough empirical data to state with confidence how much specific actions, policies or programs influence objective measures of sustainability. Nevertheless, cities that “take sustainability seriously” are presumably making progress toward greater sustainability.

The AUSI outcome measures break the concept of sustainability down into three components: 1) economic, 2) social, 3) and environmental. Over the course of the project’s first year discussions, we will have to define exactly how to measure these indicators. The policy measures examine 4) governance and 5) planning institutions designed to achieve economic, social, and environmental sustainability results.

Weighting Indicators

Among the most important considerations in the construction of an index is the weighting of the individual indicators. The different pillars of sustainability are interlinked and can influence each other. A variety of qualitative and quantitative methods can be used to weight the categories. It is beyond the scope of this paper to analyze the intricacies of statistical methods commonly used to calculate the weighting of categories. However, we will reference papers that can be viewed to expand upon this discussion.

The first necessary step is to normalize all the data into standardized units (per capita, percent, etc.) in order to make comparisons across space and time possible. Once normalized, each category must be weighted based on the strength of its effect on the overall sustainability of the system. Many indexes until recently have simply given each category equal weight. McKinsey's China Urban Sustainability Index, published in 2014, grappled with the challenges of weighting categories quite a bit (Li, Li, Woetzel, Zhang, & Zhang, 2014). The team first decided in 2011 to proceed from the assumption that all the categories (society, environment, economy, resources) had similar influence, however in 2013 the society and environment categories were increased in importance. This weighting resulted from an analysis that explored the changes in each sustainability category between 2008 and 2011. The research found that the strongest indicators of urban sustainability within China were healthcare and pension coverage (society), as well as Internet and mass-transit use (built environment). The index designers decided to give these two themes greater weight in order to highlight the changes in urban sustainability within China. This example represents a purely qualitative weighting, with the researchers taking a "weak sustainability" approach where social improvements can offset environmental degradation. The researchers working on the Chinese index decided to weight the categories with the most change because they were interested in analyzing growth and the drivers of growth. As framework designers, we have an ability to make qualitative choices in regard to weighting categories, depending on what issues we wish to highlight. Such weighting must be justifiable to maintain the scientific validity of the index and ensure its value to policy makers.

Another method frequently used to weight indicators was to consult experts (such as local policy makers) and then assign weight to the indicators based on their opinion of what was most important to sustainability in the region. This simple weighting made indexes more transparent and easy to understand, factoring into the accessibility of an index (Esty & Porter, 2005). However, recent statistical studies, applying regression analysis and Practical Component Analysis, of these weighting methods have raised questions about their effectiveness. A 2007 economic study by Christoph Böhringer found that a large number of indexes were so focused on the accessibility of their research to policy-makers that they "failed to fulfill their fundamental scientific requirements, making them rather useless if not misleading with respect to policy advice (Böhringer & Jochem, 2006)." A systematic approach to normalizing, aggregating, and weighting indicator categories is always preferable. Several recent papers discuss technical methods and models for weighting categories (Krajnc & Glavič, 2005; Nardo, Saisana, Saltelli, & Tarantola, 2005).

Data Availability and International Data Collection Centers

There are a number of issues to consider in collecting data.

- Is data collected across cities comparable? The Arctic region spans numerous countries, all of which have different methods and schedules for collecting information on their economies and societies. The diversity, both within cities and across the region, is extenuated by the variability in social, political, and economic systems within the Arctic.

Data drawn from official government census databases might be formatted differently or have been taken at a different time.

- Will the accuracy of an indicator selected to represent a variable within the index hold true across the entire urban area, or is it specific to a single neighborhood or sub-regions within the city? Any indicator must be able to represent an entire urban area, which are inherently patchy and diverse.

Europe boasts the most urban sustainability indexes of any region in the world, and these indexes often focus on different aspects of sustainability. The richness of these indexes results largely from the resources of the Eurostat data collection agency. This institution provides standardized data collection methods, taking in the same measures across many countries. This centralized data center has made it easy to design and test the functionality of many different indexes, as well as providing historical data with which to validate the accuracy of measures.

Unfortunately, the Arctic does not have a similar system in place that is well developed enough to serve our purposes. The Artic Council publishes papers using this type of internationally standardized data, however, it does not always publish the data that the research was based on.

On March 28, 2016, the NSF created the Artic Data Center (http://arcticdata.io/). (see https://www.arcus.org/witness-the-arctic/2016/2/article/25687?utm_source=wtav20i2&utm_medium=email&utm_campaign=wta) Also there is the Sustaining Arctic Observing Networks (SAON), which is an initiative of the Arctic Council together with the International Arctic Science Committee (IASC) and the World Meteorological Organization (WMO). The purpose of SAON, according to its website, is "to support and strengthen the development and multinational engagement for sustained and coordinated pan-Arctic observing and data sharing systems that serve societal needs, particularly related to environmental, social, economic and cultural issues."[9]

The collection of similar datasets across all the cities of interest in the index will be challenging and resource intensive, so work with potential partner organizations to lessen the workload of this data collection would be useful.

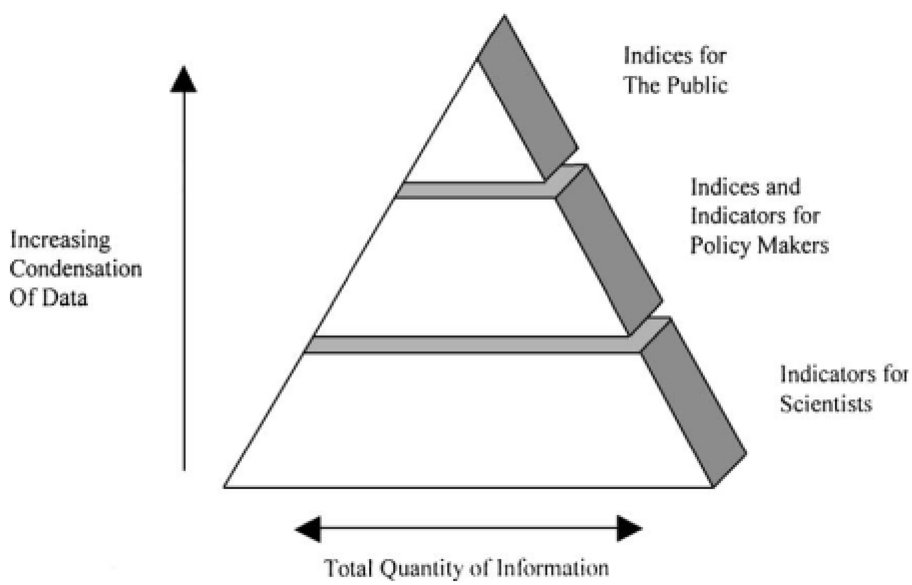
Informing Policy and Assessing Performance

The publication of any urban sustainability index is relatively meaningless to the practical development of sustainable development solutions without the participation of key stakeholders. A 2015 assessment of several urban sustainability indexes by the European Commission found that indexes and indicators that have "broad political support have been more successful than those proposed by academic institutions or non-government agencies (Science for Environment Policy, 2015)." Policy makers, as well as those who are affected by the policies, often have a better understanding of the potential success of any indicator or policy based on the advice of an index score. Community involvement and political support should be strongly encouraged throughout the process of designing the index and its implementation. This involvement will increase the accessibility of the index to policy makers as they will have a better understanding of how the design functions and the reasoning behind the selection of the indicators. Moreover, involved communities can potentially be encouraged to help in data collection and most importantly, report back on the effectiveness of policies.

[9] http://www.arcticobserving.org/

Communicating the findings of an urban sustainability index to policy-makers presents considerable challenges. According to Shields et al (Shields, Šolar, & Martin, 2002) "indicators of sustainability will only be effective if they support social learning by providing users with information they need in a form they can understand and relate to." The policy advice that results from scientific research is by far the most effective when it is communicated in a way that is significant to the target audience, characterized within the context of their values and objectives. As shown in Figure 1, drawn from the Shields article, the number of indicators used to effectively explain scientific concepts can range from many to few, depending on the target community being informed. In order for the applications that result from the scientific results of sustainability indexes to be effective, the society "must understand the status and functioning of social, economic and environmental systems and be aware of the consequences of their choices." Moreover, policy makers are more likely to adopt realistic policy goals if they understand the interconnected nature and interactions between the different pillars of sustainability, the regional context, and the reasoning behind the weighting of these components relative to each other. This understanding can only be achieved through the participation of the public and policy-makers throughout as much of the design and research process as possible. This input will facilitate the selection of indicators that are meaningful to the public and embody an understanding of their values.

Figure 1: The Condensation of Data for Communication to Different Target Groups



In the Arctic region this inclusionary ideal is complicated by the reality of the geographic constraints and differing political systems. Though many Arctic cities deal with the same issues of remoteness and mono-economies, the importance of these issues varies from city to city. The greatest similarity among all the cities is the environmental change occurring throughout the Arctic, specifically accelerated warming and permafrost thawing. But even here we must consider data availability. Different countries have vastly different strategies regarding economic growth. It will be important to accommodate these different wishes within the policy advice we distribute, perhaps altering the advice depending on the needs and desires of involved policy groups. This could be achieved again through the transparent selection of indicators and their weighting. Another strategy would be to create an international benchmark against which to compare all the other cities. This was done in the China Urban Sustainability Index, comparing Chinese cities to world cities such as New York and London.

Among the most important functions of an urban sustainability index is to assess the performance of policies meant to increase sustainable development. There are quantitative ways to assess the success of many economic policies (GDP), or even environmental policies (% reduction in pollutants), and some social policies (% change in poverty), however there are also some more abstract components of sustainability such as population well-being, which are qualitative in nature. For the purpose of evaluating the performance of policies meant to alter these inherently hard-to-measure parts of sustainability, community involvement is the key. In the United States, the STAR Community Rating System is a way for community leaders to measure their progress towards sustainability on a local level.[10] This index highlights quality of life and wellbeing and assesses these on a small scale within the target community. Though no official case studies have been published, this sort of decentralized assessment has been applied to over 30 US cities. The success or failure of state-level or national-level policies can be assessed at the community level. This type of performance assessment system might be attractive to Arctic cities, which often are isolated and individually/uniquely affected by a policy imposed at the national level. This community feedback will in turn also provide appropriate criticism through which to adapt or alter policy advice produced from the index.

Existing Arctic Indicators

Arctic researchers have also begun to work on developing indicators, but they have not yet focused specifically on urban sustainability indicators in Arctic conditions. Arctic indicators first arose with an emphasis on social and environmental concerns and were associated with the need of Arctic communities and policy-makers to resolve complex problems. Much work needs to be done. A recent survey of Arctic sustainability research called for sustainability indicators that better link social and ecological processes (Petrov et al., 2015, p. 9). Additionally there is a need for greater knowledge about urban areas in the Arctic since the existing "sustainability literature pays negligible attention to urban areas and urban-rural relationships (Petrov et al., 2015, p. 11)." Finally, a key task for the proposed Agenda 2025 is the design of sustainability indicators and monitoring systems (Petrov et al., 2015).

One of the most prominent efforts to develop a set of indicators for the Far North so far has been the Arctic Social Indicators (ASI) project. This effort began in 2006 in response to the publication of the Arctic Human Development Report, the first social sciences/humanities report commissioned by the Arctic Council. That report declared that "the SDWG [Sustainable Development Working Group] should organize a workshop to devise a small number of indicators to be used in monitoring or tracking changes in human development in the Arctic over time (Einarsson, Larsen, Nilsson, & Young, 2004, p. 11)." As a result, for the first time, Arctic scholars sought systematic ways to measure "social, economic and cultural trajectories of change (J. Larsen, Schweitzer, & Petrov, 2014)." They were particularly concerned that life in the Arctic

[10] www.STARcommunities.org/communities.

was different than life elsewhere and, therefore, sought to add new categories to existing indexes such as the United Nations Human Development Index, including fate control, cultural integrity, and contact with nature (Einarsson et al., 2004, p. 11). The first Arctic Social Indicators report, published in 2010, included six general domains to measure:

- Health and Population
- Material Wellbeing
- Education
- Cultural Wellbeing
- Contact with Nature
- Fate Control

The report went on to develop seven indicators within these six domains:

(1) Infant Mortality (Domain: Health/Population)
(2) Net-migration (Domains: Health/Population and Material Well-being)
(3) Consumption/harvest of local foods (Domains: Closeness to Nature and Material Well-being)
(4) Per capita household income (Domain: Material Well-being)
(5) Ratio of students successfully completing post-secondary education (Domain: Education)
(6) Language retention (Domain: Cultural Well-being)
(7) Fate Control Index (Domain: Fate Control) (J. N. Larsen, Schweitzer, & Fondahl, 2010, pp. 153-154)

Criteria for including these particular indicators included “data availability, data affordability, ease of measurement, robustness, scalability and inclusiveness (J. Larsen et al., 2014).”

On the basis of the Arctic Social Indicators, the team commissioned a series of case studies to test the usefulness of the indicators. As the final report, published in 2014, points out, the indicators were focused on indigenous peoples living in the Arctic and have less to tell us about other people there. “Although ASI-I insists that the ASI framework must apply to both Indigenous and non-Indigenous Arctic residents, the nature of the data and indicators themselves in the Cultural Vitality, Contact with Nature, and Fate Control domains allow measuring wellbeing of Indigenous people and often precludes us from considering other groups. This is a major limitation in many case studies presented in the current report (J. Larsen et al., 2014, p. 46).”

Another limitation was that “significant data challenges and incompatible units of measurement across national and administrative borders prohibit the application of ASI indicators to all regions of the Arctic (J. Larsen et al., 2014, p. 47). In particular,

> Our original ambition had been to produce extensive sets of comparable data featuring ASI indicators for each of the six ASI domains. However, this task soon proved impossible given the current state of data quality and lack of data availability both at the panarctic level and at different geographical scales. It became clear that we had to limit our analysis to selected regions and, furthermore, that our set of indicators could not be compared between regions in any meaningful way given existing differences in data protocols in addition to other data issues. Furthermore, all five regional case studies

> required our teams to deviate to varying degrees from the technical definitions of individual ASI indicators. It was necessary to make adjustments to tailor the analysis to meet the regional availability of data and, hence, to settle for the best possible proxies or in some cases substitute with secondbest alternative indicators – though without compromising the validity of the analysis (J. Larsen et al., 2014, p. 278).

Overall, the Russian case study, which focused on the region of Sakha (Yakutia), proved to the be the least data-rich region. In this region, as in others, one could often pick the indicator that one wanted to use about the region. For example, if you wanted to highlight a positive trend, you could emphasize that infant mortality rates were falling, but, if you took a more pessimistic view, you could stress that suicide rates increased after the collapse of the Soviet Union. Governments are also likely to try to manipulate indicators in an effort to convince domestic and international audiences that they are performing well (Cooley, 2015, p. 5; Libman & Obydenkova, 2016; Zaloznaya & Hagan, 2012). Such findings point toward the need to collect several indicators for each domain to develop a complete and nuanced picture of the situation.

Another set of indicators came from Andrey Petrov's project on the Inuvialuit, a group of indigenous people in the Arctic (http://inuvialuitindicators.com), as part of the Canadian Resources and Sustainable Development in the Arctic (ReSDA) project (http://yukonresearch.yukoncollege.yk.ca/resda/). This dataset includes information on population, education, culture, the labor force, wellbeing, income, government and housing.

Conclusion

Sustainability and sustainable development have been on research agendas in a variety of contexts for over 40 years now. In the early stages, it was a battle just to get people to agree on what constituted a definition of sustainability. There was even more debate about how to properly measure it and the result was a cacophony of differing systems and approaches. There was a desire to create one single definition and this resulted in the publication of indexes based on a large number of indicators. In the fear of leaving out an indicator that would later turn out to be crucial, indexes such as the OECD Core Set of Indicators for Environmental Performance Reviews, were purposefully broad. It was not until the early 2000s, when the effects of climate change began to be too significant to ignore and urban development showed no signs of slowing, that the broader scientific community began to question how much future growth the planet could sustain. Such concerns seemed to jumpstart the international community into action, and the debate around sustainability shifted away from how to define it and measure it, to the implementation of effective policy.

The one-size-fits-all approach to sustainability indexes led to a dilution of meaning, understanding, and as a result, relatively ineffectual policy advice. By refining the number of indicators used, as well as involving more policy makers, sustainability indexes have been able to improve their effectiveness over the past decade. Advances in methodologies to decide the appropriate weights of indicators have meanwhile helped improve the scientific basis for a refined set of indicators. Rather than design a broad and generalized index, a targeted approach that highlights community needs and values is better translated into effective policy. Focusing on local concerns maximizes both the scientific accuracy and the political accessibility of the index.

In the last decade, indexes have become much more successful at translating scientific knowledge into effective policy advice. This progress has been most apparent in Europe, where there has been a multitude of urban sustainability indexes created to track cities' progress towards various regional sustainable development treaties. A key driver is the Eurostat Agency, which collects and freely distributes much of the population, climate, and economic data that these indexes are based on. The development of such a system, possibly through the expansion of the Arctic Data Portal, would go a long way towards guaranteeing the reproducibility of an Arctic Urban Sustainability Index, and could motivate more research in the region.

Moving forward, our task in 2016 revolves around the selection of appropriate indicators to fill out the framework we have built. These indicators must be able to represent the unique regional challenges facing the Arctic, which presents numerous challenges in terms of data gathering. The indicators will be partly unique to the Arctic region, but globally used indicators must also be considered to strike an artful balance between accessibility and accuracy. We must also recognize the challenges of translating our research into policy.

Appendix: Arctic Urban Sustainability Index (First Draft from Project Proposal)

The AUSI contains two kinds of measures: output and capacity to achieve the desired outputs. In the first category are the economic, social, and environmental measures that contribute to sustainability outcomes. The methodology for measuring the ability of cities to achieve the desired goals has two components, measuring the capacity of the political system to make decisions that support sustainability and the system's ability to adapt to change. All five of these indicators will be comparable across cases and time. Ultimately, we will aggregate all of the policy indicators to create composite measures. The current version of the Index also contains a preliminary weighting of the various indicators. This first draft is a just a starting point and we can change all elements of it.

Indicators for an Index of Arctic Urban Sustainability

Sustainability Component	Measures	Index (1-500)
Economic	Access/remoteness (1-20), population's well-being (1-20), infrastructure vulnerability (1-20), intellectual capital (1-20), availability of labor (1-20)	1-100
Social	State of public services (1-50), criminality (1-25), Diversity (1-25)	1-100
Environmental	Climate and environmental change impacts on urban centers (1-50), Impacts of urban centers on natural systems (1-50)	1-100
Political Capacity	Representation (1-20), Budgeting (1-20), institutions (1-20), state-society relations (1-20), urban history (1-20)	1-100
Ability to Plan	Household capital (1-25), human capital (1-25), Planning (1-50)	1-100

Index Dimensions

Economic Sustainability. In defining economic sustainability, co-PI Brent Ryan of MIT will lead an Arctic PIRE team including Russians and Canadians that focuses on the central concern that the city needs to be a place where individuals can find work and where corporations can both produce goods and sell them effectively. For Arctic cities today, the key driver of development is natural resource exploration.

A defining problem for many Arctic cities is that they are monotowns: cities that are dependent on one factory for the vast majority of their jobs and tax revenue. In Russia, these towns have been a source of concern since the collapse of the Soviet Union. Following earlier efforts to reduce the population of these towns, more current Russian thinking is that they can survive without diversification since the state provides subsidies to support industries and their related jobs. The Kremlin's goal is to alleviate economic pain and prevent social unrest. Such city-defining factories often provide municipal services that one would often expect from local government (Commander & Jackman, 1997). The downside is, however, that such subsidies support inefficient industry (Crowley, 2015). One analysis found that monotown enterprise output is up to 70 percent less efficient than its peers (Commander, Nikoloski, & Plekhanov, 2011, p. 21).

There are five key indicators for measuring economic urban sustainability in these conditions. First is the level of access or remoteness of the city, particularly its connection to transportation infrastructure. Second, is the well-being of the population, particularly the level of income for residents, unemployment rates, the potential for layoffs in factories, and level of state subsidies required to keep local factories operating. Third is infrastructure vulnerability, measured in terms of the possibility of collapse as a result of permafrost thawing. A fourth measure examines intellectual capital, defined in terms of the presence of local institutions of higher learning and training facilities. A fifth and final measure is the availability of labor. Data for these measures often come from government statistical agencies, but are not usually presented in a manner so as to facilitate measuring sustainability.

Social Sustainability. Co-PI Marlene Laruelle of GW and a Russian colleague will lead a team that follows the World Bank in defining social inclusion as the process of improving the terms for individuals and groups to take part in society. Cities are socially sustainable when they offer a wide range of both material and cultural infrastructure that helps inhabitants feel integrated and develop a feeling of inclusion and belonging (Sachs, 2015). Arctic cities typically have difficulty providing a robust level of social inclusion given the high cost of infrastructure, their geographical isolation from the rest of the country, and the mobility patterns of their inhabitants. Arctic cities are inhabited by a variety of residents: early settlers who have been present for decades, recent arrivals seeking work, and indigenous populations. To measure social inclusion, members of the Arctic PIRE will employ three sets of indicators:

1. The state of public services, particularly offices for state administrative services, schools, medical facilities, and cultural institutions (number, budget, location in the city),
2. The level of criminality, in particular juvenile criminality, violence and social protest.
3. Ethnic and religious diversity. Many of the new arrivals in Russian Arctic cities are from Central Asia and the South Caucasus; many of those arriving in Canadian and Norwegian Arctic cities are from the Middle East. To measure this dimension, we will calculate the level of mobility in the city (percent of population present for less than five years), ethnic segregation (presence of ethnic neighborhoods, ethnically mixed areas), and cultural markers of diversity (religious buildings, cultural centers for minorities).

This set of indicators will draw on a diverse collection of data sources, including 1. official urban level statistics (for the Russian case, we will get access to them through our Russian colleagues), 2. analysis of selected open sources, such as local, city-based newspapers, that provide regular accounts of violence or street protests, ethnic tensions, as well as cultural activities and the general tenure of social life, and 3. fieldwork done by co-PI Laruelle and the Russian team (interviews and focus groups in some selected Arctic cities).

Environmental Sustainability. Environmental sustainability within the project evaluates the link between human and natural systems. The causation flows in two directions: climate change is having an impact on the urban environment, while cities are affecting the landscape around them. Co-PIs Streletskiy and Shiklomanov of GW will measure this two-fold phenomenon by leading a team including St. Petersburg-based Oleg Anisimov and his Russian colleagues.

Air temperature in the Arctic has been rising at approximately twice the global rate since the 1980s and permafrost temperatures have increased between 0.5 to 2°C (Arctic Mapping and Assessment Programme, 2012; Intergovernmental Panel on Climate Change, 2014; Whiteman, Hope, & Wadhams, 2013). These changes are projected to continue in the future leading to widespread environmental, economic and societal impacts in Arctic settlements. The majority of the existing infrastructure in Russia was designed in the 1950s-1980s and did not take into account changes in climatic conditions beyond natural variability (D. Streletskiy, Anisimov, & Vasiliev, 2014). Over the last decade the rate of building failures within the Russian Arctic settlements has increased by up to 90%, with the percentage of buildings with deformations varying from 10% in Norilsk to 80% in Vorkuta (Grebenets, Streletskiy, & Shiklomanov, 2012). A hazardous situation is emerging with respect to transportation routes and facilities (D. A. Streletskiy, Shiklomanov, & Nelson, 2012). Railroads, paved roads and runaways built on permafrost suffer from subsidence caused by thawing of the ground ice (: . National Research Council, 2008). Climate warming has caused a reduction of both the exploitation season of the winter roads and the bearing capacity of roads (Lonergan, Difrancesco, & Woo, 1993). Serious troubles also involve oil and gas pipelines with some 35,000 pipeline accidents reported in West Siberia alone (Anisimov et al., 2010). Shiklomanov and Streletskiy will work with their colleagues in Russia to provide a comprehensive measure of the impact of climate change on infrastructure. They have access to all available observational data on climatic and soil variables from all stations of the Roshydromet network, CMIP5 and landcover data, as well as data on permafrost characteristics for selected urban centers required to quantify impacts of climate and environmental change on Arctic urban centers by estimating changes in 1) infrastructure stability by using foundation bearing capacity, 2) energy use by calculating the duration of the heating season, 3) transportation accessibility by calculating the duration of the winter roads operation season.

To evaluate the impact of industrial and related urban development on landscape dynamics, Ryan Engstrom, Michael Mann, and their Russian colleagues will conduct remote sensing-based assessments of changes in development patterns and urban heat island effects. Satellite imagery analysis in the Arctic environment is challenging due to consistent cloud cover, data gaps, long periods of darkness, high heterogeneity of landscapes and the highly scattered nature of development and associated disturbances. To overcome these challenges, Engstrom and Mann will utilize an innovative “Landsat dense time stacking” approach recently developed to map changes in urban morphologies (Schneider, 2012). Within the framework of this proposal, we will further refine this method by incorporating available Commercial High Spatial Resolution Sensor (CHSRS) declassified intelligence imagery acquired by the first generation (1960s-1970s) of U.S. photo-reconnaissance satellites (e.g., CORONA, ARGON, LANYARD) and apply it to several contrasting regions characterized by: intensive urban development (northern West Siberia); relative stagnation (northern Central Siberia); and decay and abandonment (northern Far East). The team will assess changes in development patterns and associated environmental impacts by analyzing decadal changes in the proportions of anthropogenic land use types (e.g., urban, transportation, industrial infrastructure) in relation to natural land cover categories (e.g water bodies, region-specific tundra types). Ground validation will be performed in selected locations during field work. All variables within this project task are quantitative and can be integrated to produce environmental sustainability input to the overall Index.

Political Capacity The Arctic PIRE will define political capacity as decision-making authority on specific issues, the power and resources required for decision-implementation, incentives for addressing sustainability issues and constraints on addressing these issues. The Index focuses on the way that government (federal, regional, local), corporations, and civil society actors interact with each other to promote specific goals. In the U.S., starting in the 1970s, the federal government played the dominant role in pursuing sustainability, but now cities are expanding their capacities to pursue sustainability objectives, and, in particular, developing partnerships with corporations and civil society (Barber, 2013; Katz & Bradley, 2013). Finding the right balance between levels of decision-making and the pursuit of economic development and environmental protection is at the heart of all Arctic policy challenges.

In order to measure the capacity of Arctic cities to adopt policies designed to achieve sustainability goals, co-PI Andrey Petrov of the University of Northern Iowa and his collaborators from the U.S., Norway, and South Korea will, first, measure how well citizens are represented in decision making bodies for the population of Arctic cities. In these terms, it will be necessary to consider the quality of the political institutions in terms of accountability, transparency, and ability to implement decisions. Data will come from electoral statistics, state statistical agencies, and detailed process-tracing reports of governance, such as the widely used index developed by McMann and Petrov (McMann & Petrov, 2000) and subsequent revisions for Russia. Second, the project will examine the specific amounts allocated in the city budget for sustainability objectives, such as promoting energy efficiency or reducing environmental impacts, and the amount actually spent. Data will come from budgets posted on city web sites and interviews with participants in the budget-making process conducted by co-PI Petrov and colleagues. Third, in institutional terms, the key yardstick will be determining which functions are assigned to federal, regional, and local levels and how much tax authority is associated with each of these responsibilities. Fourth, in terms of state-society relations, Petrov and team will consider the level of interaction among state/firms, state/civil society, and firms/civil society. Are there institutions to facilitate these interactions and are budgetary funds committed to them? The data for this kind of analysis will be derived from city-level case studies of government, corporate, and civil society actors. Finally, in terms of urban history, the team will measure whether there is evidence of projects that have already been implemented (with results that can be measured), or is everything planned for the future? Data will come from self-reporting by city governments and reports from social actors.

Ability to Engage in Forward-Looking Planning Co-PIs Matthew Berman of the University of Alaska, Anchorage, Matthew Jull and Leena Cho, both of UVA, will lead a Arctic PIRE team including Russians and Finns measuring the ability of Arctic cities to cope with the consequences of past practices and current challenges while preparing their cities for the future. In order to understand how communities can best respond to changing conditions with forward-looking policy, they draw on the literatures that define vulnerability, resilience, and adaptive and transformative capacities (Adger, 2006; Brose, 2015; Wilson, Pearson, Kashima, Lusher, & Pearson, 2013).

To measure the "ability to cope" they will examine the assets that help households undertake actions to avoid adverse outcomes and increase their effectiveness. These assets include household capital, human capital, and ability to engage in forward-looking urban planning and design. To understand the ability of households in the Arctic to cope with the challenges they face, the team leaders and co-PI Anisimov will work will local sociologists to conduct surveys of residents to determine the size of their households budgets, the components of their income, and the stressors on their budgets that impact the level of resources that households have to cope. The team will measure human capital by gathering data examining linkages among urban residents with others in the city (bonding capital) and outside the city (bridging capital) as well as city residents' ability to act collectively (measured in number of social ties inside and outside community).

The best way to measure commitment to sustainability is through the existence of a long-term plan (20-40 years) defining how the city will manage its infrastructure (sources of energy, waste management, transportation, etc.) to address changing conditions, while transforming this infrastructure over time to improve the urban area's ability to respond. Building on their work in 20 U.S. cities, Keeley and Benton-Short will examine 10 Arctic municipal sustainability plans and documents and compare how sustainability measures are conceptualized and operationalized through an analysis of: 1) established numeric/measurable benchmarks, 2) other stated goals or objectives, 3) specific steps to be taken to meet these goals and 4) related modes of governance (such as public education, incentives to the public, construction of infrastructure, development of financial policy or the use of sanctions) (Kern & Alber, 2008). These members of the team will generate a matrix of existing, relevant sustainability benchmarks, goals, and objectives and the modes of governance used to achieve these, and suggest best practices in these areas. These data can then be utilized by local communities and stakeholders to assess their applicability in Igarka and Norilsk in Russia and Barrow and Nome in the U.S. as part of the education outreach described below.

The final measure will examine how effectively urban planners are working to achieve forward-looking sustainability goals. Architects building cities like Resolute Bay, Canada, and Norilsk, Russia have traditionally experimented with a variety of design elements – the shape and size of the buildings, their ability to shelter their residents from the elements, their proximity to water, efforts to integrate different populations, attempts to improve the local quality of life (such as by encouraging social interaction), and methods for ensuring that the buildings do not thaw the permafrost on which they are built – that impact the city's overall sustainability (Jull & Cho, 2013; Marcus, 2008; Slabuha, 2007). Co-PIs Jull and Cho will examine the impact of these different design elements on the future of Arctic cities.

Appendix: Resources

The “ICSID database on economic and political indicators for the Russian regions” provides an extensive list of resources for data on the Russian regions.

Appendix: Sustainability Indexes that Have Been Applied to the Urban Landscape

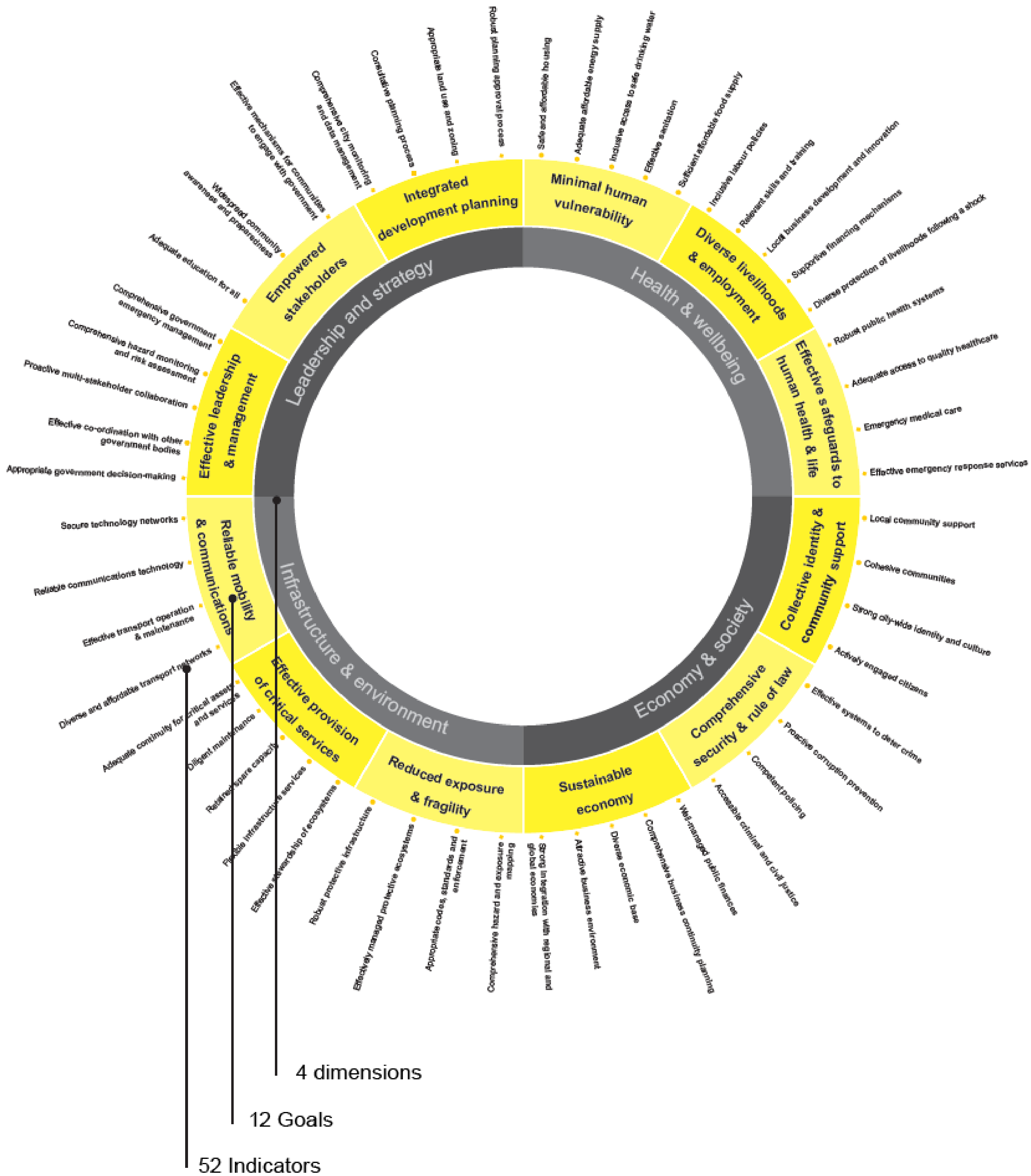
Eleven Signs a City Will Succeed (Fallows, 2016)

This article appears in the March print edition of the Atlantic Monthly alongside the cover story, "Can America Put Itself Back Together?"—a summation of James and Deb Fallows's 54,000-mile journey around America in a single-engine plane. More dispatches from their ongoing reporting trip can be found here.

By the time we had been to half a dozen cities, we had developed an informal checklist of the traits that distinguished a place where things seemed to work. These items are obviously different in nature, most of them are subjective, and some of them overlap. But if you tell us how a town measures up based on these standards, we can guess a lot of other things about it. In our experiences, these things were true of the cities, large or small, that were working best:

1. Divisive national politics seem a distant concern.
2. You can pick out the local patriots.
3. "Public-private partnerships" are real.
4. People know the civic story.
5. They have a downtown.
6. They are near a research university.
7. They have, and care about, a community college.
8. They have unusual schools.
9. They make themselves open.
10. They have big plans.
11. They have craft breweries.

City Resilience Index



Source: ARUP, The Rockefeller Foundation, http://bsdcri.wpengine.com/

Table 4 Comparison of selected sustainability indicators that have been, or can be, used for assessing urban sustainability

Indicator	Publication year	Developer	Normalization method*	Weighting method*	Aggregation method*	Scale originally intended	Applied at urban scale?
City Development Index (CDI)	1997	UN-Habitat	Distance from mean	PCA or experts' opinions	Weighed average	Urban	Yes
Ecological Footprint (EF)	1992	Wackernagel and Rees	Global hectares	Equal	Summation	Local to global	Yes
Environmental Performance Index (EPI)	By-yearly since 2006	Yale University and Columbia University	(0, 100)	PCA or experts' opinions	Weighed average	Global, National	Not yet
Genuine Progress Indicator (GPI)	1994	Redefining Progress	Monetized	Equal	Summation	Global, National	Yes
Genuine Savings (GS)	1999	World Bank	Monetized	Equal	Summation	Global, National	Yes
Green City Index (GCI)	2009	Economic Intelligence Unit and Siemens	(1, 10)	Equal	Average	Urban	Yes
Human Development Index (HDI)	Yearly since 1990	United Nations Development Programme	(0, 1)	Equal	Average	Global, National	Yes
Happy Planet Index (HPI)	2006	New Economics Foundation	(0, 100)	–	–	Global, National	Not yet
Sustainable Society Index (SSI)	2006	Sustainable Society Foundation	(0, 10)	Unequal	Weighted average	Global, National	Yes
Wellbeing Index (WI)	2001	IUCN and International Development Research Centre	(0, 100)	Unequal, categorical	Weighed average	Global, National	Not yet

Source: (Huang et al., 2015)

STAR Community Rating System

Table of STAR Goals and Objectives

Built Environment	Climate & Energy	Economy & Jobs	Education, Arts & Community	Equity & Empowerment	Health & Safety	Natural Systems
Ambient Noise & Light	Climate Adaptation	Business Retention & Development	Arts & Culture	Civic Engagement	Active Living	Green Infrastructure
Community Water Systems	Greenhouse Gas Mitigation	Green Market Development	Community Cohesion	Civil & Human Rights	Community Health & Health System	Invasive Species
Compact & Complete Communities	Greening the Energy Supply	Local Economy	Educational Opportunity & Attainment	Environmental Justice	Emergency Prevention & Response	Natural Resource Protection
Housing Affordability	Industrial Sector Resource Efficiency	Quality Jobs & Living Wages	Historic Preservation	Equitable Services & Access	Food Access & Nutrition	Outdoor Air Quality
Infill & Redevelopment	Resource Efficient Buildings	Targeted Industry Development	Social & Cultural Diversity	Human Services	Indoor Air Quality	Water in the Environment
Public Spaces	Resource Efficient Public Infrastructure	Workforce Readiness		Poverty Prevention & Alleviation	Natural & Human Hazards	Working Lands
Transportation Choices	Waste Minimization				Safe Communities	

Weighting of Goal Areas

STAR's seven Goal Areas serve as the foundation of the system's interconnected, triple bottom line approach to sustainability. There are currently no universally accepted standards for rating one sustainability goal as of greater importance or value than any other; therefore, with one exception, STAR's Goal Areas are equally weighted at 100 points each. Education, Arts & Community is valued at 70 points because it has a fewer number of STAR Objectives overall.

Goal Area	Points Available
Built Environment	100
Climate & Energy	100
Economy & Jobs	100
Education, Arts & Community	70
Equity & Empowerment	100
Health & Safety	100
Natural Systems	100
Innovation and Process	50
Total	**720**

Action Types	
Education and Outreach	*Preparatory*
Plan Development	
Policy and Code Adjustment	
Partnerships and Collaboration	
Practice Improvements	
Inventory, Assessment or Survey	
Enforcement and Incentives	*Implementation*
Programs and Services	
Facilities and Infrastructure Improvements	

Figure 5 **Summary of Short-Term Indicators[a] by Environmental Issue[b]**

	PRESSURE	STATE	RESPONSE
Issues	**Indicators of environmental pressures**	**Indicators of environmental conditions**	**Indicators of societal responses**
1. Climate change	Emissions of CO_2	Atmospheric concentrations of greenhouse gases Global mean temperature	Energy intensity
2. Stratospheric ozone depletion	Apparent consumption of CFCs	Atmospheric concentration of CFCs	
3. Eutrophication	Apparent consumption of fertilizers, measured in N,P	BOD, DO, N and P in selected rivers	% of population connected to waste water treatment plants
4. Acidification	Emissions of SOx and NOx	Concentrations in acid precipitations (pH, SO_4, NO_3)	Expenditure for air pollution abatement
5. Toxic contamination	Generation of hazardous waste	Concentration of lead, cadmium, chromium, copper in selected rivers	Market share of unleaded petrol
6. Urban environmental quality		Concentrations of SO_2, NO_2, particulates in selected cities	
7&8 Biological diversity and landscape	Land use changes	Threatened or extinct species as % of known species	Protected areas as % of total area
9. Waste	Generation of municipal, industrial, nuclear, hazardous waste	not applicable	Expenditure on waste collection and treatment Waste recycling rates (paper and glass)
10. Water resources	Intensity of use of water resources		
11. Forest resources		Area, volume and distribution of forests	
12. Fish resources	Fish catches		
13. Soil degradation (desertification and erosion)	Land use changes		
14. General indicators, not attributable to specific issues	Population growth and density GDP growth Industrial and agric. production Energy supply and structure Road traffic and vehicle stock	not applicable	Pollution abatement and control expenditure Public opinion on the environment

a) Only indicators which are available in the short term at international level are shown in this table. See Chapter 3 for other indicators. This table identifies key elements of indicators: at this point, no normalisation with respect to GDP, population, etc. is suggested. See Chapter 3 on use of indicators for a discussion.

b) For a brief discussion of each individual issue, see Chapter 3.

Poverty	Income poverty	Proportion of population living below national poverty line	Proportion of population below $1 a day
	Income inequality	Ratio of share in national income of highest to lowest	
	Sanitation	Proportion of population using an improved sanitation facility	
	Drinking water	Proportion of population using an improved water	
	Theme Sub-theme	Core indicator	Other indicator
Poverty (continued)	Access to energy	Share of households without electricity or other modern energy services	Percentage of population using solid fuels for cooking
	Living conditions	Proportion of urban population living in slums	
Governance	Corruption	Percentage of population having paid bribes	
	Crime	Number of intentional homicides per 100,000	
Health	Mortality	Under-five mortality	
		Life expectancy at birth	Healthy life expectancy at birth
	Health care delivery	Percent of population with access to primary health care	Contraceptive prevalence rate
		Immunization against infectious childhood	
	Nutritional	Nutritional status of	
	Health status and risks	Morbidity of major diseases such as HIV/AIDS, malaria	Prevalence of tobacco use
			Suicide rate
Education	Education level	Gross intake ratio to last grade of primary	Life long learning
		Net enrolment rate in	
		Adult secondary (tertiary) schooling	
	Literacy	Adult literacy rate	
Demographics	Population	Population growth	Total fertility rate
		Dependency ratio	

	Tourism		Ratio of local residents to tourists in major tourist regions and destinations
Theme	Sub-theme	Core indicator	Other indicator
Natural hazards	Vulnerability to	Percentage of population living in hazard prone	
	Disaster preparedness and		Human and economic loss due to natural disasters
Atmosphere	Climate change	Carbon dioxide	Emissions of greenhouse gases
	Ozone layer	Consumption of ozone depleting substances	
	Air quality	Ambient concentration of air pollutants in urban areas	
Land	Land use and status		Land use change
			Land degradation
	Desertification		Land affected by desertification
	Agriculture	Arable and permanent cropland area	Fertilizer use efficiency
			Use of agricultural pesticides
			Area under organic farming
	Forests	Proportion of land area covered by forests	Percent of forest trees damaged by defoliation
			Area of forest under sustainable forest management
Oceans, seas and	Coastal zone	Percentage of total population living in	Bathing water quality
	Fisheries	Proportion of fish stocks within safe biological	
	Marine environment	Proportion of marine area	Marine trophic index
			Area of coral reef ecosystems and percentage live cover
Theme	*Sub-theme*	Core indicator	Other indicator
Freshwate	Water	Proportion of total water resources used	

r	quantity	Water use intensity by economic activity	
	Water quality	Presence of faecal coliforms in freshwater	Biochemical oxygen demand in water bodies
			Wastewater treatment
Biodiversity	Ecosystem	Proportion of terrestrial area protected, total and by ecological region	Management effectiveness of protected areas
			Area of selected key ecosystems
			Fragmentation of habitats
	Species	Change in threat status of species	Abundance of selected key species
			Abundance of invasive alien species
Economic development	Macroeconomic performance	Gross domestic product (GDP) per capita	Gross saving
		Investment share in GDP	Adjusted net savings as percentage of gross national income (GNI)
			Inflation rate
	Sustain able	Debt to GNI ratio	
	Employment	Employment-	Vulnerable employment
		Labor productivity and unit	
		Share of women in wage employment in the non-agricultural sector	
	Information and communication technolo	Internet users per 100 population	Fixed telephone lines per 100 population
			Mobile cellular telephone subscribers per 100 population
Theme	*Sub-theme*	Core indicator	Other indicator
Freshwater	Water quantity	Proportion of total water resources used	
		Water use intensity by economic activity	
	Water quality	Presence of faecal coliforms in freshwater	Biochemical oxygen demand in water bodies
			Wastewater treatment

Biodiversity	Ecosystem	Proportion of terrestrial area protected, total and by ecological region	Management effectiveness of protected areas
			Area of selected key ecosystems
			Fragmentation of habitats
	Species	Change in threat status of species	Abundance of selected key species
			Abundance of invasive alien species
Econom ic develop ment	Macroec onomic perform ance	Gross domestic product (GDP) per capita	Gross saving
		Investment share in GDP	Adjusted net savings as percentage of gross national income (GNI)
			Inflation rate
	Sustain able	Debt to GNI ratio	
	Employment	Employment-	Vulnerable employment
		Labor productivity and unit	
		Share of women in wage employment in the non-agricultural sector	
	Informat ion and commun ication technolo	Internet users per 100 population	Fixed telephone lines per 100 population
			Mobile cellular telephone subscribers per 100 population
Theme	*Sub-theme*	Core indicator	Other indicator
Econom ic develop ment	Research and		Gross domestic expenditure on R&D as a percent of GDP
	Tourism	Tourism contribution to GDP	
Global econom ic partner ship	Trade	Current account deficit as percentage of GDP	Share of imports from developing countries and from LDCs
			Average tariff barriers imposed on
	External financing	Net Official Development Assistance (ODA) given or received as a percentage	Foreign direct investment (FDI) net inflows and net outflows as percentage of GDP
			Remittances as percentage of GNI

Consumption and production patterns	Material consumption	Material intensity of the economy	Domestic material consumption
	Energy use	Annual energy consumption, total and by	Share of renewable energy sources in total energy use
		Intensity of energy use, total and by economic activity	
	Waste generation and managemen	Generation of hazardous waste	Generation of waste
		Waste treatment and disposal	Management of radioactive waste
	Transportation	Modal split of passenger	Modal split of freight transport
			Energy intensity of transport

Global City Indicators Facility Indicators

Theme	Indicator
People	Total city population
	Population density (per square kilometer)
	Percentage of country's population
	Percentage of population that are children (0-14)
	Percentage of population that are youth (15-24)
	Percentage of population that are adult (25-64)
	Percentage of population that are senior citizens (65+)
	Male to female ratio (# of males per 100 females)
	Annual population change
	Population Dependency Ratio
	Percentage of population that are new immigrants
	Percentage of population that are migrating from elsewhere in
Housing	Total number of households
	Total number of occupied dwelling units (owned & rented)
	Persons per unit
	Dwelling density (per Square Kilometer)
Economy	Average household income (US$)
	Annual inflation rate based on average of last 5 years
	Cost of living
	Income distribution (Gini Coefficient)
	Country's GDP (US$)
	Country's GDP per capita (US$)
	City Product per capita (US$)
	City Product as a percentage of Country's GDP
	Total employment
	Employment percentage change based on the last 5 years
	Number of Businesses per 1000 Population
	Annual average unemployment rate
	Commercial/industrial assessment as a percentage of total
Government	Type of government (e.g. Local, Regional, County)
	Gross operating budget (US$)
	Gross operating budget per capita (US$)
	Gross capital budget (US$)
	Gross capital budget per capita (US$)
Geography and Climate	Region
	Climate Type
	Land Area (Square Kilometers)
	Percentage of non-residential area (square kilometers)
	Annual average temperature (Celsius)
	Average annual rain (mm)
	Average annual snowfall (cm)

	Core Indicator	Supporting Indicator
City Services		
Education	Student/teacher ratio	Percentage of school-aged population enrolled in schools
	Percentage of students completing primary and secondary education:	Percentage of male school-aged population enrolled

	Percentage of students completing primary education	Percentage of female school-aged population
	Percentage of students completing secondary education	
Fire and Emergency Respons	Number of firefighters per 100,000 population	Response time for fire department from initial call
	Number of fire related deaths per 100,000 population	
Health	Number of in-patient hospital beds per 100,000 population	Number of nursing and midwifery personnel per
	Number of physicians per 100,000	
	Average life expectancy	
	Under age five mortality per 1,000 live	
Recreation		Square metres of public indoor recreation space
		Square metres of public outdoor recreation space per capita
Safety	Number of police officers per 100,000 population	Violent crime rate per 100,000 population
	Number of homicides per 100,000	
Solid waste	Percentage of city population with regular solid waste collection	Percentage of the city's solid waste that is disposed of in an
	Percentage of city's solid waste that is recycled	Percentage of the city's solid waste that is burned openly
		Percentage of the city's solid waste that is disposed of in an
		Percentage of the city's solid waste that is disposed of in a
		Percentage of the city's solid waste that is disposed of by other
Transportation	Km of high capacity public transit system per 100,000 population	Number of two-wheel motorized vehicles per
	Km of light passenger transit system per 100,000 population	Commercial Air Connectivity (number of nonstop commercial
	Number of personal automobiles per capita	Transportation fatalities per 100,000 population
	Annual number of public transit trips per capita	
Wastewater	Percentage of city population served by	Percentage of the city's
	wastewater collection	receiving primary treatment
	Percentage of the city's wastewater that	Percentage of the city's
		Percentage of the city's
Water	Percentage of city population with potable	Total water consumption per
	Domestic water consumption per capita	Percentage of water loss
	Percentage of city population with	Average annual hours of water
Energy	Percentage of city population with	Total electrical use per capita
	Total residential electrical use per capita	The average number of electrical
		Average length of electrical
Finance	Debt service ratio (debt service	Tax collected as percentage of tax

		Own-source revenue as a
		Capital spending as a percentage
Governance		Percentage of women employed in
Urban	Jobs/Housing ratio	Areal size of informal settlements
		Green area (hectares) per 100,000
	Core Indicator	Supporting Indicator
Quality of Life		
Civic Engageme nt	Voter participation in last municipal election (as a percent of eligible voters)	Citizen's representation: number of local officials elected to office per 100,000
Culture		Percentage of jobs in the cultural
Economy		Percentage of persons in full time employment
Environment	PM10 concentration	Greenhouse gas emissions measured in tonnes per capita
Shelter	Percentage of city population living in slums	Percentage of households that exist without registered legal
		Number of homeless people per 100,000
Social Equity		Percentage of city population living in poverty
Technolog y & Innovation	Number of internet connections per 100,000 population	Number of new patents per 100,000 per year
		Number of higher education degrees
		Number of telephone connections (landlines and cell phones) per
		Number of landline phone connections
		Number of cell phone connections per

Future Indices Under Development

Economy	Competitiveness Index
Energy	Total Energy Use Index
Environment	Greenhouse Gas Index
Governance	Governance Index
Recreation and Culture	Recreation and Culture Index
Social Equity	Social Capital Index
Subjective Well-Being	Subjective Well-Being Index

Transportation	Urban Accessibility Index
Technology	Creativity Index
Water	Water Quality Index

China Urban Sustainability Index

23 indicators are included in four categories with emphasis on Society and Environment

Bold = indicator not in USI 2011

Category (weight = 100%)		Components (weight within category = 100%)	Indicators
Society (33%)	Social welfare (33%)	**Employment (25%)**	**Urban employment rate (%)**
		Doctor resource (25%)	**Number of doctors per capita (per thousand persons)**
		Education (25%)	**Middle school students in young population (%)**
		Pension (13%)	**Pension security coverage (%)**
		Healthcare (13%)	**Health care security coverage (%)**
Environment (33%)	Cleanliness (17%)	Air pollution (11%)	Concentration of SO2, NO2, PM10 (mg per cubic meter)
		Industrial pollution (11%)	Industrial SO2 discharged per unit GDP (tons per bn RMB)
		Air qualified days (11%)	**Days of air qualified equal or above level II[1] (%)**
		Waste water treatment (11%)	Wastewater treatment rate (%)
		Household waste management (5%)	Domestic waste treated (%)
	Built environment (17%)	Urban density (11%)	Persons per square kilometer of urban area
		Mass transit usage (11%)	Passengers using public transit (per capita)
		Public green space (11%)	Area of public green space (%)
		Public water supply (5%)	**Public water supply coverage (%)**
		Internet access (11%)	**Household access to Internet (%)**
Economy (17%)	Economic development (17%)	**Income level (33%)**	**Disposable income per capita**
		Reliance on heavy industry (33%)	GDP from service industry (%)
		Capacity investment (33%)	Government investment in R&D (per capita)
Resources (17%)	Resource utilization (17%)	Energy consumption (33%)	Total energy consumption (SCE per unit GDP)
		Power efficiency (33%)	Residential power consumption (kwh per capita)
		Water efficiency[2] (33%)	**Total water consumption (liters per unit GDP)**

1 Air qualified days defined as days qualified equal or above Air Pollution Index level II. There are six levels by API. Level II means air quality is general acceptable to public, except for specially sensitive population.
2 Cities are classified by water resource and then are scored within their own group to minimize distortion by natural water resource

SOURCE: McKinsey analysis, UCI

UN Development Goals 2015-2030 - Goal 11: Sustainable Cities and Communities

SUSTAINABLE DEVELOPMENT GOALS
17 GOALS TO TRANSFORM OUR WORLD

Home About Secretary-General Goals Take Action Key Dates Media Watch and Listen

Cities are hubs for ideas, commerce, culture, science, productivity, social development and much more. At their best, cities have enabled people to advance socially and economically.

However, many challenges exist to maintaining cities in a way that continues to create jobs and prosperity while not straining land and resources. Common urban challenges include congestion, lack of funds to provide basic services, a shortage of adequate housing and declining infrastructure.

The challenges cities face can be overcome in ways that allow them to continue to thrive and grow, while improving resource use and reducing pollution and poverty. The future we want includes cities of opportunities for all, with access to basic services, energy, housing, transportation and more.

Facts and figures | Goal 11 targets | Links

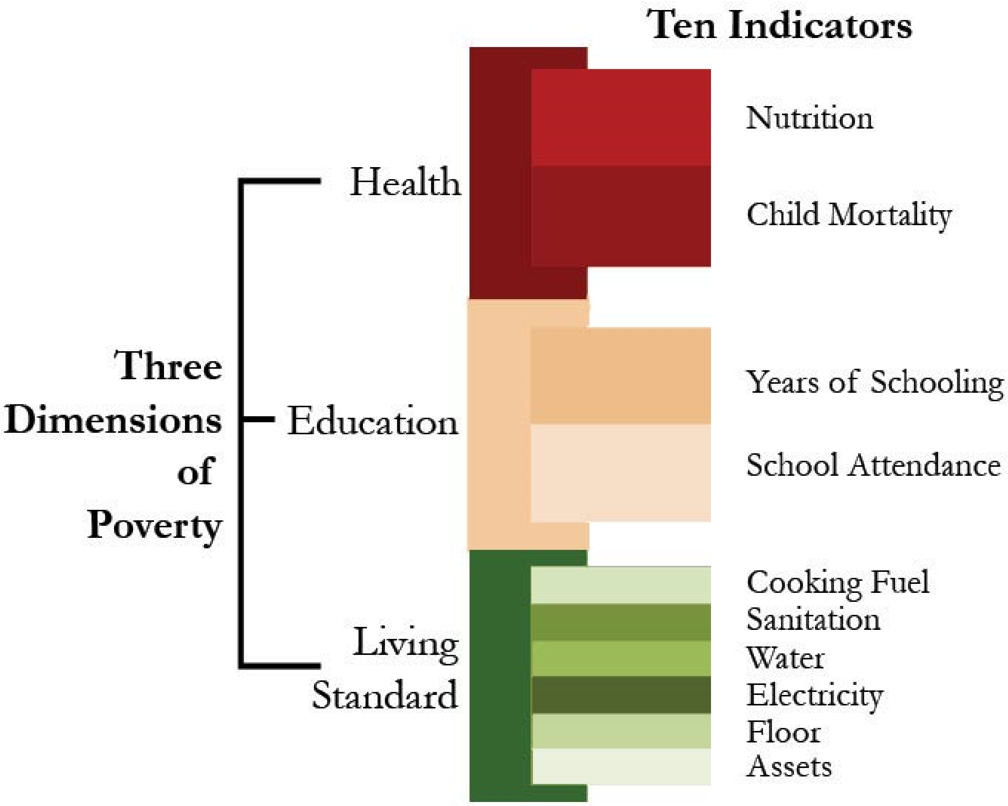
- By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums
- By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
- By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
- Strengthen efforts to protect and safeguard the world's cultural and natural heritage
- By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
- By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
- By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
- Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning
- By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
- Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

Urban Sustainability Indicator: European Foundation for the Improvement of Living and Working Conditions

Indicator	Data components/measure
Global climate	Emitted total CO_2, CH_4, N_2O and CFCs and halons
Air quality	Number of days per year on which alarm levels are exceeded and traffic circulation is stopped
Acidification	Deposition of SO_2, NO_2 and NH_3 per hectare
Ecosystem toxification	Sum of emitted quantities of cadmium, polyaromatic hydrocarbons, mercury, dioxin, epoxyethane, fluorides and copper, and radioactive substances, weighted according to their toxicity and their residence time in the environment
Urban mobility/clean transport	Total number of trips (and their length) by private car and number of trips, (and their length) for commuting and basic needs/inhabitant/year
Waste management	Tonnes of waste disposed of per inhabitant and per year (building and demolition waste, industrial waste, domestic waste, retail and service waste)
Energy consumption	Tonnes of oil equivalent per inhabitant per year for domestic use, industrial use, the tertiary sector and public spaces
Water consumption	Metres[3] per inhabitant per year (total water extracted minus water from recycling and water used for maintenance of public and green spaces)
Nuisance	Percentage of the population affected by noise, odour or visual pollution
Social justice	Percentage of the population affected by poverty, unemployment, lack of access to education, information, training and leisure
Housing quality	Percentage of the population affected by lack of housing or poor housing environments
Urban safety	Total percentage of the population affected seriously by crime or traffic accidents
Economic urban sustainability	Total individual incomes in city minus: city fiscal deficit, environmental expenditure and pollution damage per inhabitant per year
Green, public space and heritage	Percentage of green or public spaces and local heritage in need of improvement
Citizen participation	Total percentage of the population participating in local elections or as active members in associations for urban improvement and quality of life
Unique sustainability	To be defined by cities — this indicator should represent the degree to which unique factors or events lead to urban sustainability with its environmental, social and economic dimensions

Global Multidimensional Poverty Index

http://www.ophi.org.uk/multidimensional-poverty-index/



References

Adger, W. N. (2006). Vulnerability. *Global Environmental Change, 16*(3), 268-281.

Anisimov, O. A., Belolutskaya, M. A., Grigoriev, M. N., Instanes, A., Kokorev, V. A., Oberman, N. G., . . . Shiklomanov, N. I. (2010). Major Natural and Social-Economic Consequences of Climate Change in the Permafrost Region: Predictions based on Observations and Modeling. Moscow: Greenpeace.

Arctic Mapping and Assessment Programme. (2012). *Arctic Climate Issues 2011: Changes in Arctic Snow, Water, Ice and Permafrost. SWIPA 2011 Overview Report. Arctic Monitoring and Assessment Programme (AMAP)*. Oslo: AMAP.

Barber, B. R. (2013). *If Mayors Ruled the World: Dysfunctional Nations, Rising Cities*. New Haven: Yale University Press.

Böhringer, C., & Jochem, P. E. P. (2006). *Measuring the Immeasurable – A Survey of Sustainability Indices Discussion Paper No. 06-073*. Oldenburg: Center for European Economic Research.

Brose, D. A. (2015). *Developing a Framework for Measuring Community Resilience: Summary of a Workshop*. Washington, DC: The National Academies Press.

Commander, S., & Jackman, R. (1997). Firms and Government in the Provision of Benefits in Russia. In M. Rein & B. L. Friedman (Eds.), *Enterprise and Social Benefits after Communism*. Cambridge: Cambridge University Press.

Commander, S., Nikoloski, Z., & Plekhanov, A. (2011). Employment Concentration and Resource Allocation: One-Company Towns in Russia. *IZA DP No. 6034*. http://ftp.iza.org/dp6034.pdf

Cooke, N. J., & Hilton, M. L. (Eds.). (2015). *Enhancing the Effectiveness of Team Science*. Washington: National Academies Press.

Cooley, A. (2015). The Emerging Politics of International Rankings and Ratings: A Framework for Analysis. In A. Cooley & J. Snyder (Eds.), *Ranking the World: Grading States as a Tool of Global Governance*. New York: Cambridge Univesity Press.

Crowley, S. (2015). Monotowns, Economic Crisis, and the Politics of Industrial Restructuring in Russia. *Russian Analytical Digest*(164), 7-10.

Davis, K. E., Kingsbury, B., & Merry, S. E. (2012). Introduction: Global Governance by Indicators. In K. E. Davis, A. Fisher, B. Kingsbury, & S. E. Merry (Eds.), *Governance by Indicators: Global Power through Quantification and Rankings*. Oxford: Oxford University Press.

Einarsson, N., Larsen, J. N., Nilsson, A., & Young, O. R. (2004). *Arctic Human Development Report*. Akureyr, Iceland: Stefansson Arctic Institute.

Esty, D. C., & Porter, M. E. (2005). National environmental performance: an empirical analysis of policy results and determinants. *Environment and development economics, 10*(4), 391-434.

Fallows, J. a. D. (2016). Eleven Signs a City Will Succeed. *The Atlantic*(March).

Gardner, G. (2016). Imagining a Sustainable City. In W. Institute (Ed.), *State of the World: Can a City Be Sustainable?* (pp. 3-9). Washington: Island Press.

Grebenets, V., Streletskiy, D., & Shiklomanov, N. (2012). Geotechnical Safety Issues in the Cities of Polar Regions. *Geography, Environment, Sustainability Journal, 5*(3), 104-119.

Heleniak, T. (2013). Boom and Bust: Population Change in Russia's Arctic Cities. http://www.gwu.edu/~ieresgwu/assets/docs/Heleniak_BoomandBust%20PopulationChange.pdf

Huang, L., Wu, J., & Yan, L. (2015). Defining and Measuring Urban Sustainability: A Review of Indicators. *Landscape Ecology, 30*(7), 1175-1193.

Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Geneva: IPCC.

Jull, M. G., & Cho, L. S. (2013). Architecture and Urbanism of Arctic Cities: Case Study of Resolute Bay and Norilsk. http://www.gwu.edu/~ieresgwu/assets/docs/JULL_CHO_%20Architecture%20_Urbanism_of%20Arctic%20Cities_FINAL_X.pdf

Katz, B., & Bradley, J. (2013). *The Metropolitan Revolution: How Cities and Metros Are Fixing Our Broken Politics and Fragile Economy*. Washington DC: Brookings Institution Press.

Kern, K., & Alber, G. (2008). *Governing climate change in cities: modes of urban climate governance in multi-level systems. Proceedings of the OECD Conference on "Competitive Cities and Climate Change"*. Paris: OECD.

Krajnc, D., & Glavič, P. (2005). A Model for Integrated Assessment of Sustainable Development. *Resources, Conservation and Recycling, 43*(2), 189-208.

Larsen, J., Schweitzer, P., & Petrov, A. (Eds.). (2014). *Arctic Social Indicators: ASI II Implementation*. Copenhagen: Nordic Council of Ministers.

Larsen, J. N., Schweitzer, P., & Fondahl, G. (2010). *Arctic Social Indicators*. Copenhagen: Nordic Council of Ministers.

Li, X., Li, X., Woetzel, J., Zhang, G., & Zhang, Y. (2014). *The China Urban Sustainability Index 2013*: McKinsey Global Institute and the Urban China Initiative.

Libman, A., & Obydenkova, A. (2016). Economic Reforms in Ukraine in Comparative Perspective: Formal and Informal Dimensions. In H. E. Hale & R. W. Orttung (Eds.), *Beyond the Euromaidan: Comparative Perspectives on Advancing Reform in Ukraine*. Stanford: Stanford University Press.

Lonergan, S., Difrancesco, R., & Woo, M. K. (1993). Climate change and transportation in Northern Canada: an integrated impact assessment. *Climatic Change, 24*, 331-351.

Marcus, A. (2008). Place With No Dawn - A Town's Evolution and Erskine's Arctic Utopia. In R. W. Liscombe (Ed.), *Architecture and the Construction of the Canadian Fabric*. Vancouver: University of British Columbia Press.

McMann, K. M., & Petrov, N. V. (2000). A Survey of Democracy in Russia's Regions. *Post-Soviet Geography and Economics, 41*, 155–182.

Mega, V., & Pedersen, J. (1998). *Urban Sustainability Indicators*. Dublin, Ireland: European Union The European Foundation for the Improvement of Living and Working Conditions.

Nardo, M., Saisana, M., Saltelli, A., & Tarantola, S. (2005). *Tools for Composite Indicators Building*: European Commission Joint Research Centre.

National Research Council. (2008). *Potential Impacts of Climate Change on U.S. Transportation*. Washington, D.C.: Transportation Research Board.

National Research Council. (2014). *Culture Matters: International Research Collaboration in a Changing World (Summary of a Workshop)*. Washington, DC: The National Academies Press.

Niemeijer, D., & de Groot, R. S. (2008). A Conceptual Framework for Selecting Environmental Indicator Sets. *Ecological Indicators, 8*(1), 14-25.

Organization for Economic Cooperation and Development. (1993). *OECD Environmental Indicators: Development Measurement and Use*. Paris: OECD.

Pearce, D. W., & Atkinson, G. D. (1993). Capital Theory and the Measurement of Sustainable Development: An Indicator of “Weak” Sustainability. *Ecological Economics, 8*(2), 103-108.

Petrov, A. N., BurnSilver, S., Chapin, T., Fondahl, G., Graybill, J., Keil, K., . . . Schweitzer, P. (2015). *Arctic Sustainability Research: Agenda 2025*. Cedar Falls: University of Northern Iowa.

Portney, K. E. (2013). *Taking Sustainable Cities Seriously: Economic Development, the Environment, and Quality of Life in American Cities*. Cambridge: The MIT Press.

Rasmussen, R. O. (2011). *Megatrends*. Copenhagen: Danish Ministry of Foreign Affairs in collaboration with the Nordic Council of Ministers.

Sachs, J. D. (2015). *The Age of Sustainable Development*. New York: Columbia University Press.

Schneider, A. (2012). Monitoring land cover change in urban and peri-urban areas using dense time stacks of Landsat satellite data and a data mining approach. *Remote Sensing of Environment*(124), 689-704.

Science for Environment Policy. (2015). *Indicators for sustainable cities. In-depth Report 12*. Produced for the European Commission DG Environment by the Science Communication Unit, UWE, Bristol.

Shields, D. J., Šolar, S. V., & Martin, W. E. (2002). The Role of Values and Objectives in Communicating Indicators of Sustainability. *Ecological Indicators, 2*(1), 149-160.

Slabuha, A. (2007). Norilsk has been conceived as a system of architectural ensembles. *Arkhitekturnyi Vestnik, 6*(99), 19-21.

Snyder, J., & Alexander, C. (2015). Conclusion: Rating the Ratings Craze: From Consumer Choice to Public Policy Outcomes. In A. Cooley & J. Snyder (Eds.), *Ranking the World: Grading States as a Tool of Global Governance* (pp. 178-193). New York: Cambridge University Press.

Steward, W. C., & Kuska, S. B. (2011). *Sustainometrics: Measuring Sustainability*. Norcross, GA: Ostberg Library of Design Management.

Stone, C. (2012). Problems of Power in the Design of Indicators of Safety and Justice in the Global South. In K. E. Davis, A. Fisher, B. Kingsbury, & S. E. Merry (Eds.), *Governance by Indicators: Global Power through Quantification and Rankings*. Oxford: Oxford University Press.

Streletskiy, D., Anisimov, O., & Vasiliev, A. (2014). Permafrost Degradation. In W. Haeberli & C. Whiteman (Eds.), *Snow and Ice-Related Hazards, Risks and Disasters*. Amsterdam: Academic Press.

Streletskiy, D. A., Shiklomanov, N. I., & Nelson, F. E. (2012). Permafrost, Infrastructure and Climate Change: A GIS-based Landscape Approach. *Arctic, Antarctic and Alpine Research, 44*(3), 368-380.

Tanguay, G. A., Rajaonson, J., Lefebvre, J.-F., & Lanoie, P. (2009). *Measuring the Sustainability of Cities: A Survey-Based Analysis of the Use of Local Indicators*. Montreal: Cirano.

United Nations. (2007). *Indicators of Sustainable Development: Guidelines and Methodologies, Third Edition*. New York: United Nations.

United Nations Conference on Environment & Development. (1992). *Agenda 21*. Rio de Janerio: United Nations.

United Nations Environment Programme. (1972). Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration). http://www.unep.org/documents.multilingual/default.asp?documentid=97&articleid=1503

Whiteman, G., Hope, C., & Wadhams, P. (2013). Climate science: Vast costs of Arctic change. *Nature, 499*, 401-403. doi: 10.1038/499401a

Wilson, S., Pearson, L. J., Kashima, Y., Lusher, D., & Pearson, C. (2013). Separating Adaptive Maintenance (Resilience) and Transformative Capacity of Social-Ecological Systems. *Ecology and Society, 18*(1), 22.

World Commission on Environment and Development. (1987). Our Common Future (Brundtland Report). http://www.un-documents.net/our-common-future.pdf

Zaloznaya, M., & Hagan, J. (2012). Fighting Human Trafficking or Instituting Authoritarian Control? The Political Co-optation of Human Rights Protection in Belarus. In K. E. Davis, A. Fisher, B. Kingsbury, & S. E. Merry (Eds.), *Governance by Indicators: Global Power through Quantification and Rankings*. Oxford: Oxford University Press.