Policy Insights

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SUSTAINABLE GREAT LAKES

A Regional Assessment of Sustainability in the Binational Great Lakes Megaregion

Dr. Daniel Hoornweg, Associate Dean and Professor; Richard Marceau Chair, Faculty of Energy Systems and Nuclear Science, Ontario Tech University

Mark Fisher, President and CEO, Council of the Great Lakes Region

Acknowledgments

About Ontario Tech University

The University of Ontario Institute of Technology is Canada's emerging leader in career-ready education and collaborative research that produces new and useful ideas. A fast-growing university with ambitious expansion plans, we are committed to social, scientific and economic innovations that create a better Canada and a better world.

About the Council of the Great Lakes Region (CGLR)

CGLR is a binational network of organizations comprised of: (1) Council of the Great Lakes Region, an Ohio nonprofit corporation exempt from federal income tax under section 501(a) of the Internal Revenue Code of 1986 (as amended, the "Code") and classified as a trade association described in Code section 501(c)(6) ("CGLR USA"); (2) CGLR Foundation, an Ohio nonprofit corporation exempt from federal income tax under section 501(a) of the Code and classified as a public charity described in Code section 501(c)(3) ("CGLR Foundation"); and Council of the Great Lakes Region, a Canadian nonprofit corporation ("CGLR Canada").

Together, the CGLR focuses on deepening the United States-Canada relationship in the Great Lakes economic region, and creating stronger, more dynamic cross-border collaborations in harnessing the region's economic strengths and assets, improving the well-being and prosperity of the region's citizens, and protecting the Great Lakes watershed for future generations. It achieves this mandate by connecting regional leaders through the annual Great Lakes Economic Forum and sector dialogues, exploring key trends shaping the region and proposing solutions and strategies that move the region forward through public policy research, and acting as a strong voice for the region's varied interests.

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SANDUSKY, OHIO, LAKE ERIE

Executive Summary

For over fifty years, governments around the world, including in Canada, discussed the importance of sustainability or sustainable development. The term rose to prominence through the work of the United Nations' 'Brundtland Commission', which released the report, Our Common Future, in 1987.

Sustainable development, in short, means ensuring that development can meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development also infers that there are socioeconomic and environmental boundaries and inter-relationships that must be understood and balanced if we are to maintain the health of the planet – and our own prosperity and well-being.

Sustainability has enjoyed far more talk than concrete action. Since 1990, for example, the international community has convened 12 major conferences with an aim to promote sustainability. Taken together, these high-profile events have provided a "global consensus" on the "priorities" for a new approach that reconciles the at-times competing demands of the environment, economy and society.

One of the more prominent undertakings was the Rio Summit in Brazil in 1992, which led to the creation of Agenda 21. Subsequently, the Millennium Development Goals were adopted by the United Nations in 2000. These were followed by the Sustainable Development Goals (SDG's) adopted in 2015. But, yet again, we are unlikely to achieve any of the 17 SDGs by the target date of 2030. That's because our ability to achieve 'sustainability' where it counts most, at the sub-national level and in our cities, remains a significant challenge, largely because a unifying framework for making sustainable management and investment decisions is lacking. This is especially the case with infrastructure spending.

Therefore, as governments contemplate massive financial stimulus in response to COVID-19, at levels far greater than the Great Recession of 2008, and now

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beyond the equivalent of the Depression in the 1930s, it's time to mainstream the application of sustainability cost curves, an innovative decision-making framework developed by Ontario Tech University that is being tested in the binational Great Lakes economic region in collaboration with the Council of the Great Lakes Region, as illustrated below for a series of projects in the Greater Toronto Area.

Using 60 biophysical and socioeconomic indicators, built from open data sources, as a baseline for sustainability, the sustainability cost curve tool can then be used to help all levels of government, as well as private sector investors, assess and compare the sustainability impact of physical infrastructure and systems, within a city, across cities, and even at larger scales like the binational Great Lakes economic region, providing a means to prioritize. This approach also helps to present infrastructure and investment choices to the public, as well as measure and compare the overall sustainability of a city to other cities around the world, and regions to other regions.

As Peter Drucker once said, "if you can't measure it, you can't improve it." Without consistent sustainability metrics for decision-making and investing, there is no answer to 'where are we going' and 'what impact are we having,' and there is no way to balance economic prosperity and environmental conservation.

Global, national, provincial, and local sustainability goals need to be anchored together, on-the-ground. Incorporating sustainability cost curves and a 'factor of sustainability' into our infrastructure planning and decision-making, much like how an engineer defines a 'factor of safety' when designing a new building, would be an excellent start and the post-pandemic recovery provides the perfect opportunity.

To accomplish this task, no new government agencies are needed, and arguably, the forums for multisector collaboration and financing required to achieve sustainability already exist. Rather, a shared definition of what sustainability is and what future we are striving for, is needed, a vision and action plan that is specific, measurable, attainable, realistic, and time-bound.

This report outlines a sustainability framework that can be used to establish a common 'sustainability' purpose in the binational Great Lakes region and the direction and targets required to monitor progress and adjust actions accordingly. Finally, this report also provides recommendations, summarized below, for the next steps on the journey toward a more sustainable, prosperous Great Lakes region:

RECOMMENDATIONS

1. **The Council of the Great Lakes Region (CGLR) should post the results of the sustainability assessment and provide regular updating (see Tables 1 and 2).**
2. **CGLR should canvas representatives within the Region to provide input and regular updating of the assessment tool.**
3. **CGLR and other stakeholders should encourage the national governments of Canada and the United States, the eight US states, the provinces of Ontario and Quebec, plus the more than 8000 municipalities that make up the Great Lakes Region, to annually publish their sustainability assessment (or delegate the measurement).**
4. **Key financiers, including impact investors and infrastructure funders, such as the Canada Infrastructure Bank and the United States Department of Transportation, should apply a sustainability assessment against all proposed impact and infrastructure investments in the Region in excess of $10 million.**
5. **The eight US states and the provinces of Ontario and Quebec should each appoint a representative to CGLR for a three-year term to serve as 'sustainability ambassador' of the Great Lakes Region.**
6. **The scale of the Great Lakes Region lends itself to pragmatic, yet highly impactful initiatives, such as the electrification of mobility and shifts to a 'circular economy'. The Great Lakes Region is therefore an optimum location to catalyze and trial a sustainability mindset in governing and building the region's future.**

The alternative to this sustainability framework, which favours spending billions of taxpayer dollars on random 'shovel-ready' projects, may do little to build the smart, sustainable, resilient Great Lakes cities and infrastructure that will enable us to live within society's goals and the earth's natural boundaries. What we build today will be with us for the next 30 to 50 years. We must build sustainably.

Introduction

The economic heft of the binational Great Lakes Region is enormous; if it were its own country, it would be the third largest economy in the world, surpassing major economies like Japan, the United Kingdom and Germany. However, perhaps more important than the region's economic size and output is the leadership role the region plays in powering the competitiveness and social progress of both countries.

Anchoring the economies of Canada and the United States, the Great Lakes region, home to roughly 107 million people, is the industrial and academic heartland of North America, supporting a sizeable portion of American and Canadian manufacturing and food production, innovation, research, talent development, and jobs. The region's economic history and achievements are remarkable, with infrastructure playing a critical role in the region's development. The region's area coincides with the watersheds feeding into the Great Lakes and St. Lawrence River and contiguous states and provinces. The US states on Pennsylvania and New York are divided between the Great Lakes and Boston – New York – Washington megaregions (Figure 1).

The Erie Canal, for example, opened in 1825, shifting the locus of development north along the eastern seaboard from Philadelphia to New York City. The Great Lakes and St. Lawrence Seaway, completed in 1959, opened the region to international shipping. And, the expansion of roads, rail lines, and ports in places like Chicago and Toronto transformed both cities into key clusters for regional, continental, and global commerce.

With over 20,000 miles of highways, 50,000 miles of rail lines and close to 70 intermodal terminals, 15 large international marine ports and 50 regional marine ports, and 12 of the top 50 North American airports, this binational, multimodal, transportation system now moves more than 50 percent of cross-border goods trade between the United States and Canada every year and over $1.0 trillion in global merchandise trade.

FIGURE 1: AREA REPRESENTED BY THE GREAT LAKES REGION

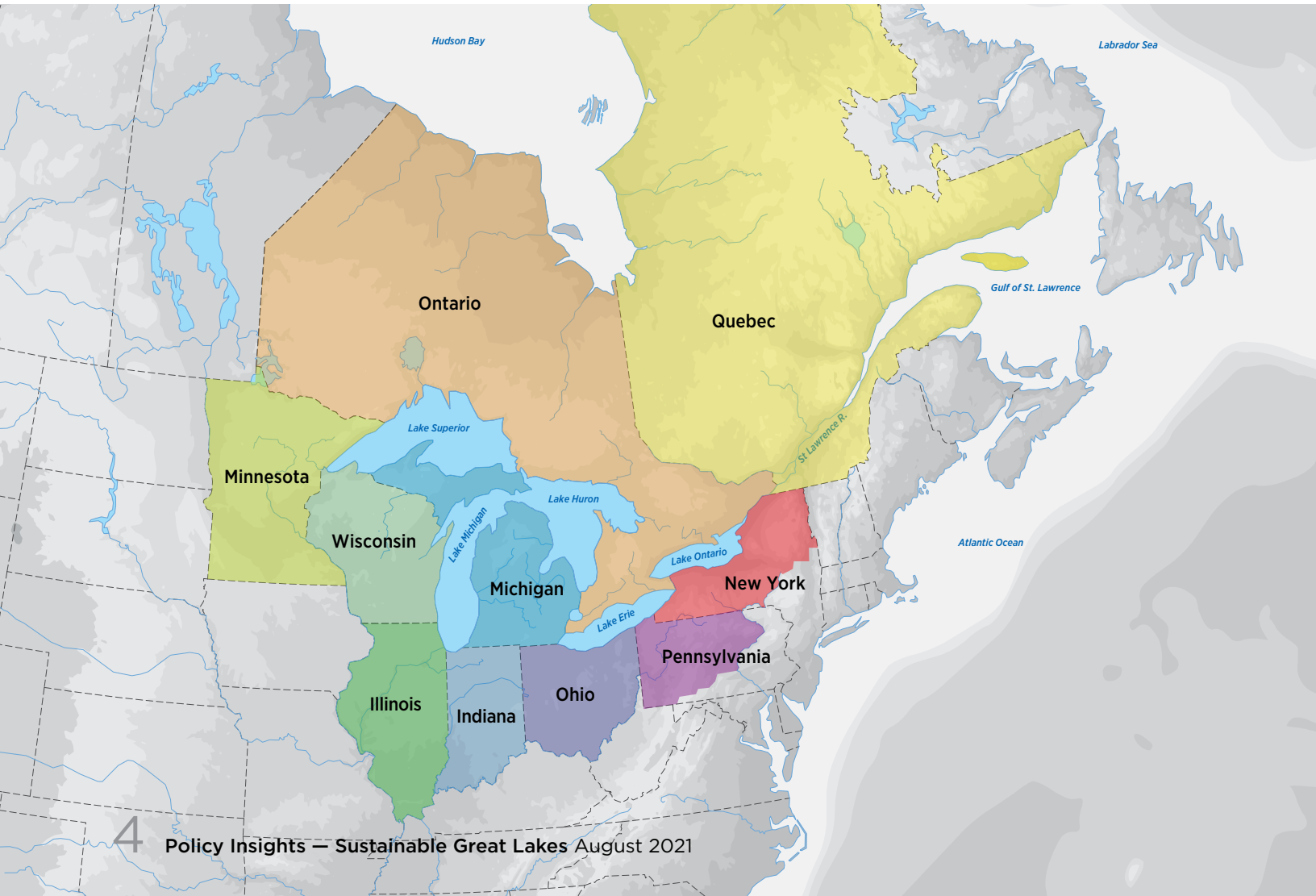
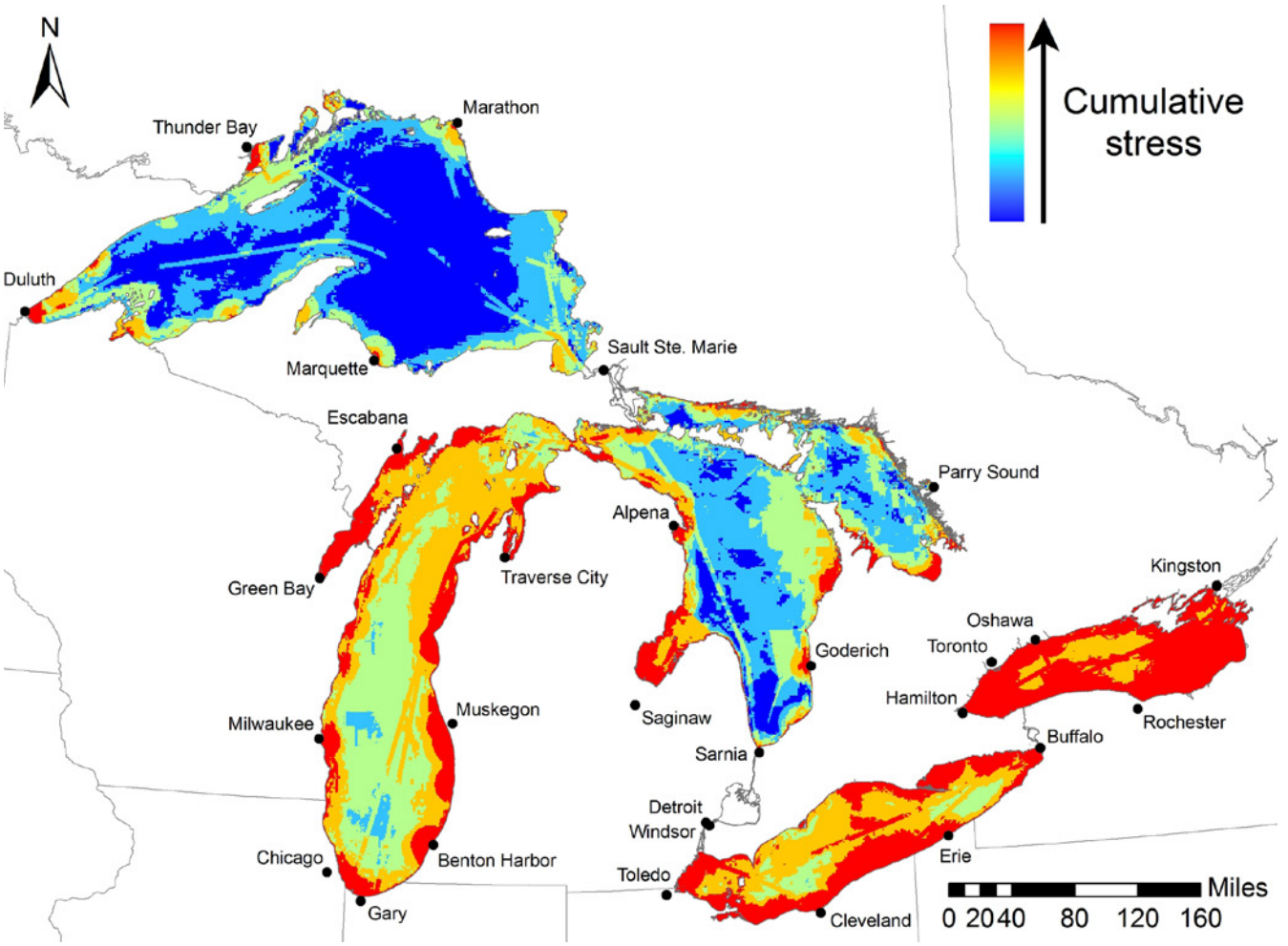


FIGURE 2: CUMULATIVE STRESSES ON THE GREAT LAKES (from Allan *et al*, 2013)



Source: Great Lakes Environmental Assessment and Mapping (GLEAM) Project

Distributed electricity had its start with Niagara Falls in the late 1890s after the great current standards war was largely settled at the 1893 Chicago World's Fair once Nikola Tesla and George Westinghouse, promoting AC transmission, won the contract to light the Fair over Thomas Edison and his DC alternative.

Today, the Great Lakes region is a binational energy hub, supported by a vast network of powerlines and pipelines that distribute vital energy resources that fuel the region's homes, sectors and cities, from clean electricity generated by hydro and nuclear assets, to petroleum products that are refined and used for manufacturing consumer and industrial products.

Farming is one of the primary uses of land in the Great Lakes region and has always been a vital component of the region's economy. Ontario and Quebec account for roughly 58%, or $12.8 billion, of Canada's agriculture and agri-food trade to the United States, while the eight Great Lakes states account for roughly 34%, or $8.4 billion, of America's agriculture and agri-food trade to Canada.

The region's economic and social development, early on and even today, has not been without its challenges. The Great Lakes, the largest freshwater system in the world and a uniquely fragile ecosystem, as well as the region's environment generally, has been negatively impacted by the acceleration of urbanization and increased economic activity over the last century (Figure 2).

A by-product of building the Erie Canal and the St. Lawrence Seaway, for example, Sea Lamprey were introduced to the Great Lakes, as well as their connecting streams and rivers, decimating fish habitats and fish stocks. To illustrate the scale of the impact, before Sea Lamprey were able to migrate into the Great Lakes, the upper Great Lakes yielded an annual harvest of about 15 million pounds of Lake Trout. According to the Great Lakes Fishery Commission, by the 1960s, Lake Trout stocks plummeted to less than 300,000 pounds.

The region's industrialization resulted in increased water pollution and contaminated sediments from a variety of activities, such as mining, pulp and paper mills, manufacturing, chemical production, and steel fabrication.

A total of 43 Areas of Concerns (AOC) were identified by the United States and Canada, areas where a number of beneficial uses had been seriously impaired as a result of the contaminated sites and ecosystems. Between 1985 and 2019, US$22.78 billion was spent on restoring all AOCs.

The Great Lakes watershed supports an estimated 3,500 plant and animal species. However, sprawling development, farming, industrial activity, the inadvertent introduction of invasive species, and climate change have had a demonstrable impact on native habitats and species, altering the region's natural spaces and biodiversity in significant ways – potentially permanently. Distressingly, more than half of the region's biodiversity is now invasive and non-native (Hartig *et al*, 2020).

In response to the region's growth and the human impact on the Great Lakes ecosystem, residents around the region were the first to mobilize for environmental protection. Earth Day in 1970, still the largest ever one-day protest in America, was catalyzed in part by the Cuyahoga (Ohio), Buffalo (New York) and Rouge River (Michigan) fires and the funeral that was held for Lake Erie as phosphorous pollution choked the lake to death.

Within a year, the United States established the Environmental Protection Agency and passed the Clean Water, Clean Air, and Endangered Species Acts. Canadians were just as vocal in demanding action, which led to the creation of Pollution Probe, now Canada's oldest environmental charity, in 1969, as well as Environment Canada in 1971.

Jointly, Prime Minister Trudeau and President Nixon also signed the first Great Lakes Water Quality Agreement (GLWQA) in 1972, updated in 1978, 1987 and 2021, committing Canada and the United States to "restore and maintain the chemical, physical, and biological integrity of the Waters of the Great Lakes." The GLWQA was one of the first international treaties to take an ecosystems approach.

Furthermore, the United States and Canada signed an Air Quality Agreement in 1991 as a result of growing concerns over air pollution in shared airsheds, such as Detroit, Michigan and Windsor, Ontario, as well as the sources and impacts of acid rain on the environment and human health across the Great Lakes region and in eastern North America. It was amended in 2000 to include ground-level ozone.

Much earlier, the United States and Great Britain on behalf of Canada, signed the Boundary Waters Treaty of 1909, a flagship bilateral agreement that gave rise to the International Joint Commission and established a framework for managing the shared waters between Canada and the United States.

UNIVERSITY OF MICHIGAN STUDENTS PARTICIPATING IN A RALLY ON THE FIRST EARTH DAY, APRIL 22, 1970

UNIVERSITY OF MICHIGAN FLICKR PHOTO

Preparing for the Future: Measuring What Matters

The binational Great Lakes region is now buffeted by future trends. Pandemics that were predicted, but detailed preparation placed on the 'to-do list', are here. Climate change is already having an impact on the Region. And, the region could also experience increased residential pressure as more people want to move to the Great Lakes because of its relatively cooler climate and increasing area of agricultural productivity (Figure 3).

Change in the Great Lakes region will intensify thanks to a number of local, regional, continental, and global trends that are large and complex. The region has ample resources – wealth, innovation, institutions, infrastructure, and people with determination, to respond and create more sustainable pathways. However, sustainability itself has been difficult to measure, and 'if you can't measure it, you can't improve it'[1]. Consequently, similar to gross domestic product (GDP) as a way to capture a country's economy, a measure of sustainability is needed.

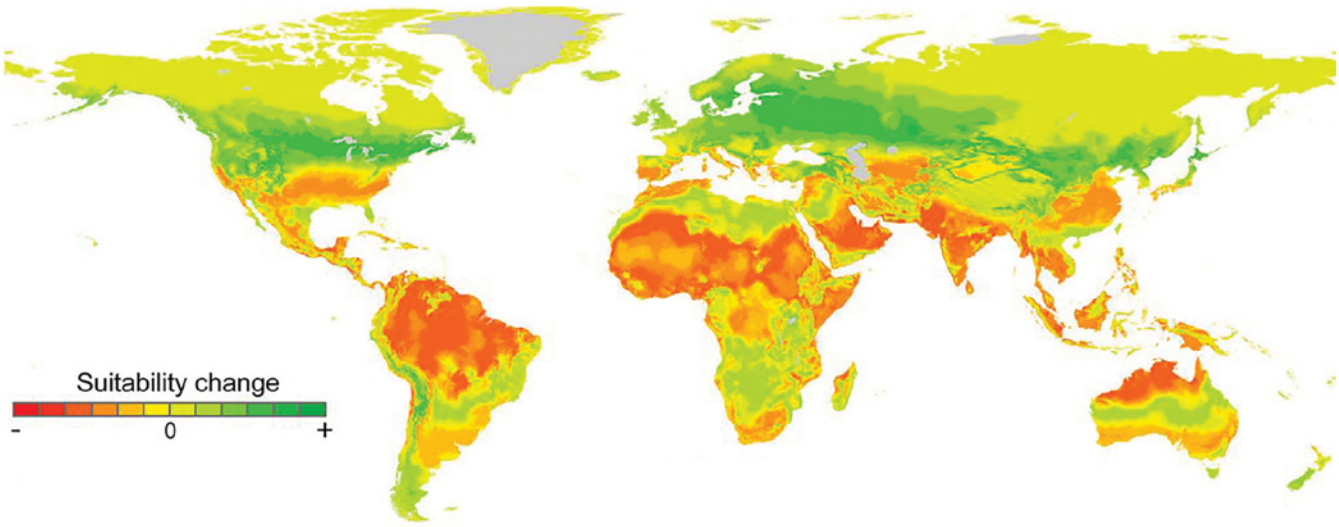
The concept of Gross Domestic Product (GDP) was used by Simon Kuznet to estimate the impact of the Depression on the United States economy in 1932. GDP was refined by John Maynard Keynes, and as World War II ended and the Bretton Woods institutions (IMF and World Bank) were created in 1944, the concept of GDP as a way to measure a country's economy was solidified.

GDP[2] has since become one of the most powerful drivers of politics, even though many argue that GDP fails to adequately capture the value of what matters most – nature and people. Kuznets understood the limitations of GDP when he noted to Congress that *"the welfare of a nation can scarcely be inferred from a measure of national income."* Robert F. Kennedy may have said it even better at the University of Kansas on March 18, 1968:

"Gross National Product counts air pollution and cigarette advertising, and ambulances to clear our highways of carnage. It counts special locks for our doors and the jails for the people who break them. It counts the destruction of the redwood and the loss of our natural wonder in chaotic sprawl. It counts napalm and counts nuclear warheads and armored cars for the police to fight the

1. Attributed to Peter Drucker
2. GDP is often used interchangeably with 'gross national product'. GNP that takes into account net income receipts from abroad.

FIGURE 3: PROJECTED GEOGRAPHICAL SHIFT OF HUMAN TEMPERATURE NICHE (from, Chi Xu *et al*, 2020. Based on RCP8.5 to 2070.)



[NB, this figure presents a 'worse case' scenario for emissions, i.e., RCP8.5, however this is indicative of the pressures the Great Lakes Region should anticipate as global climate shifts make the region relatively more attractive for agriculture and residency.]

riots in our cities. Yet the gross national product does not allow for the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country, it measures everything in short, except that which makes life worthwhile."

Alternatives, or supplements, to GDP have been proposed. Among the most prominent are: Genuine Progress Indicator (see GPI*Atlantic* http://gpiatlantic.org/gpi.htm); Human Development Index (UNDP started 1990, http://hdr.undp.org/en/2019-report) and; Gross National Happiness (King Wangchuck, Bhutan, 2008). These metrics have limitations as well, e.g., potential for political manipulation and irregular data reporting.

Another alternative suite of metrics is the Sustainable Development Goals (SDGs). The SDGs were updated from the Millennium Development Goals (MDGs) that were launched in 2000 with the support of 191 nations and 22 international organizations. There were eight goals with 21 targets to 2015. The SDGs replaced the MDGs in 2015 with 17 goals and 169 targets to 2030. However, like the MDGs, a 2019 UN report suggests that none of the SDG 17 goals are on track to be met by 2030 (and this was pre-pandemic)[3].

Learning from the ubiquity of GDP, as well as its limitations, along with the complexity of something as broad and politically contextual as sustainable development goals, measuring a megaregion's, a city's, or a community's socio-economic and environmental well-being (*i.e.*, sustainability) is inherently difficult. The majority of sustainability measures are at a national level (Annex 1), which is too broad for meaningful action against baselines, overlooking where the economy and society operates and where environmental degradation originates.

Many different sustainability indicators are needed to capture progress; similar to an airline pilot continuously checking altitude, location, wind speed, fuel and trim. Measuring sustainability is also like measuring the health of a patient. Baseline metrics, such as blood pressure and weight, measured over time and trends observed, are critical, ideally moving toward a better direction.

Furthermore, sustainability metrics for a city like Chicago must also be comparable to measures in Beijing, Kinshasa

3. See: https://unstats.un.org/sdgs/report/2019/

RISING WATER LEVELS, TORONTO ISLAND, LAKE ONTARIO 2020

and Toronto, and they must also be understandable to the homeowner in Cleveland, the state or provincial lawmaker in Michigan or Ontario, or the CEO of a Great Lakes company, whether it be a small or large multinational firm.

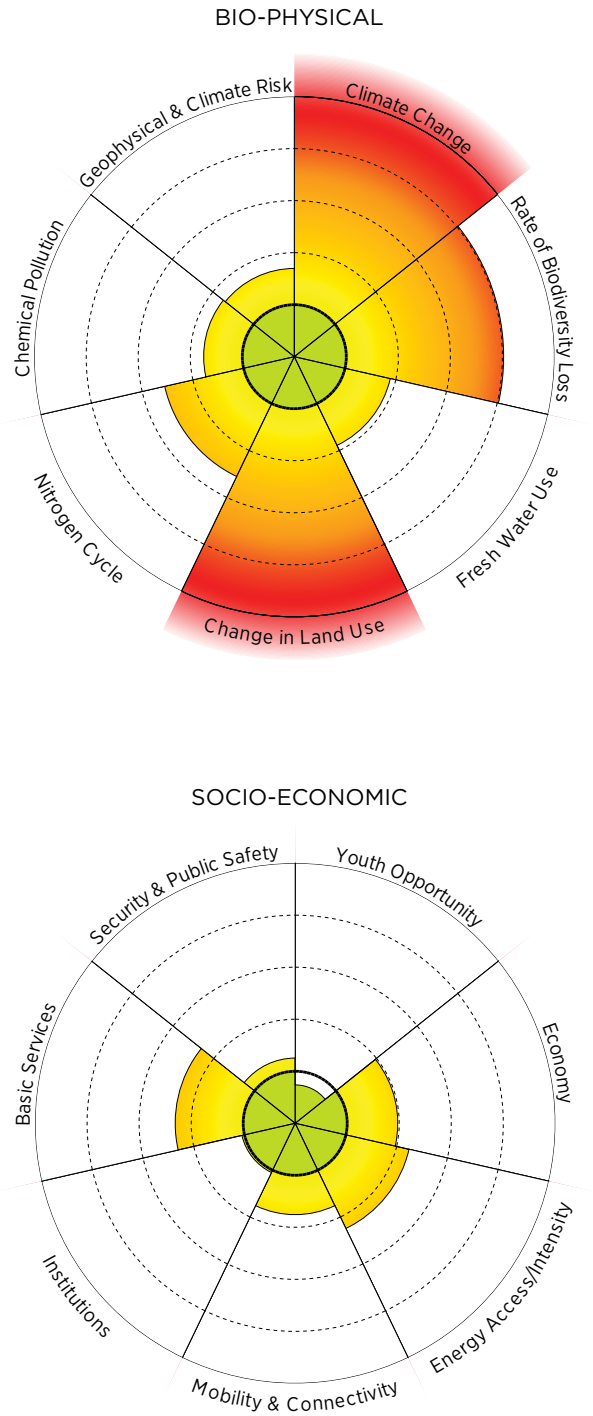
Put simply, without relatable sustainability metrics, there is no collective answer to 'where are we going'? Similar to how an engineer defines a 'factor of safety' for every new building, a 'factor of sustainability' needs to be determined *before* a community investment is made. So far this has largely been unachievable around the world.

With this in mind, the following sustainability metrics, divided into two broad categories, bio-physical and socio-economic, are proposed, using the binational Great Lakes Region as a case study (Figure 4). The metrics can be collected nationally, as well as by the cities like Toronto, Montreal, Detroit and Chicago (Annex 2) and the more than 8,000 other individual municipalities that make up the region, using the following requirements:

- Updated regularly; ideally annually.
- Sufficiently broad to capture bio-physical and socio-economic aspects of sustainability.
- Sufficiently detailed and standardized to enable targeted financing.
- Captures the global, as well as local contribution to planetary boundaries like biodiversity loss and climate change.
- Scalable, ideally from community (e.g., postal code), city, region, state or province, country.
- Many metrics could be monitored in real-time.
- Cost effective (affordable in low-income countries), data collected locally.
- Broad use of open-source data. Not possible for regions to withhold data (could be collected by researchers, statistics departments and government employees).
- Readily communicated to the general public – legitimate and understandable.
- Non-proprietary.
- Standardized, or readily avail themselves to standardization.

Once an urban areas sustainability can be defined, the assessment tool is sufficiently robust to evaluate and communicate 'localized' sustainability strategies and priorities, allowing a broad range of stakeholders the opportunity to encourage more sustainable development. The use of sustainability cost curves, shown in Annex 3, can then provide a straightforward way to assess the overall sustainability of infrastructure investments and alternatives within a macro-region or individual cities so that policymakers and investors understand the choices and potential trade-offs in achieving sustainability.

FIGURE 4:
SUSTAINABILITY ASSESSMENT OF THE GREAT LAKES REGION



Source: https://www.city-sustainability.com/

Bio-Physical Indicators, Great Lakes Region

The region's degree of sustainability in the bio-physical sector is captured through 22 indicators in seven broad themes. Indicators are selected on several criteria. Indicators need to be readily available and clearly defined, e.g., those provided through ISO 37120 Sustainable cities and communities, they should be updated at least annually, they should be scalable from smaller communities to countries, and they should be relevant globally, either aspirational or clearly met, e.g., percent of households having potable water supply. Researchers should also be able to obtain the data from alternative sources if the community does not self-publish.

Bio-physical indicators are modelled after planetary boundaries proposed by Rockstrom *et al* (2009) and updated by Steffen *et al* (2015). These boundaries provide a 'safe operating space for humanity'. The boundaries are proposed as planetary limits. However, to ensure relevancy, the boundaries need to capture potential impacts *on*, and contribution *from*, cities and urban areas (megaregions). The impact from cities is measured, as well as possible, for all impacts, *i.e.*, embodied, or Scopes 1, 2 and 3 (see climate change).

The nine themes within Rockstrom and Steffen's boundaries are adapted for urban areas. Six of the themes included are: climate change, biosphere integrity (biodiversity impacts), freshwater use, change in land use, biochemical flows (nitrogen), and chemical pollution. An additional theme, geophysical and climate risk, captures threats to urban areas. Stratospheric ozone depletion, aerosol loading, and ocean acidification are not included as they are captured in other themes (from an urban perspective). For simplicity, only nitrogen cycle is considered as it usually mirrors the phosphorous cycle.

Climate Change

The build-up of anthropogenic gases in the atmosphere is warming the planet. At the start of the Industrial Revolution, the atmospheric concentration of carbon dioxide (CO_2) was 280 ppm, today the concentration is 417 ppm, and rising by about 3 ppm per year (COVID-19 might reduce that by 10 to 15 percent for one or two years). The existing increase of CO_2e has already led to an average 1°C global warming (leading to noticeable widespread climate change).

Another 0.5°C increase is likely already built into climate warming. The Paris Agreement suggests a framework to limit temperature increases to 2°C (a maximum upper limit). This is a Herculean goal and the current Nationally Determined Contributions presented by signatories of the

INDUSTRIAL SECTOR, HAMILTON, LAKE ONTARIO

Paris Agreement (including the USA) are insufficient to meet the 2° goal.

In 2019, total global CO_2 emissions were about 50 $GtCO_2$. Meeting the Paris targets of limiting temperature increases below 2°C requires these emissions reduced below 10 $GtCO_2$, and for the aspirational goal of limiting warming increases below 1.5°C requires net zero CO_2 emissions by 2050.

Measuring greenhouse gas emissions is complicated, especially for sub-sovereign areas such as the Great Lakes region. Global emissions monitored by the UNFCCC include six gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6), and nitrogen triflouride (NF_3). Carbon dioxide, especially those emitted from combusted fossil fuels make up about 76 percent of total GHG emissions. The global (total) of GHG emissions is relatively straightforward – each of the world's 197 parties to the UNFCCC provides an annual inventory of GHG emissions generated within the country (maritime and aviation largely excluded, but well-known). The global total is the sum of these 197 territorial inventories.

Businesses, cities, and regions, however, need to inventory their GHG emissions across the full life-cycle of activities, in all territories. Recognizing this need, the World Business Council for Sustainable Development and World Resource Institute supported development of ISO 14064 which ensured a methodology for businesses and regional governments to encompass all emission without 'double-counting'. Emissions are divided into three scopes: **Scope 1 – Direct Emissions**, e.g., fuel combustion and fleet vehicles; **Scope 2 – Indirect Emissions** from energy used; **Scope 3 – All Other Indirect Emissions** outside direct control but covering full life-cycle, e.g., emissions associated with the manufacture of purchased items such as cement and food.

Scope 3 emissions are also often called embodied, virtual or consumption. Cities and regions, along with businesses, need to account for consumption emissions as these can often be the largest share of emissions. Many municipal GHG inventories only account for emissions associated with municipal operations – usually only a few percent of total emissions. They might be broader as territorial inventories. City inventories should however include embodied emissions associated with lifestyles of residents, e.g., international travel, GHG emissions embodied on food and durables, building materials.

The city-association C40 provides preliminary analysis for consumption emissions associated with all activities of residents and corporate and government activities in a few cities. In almost all high-income countries urban emissions measured as 'consumption' values are higher than the more typical Scopes 1 and 2.

GHG emissions by state and province in the Region range from 6 tonnes/person in Quebec to 29 tonnes CO_2e per person in Indiana (Scopes 1 and 2). The wide difference between emissions is driven mostly by the type of electricity generation (hydro and nuclear vs coal) and amount and type of industrial activity.

The average GHG emissions in the Region are 17 t CO_2e per person (territorial). This estimate is with a data confidence of '4 stars' out of five, as each state and province regularly publishes GHG emissions inventories. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

An estimate of 18.5 t CO_2e per person in the Region when measured by consumption. This reflects the high affluence of the Region and purchasing of products with widespread embodied emissions. Consumption-based estimates are relatively new and some data needs to be estimated, therefore there is a lower data confidence of '2 stars'.

The current global average GHG emission is about 4.71 t CO_2e per person (about 50 percent higher in urban areas). The SDGs (and Paris Agreement) target is less than 2 t CO_2e per person.

Monarch butterflies migrating, Point Pelee National Park, Ontario

Biodiversity Loss

Likely the greatest threat to planetary sustainability is biodiversity loss. Species are not uniformly distributed, nor is their number and condition easily monitored. Residents of urban areas impact biodiversity in three broad ways: destruction and degradation of local ecosystems (local habitat loss); destruction and degradation of ecosystems in other areas (global habitat loss), and; direct use of threatened and endangered species, e.g., buying animal parts in city-markets and manufactured products. Non-direct impacts on biodiversity are similar to Scope 3, or embodied (vicarious) impacts. These impacts would be affected by local purchasing habits, e.g., is trade in endangered species common; and general consumption practices, e.g., where is food sourced, type of building materials.

ECOLOGICAL FOOTPRINT
The concept of an 'ecological footprint' was developed by William Rees and Mathis Wackernagel in 1994. The measurement quantifies the area of biologically productive land and water an activity requires to produce all the resources it consumes and to absorb the waste it generates. The ecological footprint is usually measured in global hectares (gha) and attempts to include all impacts across the life-cycle of the activity, e.g., Scopes 1, 2 and 3 (production and consumption).

The measurement is somewhat rudimentary, as activities like CO_2 emissions and seafood harvesting may not have spatial equivalents. However, the ecological footprint is incorporated into WWF's 'One Planet Living' campaign and the concept is well known.

The ecological footprint of the United States is estimated at 8.1 gha per person and Canada is 7.7 gha. The aggregate average for the Great Lakes region is 8.06 gha. The global current average ecological footprint per person is 2.75 gha and needs to be below 1.7 gha to be considered sustainable.

The Global Footprint Network provides annual estimates of ecological footprints by country. The Ecological Footprint generally refers to the Ecological Footprint of consumption. Ecological Footprint is often referred to in short form as Footprint.

BIODIVERSITY IMPACT (INDEX)
City-sustainability.com developed an Index of Biodiversity Impact ranking all cities and regions from 1 – 5. The index is an estimate of overall impact on biodiversity, both locally within the community's ecosystems and globally. The index encompasses aspects such as trade in endangered species, impact on migratory routes, e.g., Toronto's towers and bird migration, and introduction of invasive species, such as those in Great Lakes watersheds.

All Canadian and United States' cities and regions have an estimated score of 3. The global average is 2.4 and the global target is less than 1.

This metric is indicative only and recently introduced, therefore a data confidence of only '1 star' is suggested.

CHANGE IN NATIVE SPECIES
A rudimentary measurement of species diversity and integrity is the number of native species lost, and number of existing species that are invasive or non-native. An estimate of the Great lakes Region suggests that about 60 percent of the current biodiversity in lost (pre-Holocene) and non-native. The goal for this indicator is to be below 20 percent lost or non-native. The more comprehensive analysis is needed to confirm these estimates, along with regular benchmarking and peer review. Therefore, the confidence rating of the indicator is '1 star'.


Agricultural irrigation, Illinois

Freshwater Use

TOTAL WATER CONSUMPTION
Freshwater consumption in the US states ranges from 1788 liters per capita per day in Pennsylvania to 4120 liters in Indiana. Ontario and Quebec consume 682 liters and 954 liters per day per person respectively. The Great Lakes Region has an aggregate average daily water consumption of 2,473 liters per person. The global target of fresh water consumption is between 200 liters (considered lifeline level) and 1522 liters (maximum sustainable value).

Municipalities, states and provinces typically collect this data annually and as long as the metrics are consistent, e.g., ISO 37120 the confidence level of the data is '4 stars'.

POTABLE WATER SUPPLY
Residents around the Great Lakes are typically provided with potable water, despite occasional contamination such as Flint, MI and Walkerton, ON. All states and provinces are estimated to have 100 percent water supply. SDG targets are above 95 percent. Almost 20 percent of the world's residents do not have potable water supply.

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Data confidence is '4 stars'.

EMBODIED WATER CONSUMPTION (INDEX)
Similar to the embodied carbon in products and processes, embodied water is also an important metric for urban residents and their local and global water consumption. Products like lettuce, beef, and building materials may be manufactured in distant countries, however the water used can still be accounted.

Accounting for embodied water is difficult. Similar to the annual 'ease of doing business' review, and Transparency International's ranking of corruption, a baseline ranking is required. City-sutainability.com provides an annual ranking, through expert consultation, and regular

refinement, of embodied water consumption by residents of monitored cities and regions. The United States' states are rated 3 (out of 5) and the Canadian provinces 4 (out of 5) to give the region an aggregate average embodied water consumption value of 3.1.

The metric is new and at this time only indicative. Therefore, a data confidence level of '1 star' is estimated.

Agricultural crops bordering a wetland and forest, Minnesota

Change in Land Use

Change in land use as a planetary boundary was first proposed by Rockstrom *et al* 2009, as the percentage of global land cover converted to cropland (in 2009 the proposed boundary was 15 percent and the status was 11.7 percent converted to cropland). This metric was updated by Steffen *et al* 2015 as the forested land as percent of original forest cover. This was further refined by tropical, temperate and boreal biomes. The global boundary was estimated at 62 percent of original forested area (less than the boundary of 75 percent).

LOCAL LAND USE CHANGE
Consistent with the broader objectives of the land use planetary boundary, the metric has three components: The first being local land use change. Similar to Rockstrom *et al* 2009 the area of cropland from original cover in the US states and Canadian provinces of the Great Lakes Region is estimated. The United States' states range from 27 percent farmland in Pennsylvania to 75 percent in Illinois and Minnesota. Ontario and Quebec are 39 percent and 19 percent cropland (i.e., farmland) respectively. The Great Lakes Region is about 50 percent cropland. The global current average is about 12 percent, and the target is below 15 percent.

Although this value is relatively easy to obtain through remote sensing and national statistics, a city or region's land use does not adequately capture the complete impact as much food is imported. Therefore, the confidence in this data is '2 stars'.

POPULATION DENSITY
Population density of urban areas can be contentious, as people may believe cities are 'too crowded', especially post-COVID. Population densities also vary between cities such as Chicago and Toronto and megaregion, such as the Great Lakes – St. Lawrence Region. Although few North American cities reach a density of 3,500 people/km^2, this is a prudent global aspirational target for larger cities. For comparison, Paris has a density over 21,000 people/km^2. Sufficient urban densities enable better services such as transit and power supply, as well as enhance economic development.

Population density within the region ranges from 26 people/km^2 in Minnesota to 110 people/km2 in Ohio. In the Great Lakes – St. Lawrence River watershed areas of Ontario and Quebec, densities are 43 people/km^2 and 26 people/km^2 respectively. The population density of the overall Great lakes – St Lawrence Region in 2019 was 53 people/km^2 (within the watershed for Ontario and Quebec).

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Data confidence is '4 stars'.

GLOBAL LAND USE IMPACT (INDEX)
City-sustainability.com developed an Index of Global land use impact ranking all cities and regions from 1 – 5. The index is an estimate of overall impact on global land use, both locally within the community's ecosystems and globally. The index encompasses aspects such as impacts to tropical biomes from items consumed in the city or region, e.g., imported palm oil and livestock raised on cleared rainforests.

The metric is difficult to fully capture as product supply chains are often complex, however the Index provides a reasonable estimation and over time the baseline will improve as more data incorporated.

The confidence in this data is '2 stars'.

Nitrogen Cycle

Increased biogeochemical flows of phosphorous (P) and nitrogen (N) threaten ecosystems. These are both driven by current agricultural practices and both exceed safe planetary boundaries. Steffen *et al* 2015 updated the P planetary boundary to consider both P *global* (flow from freshwater systems to the ocean; PB estimated at 11 million tonnes P yr^{-1} with current value of – 22 million tonnes P yr^{-1}) and P *regional* (flow from fertilizers to erodible soils; PB estimated at 6.2 million tonnes P yr^{-1} with current value ~14 million tonnes P yr^{-1}).

The biological fixation of N for fertilizer is about 150 million tonnes per year (an increase from ~121 million tonnes in Rockstrom *et al* 2009 original planetary boundary estimates). The proposed planetary boundary is 62 million tonnes per year.

Phosphorus is of particular concern in the Great Lakes ecosystem as Lake Erie's widespread eutrophication was attributed to P (fertilizer run-off, municipal wastewater, and cleaning products). However, for consistent measurement of the biogeochemical flows planetary boundary, only nitrogen (N) is proposed to be monitored, and that metrics, similar to others in City-Sustainability. com be presented as per person contributions: contributed both locally and associated with purchased practices and products wherever they are carried out around the world.

Residents of the Great Lakes Region are estimated to consume 23 kg N per person per year. The proposed boundary is less than 9 kg N per person per year. This data is reasonably well-known globally (manufacturing records) however it is difficult to accurate ascribe differentiated values by region, therefore the confidence in the data is '2 stars'.

Northern Pike and plastic pollution, Lake St. Clair

Chemical Pollution

Rockstrom *et al* 2009 suggested an aggregate planetary boundary of 'chemical pollution' that included examples such as persistent organic pollutants, plastics, endocrine disrupters, heavy metals, nuclear waste, as well as ozone depleting substances. Steffen et al 2015 updated these to 'novel entities'. Novel entities include substances and modified life forms that have the potential for unwanted geophysical and biophysical effects. Antibiotic resistant organisms, nanomaterials and plastic polymers are included. Novel entities, like CFCs, antibiotic resistant bacteria, and micro plastics, present unintended consequences.

For cities and regions, simpler, surrogate measures of chemical pollution are used. These may be adjusted in future as more information and the means of attribution improves.

POPULATION WITH REGULAR SOLID WASTE COLLECTION
For participating municipalities this metric is routinely published (and defined) with ISO 37120. Data confidence is '4 stars'.

In the region 100 percent of households are assumed to have solid waste collection (or access to service). The SDG is greater than 76 percent, up from the current estimate of about half.

POPULATION SERVED BY WASTEWATER COLLECTION
For participating municipalities this metric is routinely published (and defined) with ISO 37120. Data confidence is '4 stars'.

In the region 100 percent of households are assumed to have wastewater collection (or access to service). The SDG is greater than 76 percent, up from the current estimate of about half. This metric is duplicated in socio-economic indicators as it serves as a place holder for development of a more comprehensive metric for the impact on ecosystems. Degree of wastewater treatment, primary, secondary and possibly tertiary is a possibility, however overall impact on receiving water bodies is the key objective (and difficult to quantify).

PM 10
PM 10 refers to air-borne particulate matter of 10 microns (μg). For participating municipalities this metric is routinely published (and defined) with ISO 37120. Measurement can be challenging as there may be seasonal and locational variances and sophisticated testing equipment is needed. Data confidence is therefore '3 stars'. For the United States' states, PM 10 (annual mean) is around 46 μgm^{-3}. For Ontario and Quebec, it is 14 μgm^{-3} and 16 μgm^{-3} respectively. The aggregate average for the Region is 43 μgm^{-3}. Current global estimates in urban areas are over 100 μgm^{-3}. Global targets are to reduce values below 10 μgm^{-3}.

PM 2.5
Similar to PM 10, PM 2.5 refers to air-borne particulate matter of 2.5 microns (μg). The smaller particle size makes it particularly important as health impacts often result from inhalation deep in the lungs. For participating municipalities this metric is routinely published (and defined) with ISO 37120. Measurement can be challenging as there may be seasonal and locational variances and sophisticated equipment is needed. Data confidence is therefore '3 stars'. For the United States' states PM 2.5 (annual mean) is around 8 μgm^{-3}. For Ontario and Quebec values are also around 8 μgm^{-3}. The aggregate average for the Region is 8.4 μgm^{-3}. Current global estimates in urban areas are over 100 μgm^{-3}. Global targets are to reduce values 10 below μgm^{-3}.

Waste Generation

In addition to the commonly provided municipal service of solid waste collection, waste generation is a key local indicator. Waste generation provides a useful metric on resource intensity of the economy. Similar to water and

energy consumption with a baseline and upper-limit target, solid waste likely has a per person minimum 'baseline' amount of about 100 kg per person. An upper limit target of 350 kg per person is an ambitious target for high-income communities (no urban area is yet meeting this target).

For participating municipalities, this metric is routinely published (and defined) with ISO 37120. Data confidence is '4 stars'. Solid waste values are territorial only; waste generated within the community (including residential, industrial, commercial and institutional).

Annual waste generation rates in 2019 varied in United States' states, from 535 kg per person in Minnesota to 1607 kg per person in Ohio. Ontario and Quebec waste generation rates were 659 kg per person and 652 kg per person respectively. The aggregate average annual solid waste generation rate in the region is 920 kg per person.

Municipal landfill, Pennsylvania

Geophysical and Climate Risk

A key indicator for cities and regions, not included as a planetary boundary, is geophysical and climate risk. The Great Lakes region is blessed by geography in that seismic activity is limited and the inland location protects communities from most hurricanes. The region is already being sought after for its relative climate and geophysical stability and abundant fresh water.

NUMBER OF NATURAL DISASTER RELATED DEATHS
The region has relatively few natural disaster related deaths. In the United States' states natural disaster deaths range from 0.003 in New York to 0.062 in Illinois per 100,000 population (annualized 10-year avg.). In Ontario and Quebec, death rates are 0.01 per 100,000 population. The Great Lakes region has an aggregate average of 0.087 disaster-related deaths per 100,000 population (annualized 10-year avg.).

The global goal is to keep levels below 0.2 deaths per 100,000 people. For participating municipalities this metric is routinely published (and defined) with ISO 37120. Data confidence is '4 stars'.

GDP LOSS DUE TO NATURAL DISASTERS
The percentage of GDP loss to natural disasters is another way to measure natural disaster impacts. For the states and provinces in the region, values range from 0.02 percent in New York to 0.16 percent in Illinois, with a regional aggregate average of 0.046 percent (10-year average).

For participating municipalities, this metric is routinely published (and defined) with ISO 37120. Data confidence is '3 stars'. The current global average is about 0.2 percent with a goal to halve the value (despite the increase in climate risk and built infrastructure).

CRITICAL INFRASTRUCTURE AT RISK
Similar to GDP loss to natural disasters a metric is available for critical infrastructure at risk (by value). The metric is challenging to collate, although it is a relatively straightforward compilation of insured costs (less profit) of infrastructure in those communities with casualty insurance broadly available. This indicator is included as a 'place holder' as communities and regions compile and publish these estimates.

RESILIENCE OF COMMUNITY (INDEX)
City-sustainability.com developed an Index of Resilience of community ranking all cities and regions from 1 – 5. The index is an estimate of overall resilience of the community including supply chain disruptions. Ontario has slightly higher resilience than Quebec (seismic and land stability). The United States' states are all relatively higher than the national average (non-coastal, no active tectonic faults).

The aggregate average for the Region is 0.76 (goal is less than 1.0). Data confidence is '2 stars'.

ND-GAIN INDEX
The University of Notre Dame oversees the ND-GAIN Country Index that uses two decades of data across 45 indicators to rank 181 countries annually based upon their vulnerability and their readiness to successfully adapt to a changing climate. The initiative originally started as an offshoot of the World Bank, growing into the Global Adaptation Institute. The institute moved to Notre Dame from Washington in 2013. ND-Gain provides ranking of countries. In a few countries, cities are also ranked. Ideally ND-Gain will become broadly available for all major cities.

The most recent ND-GAIN estimates rank Canada 13th (score of 68.8) and the US 15th (score of 67.9). Canada's vulnerability is rated 0.296 (lower is better) and readiness of 0.697. US vulnerability is rated 0.039 and readiness 0.697. Evaluations include vulnerability (food, water, health, ecosystem services, human habitat, and infrastructure) and readiness (economic, governance, social readiness): Details available online.

The aggregate average rating for ND-GAIN of the Great Lakes Region is 68.2. Data confidence is higher for countries. This value is down-scaled from national estimates with a data confidence of '2 stars'.

TABLE 1: BIO-PHYSICAL INDICATORS, GREAT LAKES REGION

INDICATORS	UNIT	GOAL	CURRENT VALUE	CONFIDENCE
Climate Change				
GHG emissions (Consumption)	tCO_2/cap/year	< 2	18.5	✪✪
GHG emissions (Scope 1&2)	tCO_2/cap/year	<2	17	✪✪✪✪
Rate of Biodiversity Loss				
Ecological footprint	global hectare demanded/capita	<1.9	16	✪✪✪✪
Biodiversity impact	Index (1-5)	<1	2.9	✪✪
Change in native species	%	<80	60	✪
Fresh Water Use				
Total per capita water consumption	Liter/capita/day	200 – 1522	2473	✪✪✪✪
Potable water supply	%	>95	100	✪✪✪✪
Embodied water consumption	Index (1-5)	<1	3.1	✪✪✪
Change In Land Use				
Local land use change	% of land converted for cropland	<15	11.7	✪✪
Population density	person/km^2	>3500	53	✪✪✪✪
Global land use impact	Index (1-5)	<1	2.5	✪✪✪
Nitrogen Cycle				
Contribution to global Nitrogen cycle	kg-N_2/capita/year	<9	23	✪✪✪
Chemical Pollution				
Population with regular solid waste collection	%	>76	100	✪✪✪✪
Population served by wastewater collection	%	>76	100	✪✪✪✪
PM 10	µg/m^3	<10	43	✪✪✪
PM 2.5	µg/m^3	<10	8.4	✪✪✪
Waste generation	Tonnes/year	100 - 350	920	✪✪
Geophysical & Climate Risk				
Number of natural disaster related deaths (10-year avg.)	per 100,000/year	<0.2	0.087	✪✪✪✪
GDP loss due to natural disasters (10-year avg.)	%	<0.1	0.046	✪✪✪✪
Critical infrastructure at risk	$billions	<50	58	✪
Resilience of community	Index (1-5)	<1	0.76	✪✪
Vulnerability/readiness	ND-Gain Index (0-100)	>50	68.2	✪✪✪

COMMUTER TRAFFIC IN CHICAGO, ILLINOIS

Socio-Economic Indicators, Great Lakes Region

The region's degree of sustainability in the socio-economic sector is captured through 38 indicators in seven broad themes. Indicators are selected on several criteria. Indicators need to be readily available and clearly defined, e.g., those provided through ISO 37120 Sustainable cities and communities, they should be updated annually, they should be scalable from smaller communities to countries, and they should be relevant globally, either aspirational or clearly met, e.g., percent of households having potable water supply. Researchers should also be able to obtain the data from alternative sources if the community does not self-publish.

Youth Opportunity

Youth opportunity captures the region's ability to provide for youth (under age 24) and includes childhood mortality, gender inequality, success in schooling, youth unemployment and average life expectancy. Ideally a key aspect captured in the indicators is how well young females are incorporated and driving the local community, a key driver of sustainable development.

UNDER 5 MORTALITY

An average of 6.1 deaths per 1000 live births with slightly higher levels in the United States than Canada. Chicago and Toronto assumed to be consistent with average values in their respective countries. Global target (SDG) is to reduce mortality rates below 17 deaths per 1000 live births. State and provincial values provided by Statista have United States' states ranging from a low of 4.6 in New York to a high of 7.2 in Indiana[4].

Key drivers of mortality levels in the Great Lakes region include accidents, including firearm related, motor vehicle, and drowning.

From the World Bank data set (2018), the global average is 39, with United States – 7, Canada – 5, and European Union – 4. Several cities and countries have values below 3, e.g., Helsinki, Finland – 2[5]. Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

Proposed Regional Target; below 3.5 per 1000 live births.

4. Statista, https://www.statista.com/statistics/252064/us-infant-mortality-rate-by-ethnicity-2011/ accessed May 4, 2020
5. World Bank, https://data.worldbank.org/indicator/SH.DYN.MORT accessed May 4, 2020

Carleton University student. Ottawa, Ontario

GENDER INEQUALITY INDEX
The gender inequality index is obtained from the Human Development Report (2019) UN Development Programme. In 2018 Canada ranked 18th (0.083) and the United States 42nd (0.182). An aggregate value of 0.16 is estimated for the Great Lakes region, with United States and Canadian values considered similar to their respective national averages. Women hold 31.7 percent of seats in parliament in Canada and 23.6 percent in the United States. The region comfortably meets the SDG target of gender inequality values less than 3, however there is room for improvement. Greater female representation is needed on corporate boards, within some professions such as engineering, and in areas such as entrepreneurism, ultra-high net worth individuals, and CEOs of major corporations (marginally around 5 percent in both Canada and the United States).

Confidence in data is suggested at '4 stars' as credible annual values published by UNDP. The metric should be broadened, e.g., share of women on corporate boards, senior political positions, and key professions. Values need to be regularly monitored, updated annually, and individual targets proposed.

FEMALES ATTENDING SCHOOLS
The region (United States and Canada) performs well in the share of females attending school; estimated at 99 percent. This exceeds the SDG goal (greater than 95 percent). Better granularity (local government level) and consistent annual tracking would be helpful. Local government capacities support the application of greater differentiation such as culture and ethnicity, immigrants, income level, to identify areas in need of improvement.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

STUDENTS COMPLETING PRIMARY SCHOOL
The region (United States and Canada) performs well in the number of students completing primary school; estimated at 98 percent. This exceeds the SDG goal (greater than 95 percent). Better granularity (local government level) and consistent annual tracking would be helpful. Local government capacities support the application of greater differentiation by groupings such as culture and ethnicity, immigrants, income level, to identify areas in need of improvement.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

STUDENTS COMPLETING SECONDARY SCHOOL
The region (United States and Canada) performs well in the number of students completing secondary school; estimated at 93 percent. This exceeds the SDG goal (greater than 90 percent). Better granularity (local government level) and consistent annual tracking would be helpful. Local government capacities support the application of greater differentiation by groupings such as culture and ethnicity, immigrants, income level, to identify areas in need of improvement.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

Achievement levels could be improved with a Proposed Regional Target above 95 percent.

YOUTH UNEMPLOYMENT RATE
The aggregate youth unemployment rate is estimated at 11 percent (2019) and at that time was below the SDG goal of less than 12 percent. Prior to COVID-19 youth unemployment rates varied considerably by state and province, with a low of 6.5 percent in Wisconsin to a high of 14.2 percent in Illinois and 18.1 percent in Ontario and 20 percent in Quebec. These rates have increased markedly with COVID-19. Unemployment, with a particular focus on youth unemployment is now a priority for all governments. 'Re-starting the economy' is a paramount political priority.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities this metric is routinely published (and defined) with ISO 37120. An aggregate long term Proposed Regional Target below 6.5 percent (less than Wisconsin pre-COVID) is suggested.

AVERAGE LIFE EXPECTANCY
The aggregate average life expectancy for the region is 80 years, consistent with the SDG target of 80 years (compared to the current global average life expectancy of 70 years for people born in 2019). Values range from 77.6 years in Indiana to 81.1 years in Minnesota and 83 years in Ontario and Quebec.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

The impact of COVID-19 on average life expectancy is not yet known. Proposed Regional Target; 84 years.

Food bank line up. Toronto, Ontario

Economy

Tracking a region's economy is challenging as people experience their local economy differently. Broad surrogate measures are needed. Five representative metrics are used: unemployment rate, Gini coefficient, population in slums or homeless, GDP, and material circularity. Some of these like GDP, can take on greater meaning as they become a goal in themselves, rather than a representative indicator.

UNEMPLOYMENT RATE
Prior to COVID-19 the aggregate unemployment rate was 4.4 percent (2019) and at that time was below the SDG goal of less than 6 percent. Prior to COVID-19 unemployment rates varied considerably by state and province, with a low of 2.9 percent in Wisconsin to a high of 4.6 percent in Ohio and 8.6 percent in Ontario and 6.4 percent in Quebec. These rates have increased markedly with COVID-19 and the rate within the Region likely exceeds 20 percent. Unemployment is now a priority for all governments as efforts unfold to 're-start the economy' post COVID-19.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities this metric is routinely published (and defined) with ISO 37120. An aggregate long term Proposed Regional Target below 4 percent.

GINI COEFFICIENT
The world inequality database highlights the growing income inequality in the United States and Canada. In 1980 the top 1% of population had 11% of the country's income: This grew to 20% in 2014. The top 10% grew from 65% of income in 1980 to 73% in 2014. Correspondingly income for the bottom 50% declined from 20% in 1980 to less than 13% in 2014.

The Gini coefficient is a gauge of economic inequality, typically measuring the variability in income among a population (wealth can also be measured but may be more difficult to value assets). Values range from highs in South Africa of 0.63 and Haiti of 0.61 to lows in Ukraine of 0.25 and Finland of 0.27. The current global Gini coefficient is 0.52 and the SDG target is 0.2.

Within the Great Lakes region, the United States' states are relatively consistent, ranging from 0.43 in Wisconsin to 0.465 in Illinois. Ontario (0.33) and Quebec (0.42) vary considerably. The aggregate average for the Region (2019) is 0.4. As highlighted by the world inequality database the degree of inequality is growing in the United States and Canada. COVID-19 is expected to exacerbate this trend.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published.

An aggregate long term proposed regional target is 0.3.

POPULATION LIVING IN SLUMS/HOMELESS
Large scale slums, or informal settlements, are rare within the Region. Homelessness is however a challenge across the Region. Homelessness varies by city and is difficult to quantify due to the lack of a standard definition and locational attribution, e.g., degree of transience. Homelessness varies in the Region's eight United States' states, from 46 in Wisconsin to 189 in New York (per 100,000 population). Ontario and Quebec are slightly slower than the United States average at 71 and 58 per 100,000 respectively. The average for the Region is 84 per 100,000.

The higher number in New York may be attributed to the inclusion of New York City in the State values (NYC is not in the Great Lakes Region). The current global estimate for homeless is 25 per 100,000 with an SDG target of 18. This value does not include the more than one billion people living in slums around the world. In much of Sub Sahara Africa more than half a country's population may live in slums. Angola, Bangladesh and Cambodia each have around 55 percent of the country living in slums (over two-thirds of the urban population).

For participating municipalities this metric is routinely published (and defined) with ISO 37120.

GROSS DOMESTIC PRODUCT
Gross domestic product, GDP, is a blunt instrument intended to represent total economic activity by measuring the monetary value of all goods and services produced in a specific time period within a region, usually a country. The modern application of GDP was launched by Simon Kuznets, in his 1937 report to the U.S. Congress, "National Income, 1929-35." In the final days of World War II, the Bretton Woods conference that established international financial institutions such as the World Bank and the International Monetary Fund, standardized GDP as tool for measuring a country's economy.[6]

Measuring GDP for sub-sovereign regions such as states and provinces is common. Increasingly GDP is reported for cities and regions. The average per capita GDP by state within the Great Lakes Region varies from $42,110 in

6. Dickinson, 2011. https://foreignpolicy.com/2011/01/03/gdp-a-brief-history/ accessed 6 May, 2020

Michigan to $118,105 in New York (2019). In the same year, Ontario's GDP was $55,296 and Quebec's $48,061. The aggregate average for the Region was $US 53,495.

The global per-capita pre-COVID-19 GDP was approximately $10,496.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published. For participating municipalities GDP is routinely published (with common methodology) as part of ISO 37120.

MATERIAL CIRCULARITY
The material efficiency of an economy can be measured by the total resources entering the economy and what fraction of those resources are recovered and recycled as cycled resources. The 2020 Circularity Gap Report estimates the total resources entering the global economy at 100.6 Gt (92 Gt of extracted resources and 8.6 Gt of cycled resources, i.e., about 8.5% material circularity). Canada and the United States are both below the global 'material circularity' average. The Great Lake region is likely consistent with national averages; therefore, a material circularity of 7.5 percent is estimated for the region. This is a long way from the global goal of 50 percent.

Measuring material circularity is difficult. There are over 100 definitions for the concept, leave alone obtaining regular and credible data. Therefor only '2 stars' for data confidence are suggested. Of the world's megaregions the Great Lakes region is one of the most able to measure material circularity. This is a metric that requires improved monitoring, but is one of the most important to reflect the economy's material efficiency.

Daniel-Johnson dam in the Manicouagan Valley, Quebec. Image courtesy Les Musées du Québec.

Energy Access and Intensity

Energy is a key component of all economies and societies. Generation and use of energy, especially fossil fuels, contributes more than 70 percent of the world's greenhouse emissions. As economies mature, they tend to enhance efficiencies and energy intensity improves (i.e., declines). A minimum level of energy access is required to fully participate in society (baseline level).

AUTHORIZED ELECTRICAL SERVICE
The provision of authorized electrical service is universal across the Region (assumed 100 percent). This metric is most relevant for low-income regions.

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars' or greater, as robust and annual values (by state and province) are published.

ACCESS TO CLEAN ENERGY FOR COOKING
Access to clean energy for cooking is universal across the Region (assumed 100 percent). This metric is most relevant for low-income regions.

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars' or greater, as robust and annual values (by state and province) are published.

ENERGY INTENSITY
Similar to material circularity energy intensity measures the efficiency of an economy (energy used per unit of economic output MJ/$). The Region's energy intensity is estimated at 5.4 MJ/$. As economies increase efficiencies the use of energy declines. There is still considerable room to improve across the Region as per capita and per unit of economy consumption is about twice that of similar levels of affluence in Europe.

Energy intensity by United States state varies from 10.2 MJ/$ in Indiana to 3.0 MJ/$ in New York, representing New York's higher levels of per capita GDP and services sector. Ontario and Quebec have relatively low energy intensity at 3.8 MJ/$ and 4.5 MJ/$ respectively. For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars' or greater, as robust and annual values (by state and province) are published.

SHARE OF LOW-CARBON IN TOTAL ENERGY
Three broad and roughly equal groups of energy make up total energy provision across the Region: transportation, building heat and industry processes, and electricity. Low carbon options in these areas include renewables in electricity generation (e.g., hydro, wind, biofuels and some solar), nuclear electricity generation, geothermal heating and cooling of buildings, and biofuels in transportation fuels. About 22 percent of Great lakes region energy is low carbon (i.e., below 50 gCO_2eq/kWh). About two-thirds of this is from nuclear generated electricity (about 296 TWh in US and 90 TWh in Canada in 2017 from 53 reactors). Electrifying transportation, decarbonizing electricity production, and possibly 'green hydrogen' are likely the largest opportunities to shift toward overall low carbon energy.

In the United States, the low carbon share of energy in the Region ranges from 33 percent in Illinois to 7 percent in Indiana. Ontario is 16 percent and Quebec 43 percent.

To meet greenhouse gas mitigation targets in climate change agreements such as the Paris Accord, the Region would need to strive for more than 80 percent of the energy generated from low carbon sources. The share of low carbon energy is declining as nuclear power plants around the Region are decommissioned (that loss is greater than increases in renewables such as wind and solar).

A new metric is required that provides the consolidated gCO_2eq/kWh or gCO_2eq/MJ of all energy. The definition of 'low' is arbitrary, and many targets specify renewable rather than low carbon (without specifying what the carbon content of the renewable energy might be). The role of nuclear energy in reducing carbon content of electricity is important around the Great Lakes as nuclear plants are decommissioned (typically replaced by natural gas generation).

The most pragmatic path to lower carbon emissions from total energy is to reduce carbon content of electricity, electrify transportation, and exclude fossil fuels from space heating and industrial processes. Nuclear generation is currently one way of reducing the carbon intensity of electricity, however public opposition to nuclear power is considerable, especially in the US states of the Region, e.g., recent closure of Indian Point NPP in New York (to be replaced mainly by natural gas generation).

The Great Lakes region is served by five broad electricity systems: Ontario (~50 gCO_2eq/kWh), Quebec (~35 gCO_2eq/kWh), New York (~230 gCO_2eq/kWh), PJM Interconnection (~350 gCO_2eq/kWh serving PN, OH) and Midcontinent (~500 gCO_2eq/kWh serving IL, IN, MI, MN, WN,). The weighted average carbon intensity for the Region's electricity is about 420 gCO_2eq/kWh.

TOTAL ENERGY USE

Total energy use is energy associated with electricity, transportation fuel, industrial processes, and space heating. The average use in the Region is 282 GJ per person. This is energy used within the Region and does not include embodied energy (Scope 3), aviation or shipping. Energy use by state varies from 195 MJ per person in New York to 445 MJ per person in Indiana. Ontario and Quebec are 212 MJ and 216 MJ per person respectively. These rates of energy use are among the highest in the world, about twice as high per person than residents of Europe for example.

Similar to water use, a lower bound ('lifeline' level) and upper bound is proposed for total energy use, with a target between 50 – 150 GJ per person.

Confidence in data is suggested at only '2 stars' as complete records are unavailable, borders and service areas are unclear, and some data needs to be gleaned from related information, e.g., fuel taxes. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

Transit train. Minneapolis, Minnesota

Mobility and Connectivity

Mobility and connectivity are the largest drivers of economy. Six indicators are used, although many others are available. Measuring mobility in a large urban region like the Great Lakes region requires nuance as various travel options need to be measured, e.g., local neighborhood as well as between two major cities such as Toronto and Chicago, or minor cities such as Sudbury, Ontario and Rockford, Illinois.

PERSONAL AUTOMOBILES

The number of personal vehicles per capita in the Region is estimated at 0.7, among the highest in the world. United States' states vary between 0.6 per person for New York and 0.9 per person for Michigan, Minnesota, Ohio and Wisconsin. Ontario and Quebec are estimated at 0.6 and 0.5 per person respectively.

The global target is 0.2 vehicles per person and is currently about 0.15 per person. For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars' or greater, as robust and annual values (by state and province) are published.

DAILY PUBLIC TRANSPORT TRIPS

The number of daily public transport trips per capita in the Region is estimated at 0.21. US states vary between 0.01 daily trips per person in Indiana to 0.56 trips per person for New York. Daily trip estimates for Ontario and Quebec are 0.38 and 0.17 trips per person respectively.

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars' or greater, as robust and annual values (by state and province) are published.

NUMBER OF INTERNET CONNECTIONS

About 40 percent of the world has internet connections today; the SDG target is to exceed 50 percent by 2030. The Great lakes region is well served by internet connections although there remain large populations with

no or limited connection. In the US states connection levels range from 68.4 percent in Indiana to 79.4 percent in Minnesota (with an eight-state average around 72 percent). Ontario and Quebec estimated at 74 percent. A Regional overall average of 73 percent estimated.

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars', as robust and annual values (by state and province) are published.

COMMUTERS USING A TRAVEL MODE OTHER THAN PERSONAL VEHICLE
The majority of the region's employees commute with their personal vehicle. An average of 24 percent of commuters use a travel mode other than personal vehicle. This is below the current global average of 30 percent, and well below the target of 50 percent.

Breakdown by state or city was not available, and the estimates will be markedly different through COVID-19 isolation, and in the new post-pandemic economy.

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars', as robust and annual values (by state and province) are published.

TRANSPORTATION FATALITIES
Transportation fatalities for the region are estimated 7.6 fatalities per 100,000 people per year. Values for United States' states range from 5.2 in New York to 12.4 in Indiana. Ontario and Quebec are 3.4 and 4.4 fatalities per 100,000 respectively. The regional average of 7.6 fatalities is lower than the SDG target of 8.6 fatalities, and much lower than the current global average of 17.2 fatalities per 100,000.

For participating municipalities this metric is routinely published (and defined) with ISO 37120. Confidence in data is suggested at '4 stars', as robust and annual values (by state and province) are published.

COMMERCIAL AIR CONNECTIVITY (NON-STOP DESTINATIONS)
Commercial air connectivity is the number of non-stop destinations available to air travelers. The measure is a useful surrogate measure of a region's connectedness. The Great Lakes region is one of the world's most-connected regions, with a current value of 350 non-stop destinations. This exceeds the goal of 150 connections (pre-COVID).

For participating municipalities this metric is routinely published (and defined) with ISO 37120. The data is not yet consistently tracked by community or region, therefore a confidence rating of '1 star' is suggested as more communities and regions regularly publish values.

Institutions

Institutions are critical in supplying and overseeing basic community services. Measuring the impact and effectiveness of institutions is challenging as they may serve larger areas heterogeneously, may serve various clients at different levels, and may be difficult to regularly track.

City Hall, Milwaukee, Wisconsin

EASE OF DOING BUSINESS
Every year the World Bank (IFC) ranks countries for their 'ease of doing business'. Some 48 attributes are assessed and overall rankings provided. Values are presented as a national rating, however typically only one or two cities within a country are assessed. For 'Doing Business 2020' The United States ranked sixth overall and Canada 23rd. This would give the overall Region an aggregate rating of 7.7.

The data is not yet consistently tracked by a community or region, therefore a confidence rating of '3 stars' is suggested as more communities and regions regularly publish values.

CORRUPTION CONVICTIONS BY CITY OFFICIALS
Corruption convictions by city officials is relatively rare across the Region. Values for United States' states range from 0.1 convictions per 100,000 people per year in Minnesota to 0.4 in Illinois, Ohio and Pennsylvania. Ontario and Quebec are estimated at 0.3 cases per 100,000. An overall aggregate estimate for the region is 0.3 cases per 100,000 population. The indicator is difficult to collect accurately as corruption should be measured across all levels of government, not just city officials. And a low value may suggest poor monitoring as opposed to low rates.

The data is not consistently tracked across all levels of government, therefore a confidence rating of '3 stars' is suggested as more communities and regions regularly publish values. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

TAX COLLECTED AS A PERCENT OF TAX BILLED
Tax collected as a percent of tax billed is relatively high in the region, estimated at 97 percent. The global target is collection rates above 95 percent. The tax collection rate here is for local governments only, however the indicator should capture tax collection across all levels of government. The data is not yet consistently tracked across all levels of government, therefore a confidence rating of '2 stars' is suggested as more governments across communities and regions regularly publish values.

For participating municipalities this metric is routinely published (and defined) with ISO 37120.

INSTITUTIONAL STRENGTH AND SUPPORT
A unique index capturing overall institutional strength and support is provided within City-Sustainability. An index 1-5 is provided. The Great Lakes region is ranked at 2.1 (lower is better). A global goal of 1 is proposed.

The data is not yet consistently tracked by community or region, therefore a confidence rating of '1 star' is suggested as more advisors regularly rate institutions.

Jardine Water Purification Plant built on reclaimed land. Chicago, Lake Michigan

Basic Services

A hierarchy of 'sustainable cities' suggests basic services are the foundation of nurturing communities. Basic services typically include potable water supply, solid waste collection and management, wastewater management and basic health care. Energy access, another basic service, is captured in Energy Access and Intensity theme.

REGULAR SOLID WASTE COLLECTION
Solid waste collection and management across the Region is of high quality, 100 percent coverage. Local governments typically provide the service and regularly provide metrics on service coverage and quality.

Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published.

For participating municipalities this metric is routinely published (and defined) with ISO 37120.

SERVED BY WASTEWATER COLLECTION
Wastewater collection and management across the Region is of high quality, 100 percent coverage. Local governments typically provide the service and regularly provide metrics on service coverage and quality. Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published.

For participating municipalities this metric is routinely published (and defined) with ISO 37120.

POTABLE WATER SUPPLY
Potable water supply across the Region is of high quality, usually 100 percent coverage. Occasional water supply problems exist, e.g., Flint, Michigan and Walkerton, Ontario and First Nation reserves. Local governments typically provide the service and regularly provide metrics on service coverage and quality. Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published.

For participating municipalities this metric is routinely published (and defined) with ISO 37120.

PHYSICIANS
The number of physicians per 100,000 people is estimated at 275 physicians. This is considerably higher than the SDG target of 175 physicians per 100,000 people. Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published.

For participating municipalities this metric is routinely published (and defined) with ISO 37120.

NURSES AND MIDWIVES
The number of nurses and midwives per 100,000 people is estimated at 1050 practitioners. This is considerably higher than the SDG target of 800 nurses and midwives per 100,000 people. Confidence in data is suggested at '4 stars' as robust and annual values (by state and province) are published.

For participating municipalities this metric is routinely published (and defined) with ISO 37120.

HEALTH SECURITY
The Global Health Security Index is published annually, benchmarking overall health security for 195 countries across six categories: prevent, detect, respond, health, norms, and risk (34 indicators). The GHS Index is a project of the Nuclear Threat Initiative (NTI) and the Johns Hopkins Center for Health Security (JHU) and was developed with The Economist Intelligence Unit (EIU) (www.ghsindex.org).

The United States is ranked 1/195 with an index score of 83.5. Canada is ranked 5/195 with an index score of 75.3. The Great Lakes region has an aggregate score of 80.7 (the global average country score is 41).

The index captures well a country's overall health security; however, it is an arbitrary assessment by an existing partnership. Annual updating is not assured. Confidence in data is suggested at '2 stars' as the index develops a baseline and independent peer review.

FOOD SECURITY
The Global Food Security Index, similar to the Health Security Index is published annually, benchmarking overall food security for 113 countries across three categories: affordability, availability, and quality and safety (34 indicators). The Food Security Index is led by the Economist Intelligence Unit sponsored by Corteva Agriscience (foodsecurityindex.eiu.com).

The United States is ranked 3rd overall with an index score of 83.7. Canada is ranked 8th overall with an index

score of 82.4. The Great Lakes region has an aggregate score of 83.1.

The index attempts to capture a country's overall food security; however, it is an arbitrary assessment by a proprietary partnership. Annual updating is not assured. Confidence in data is suggested at '1 star' as the index develops a longer-term baseline and independent peer review. The index is the best available to provide a dynamic quantitative and qualitative benchmarking model, that measures key drivers of food security across both developing and developed countries.

Coast Guard boat Maumee River, Toledo, Ohio

Security and Public Safety

Security and public safety are evaluated by three largely municipal indicators: fire related deaths, homicides, violent crime rates. Two indices are included: the nascent Healthcare Index (as part of city-sustainability.com) and the more established World Happiness Report (subjective well-being). An additional indicator for suicide rate could be added in future.

NUMBER OF FIRE RELATED DEATHS
The number of fire related deaths is routinely collected by municipalities. Values range in the United States' states between 0.77 deaths per 100,000 people per year in New York to 1.23 deaths in Indiana. In Ontario and Quebec, the values for 2019 were 0.61 and 0.1 deaths respectively. The aggregate value for the Great Lakes region is 0.88. The global target is 0.5 deaths per 100,000 people; compared to the current estimate of 3.05 deaths per 100,000 population per year.

Confidence in data is suggested at '4 stars' as robust and annual values are published by most municipalities. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

NUMBER OF HOMICIDES
The number of homicides is routinely collected by municipalities. Values range in the United States' states between two homicides per 100,000 people per year in Minnesota to 6 homicides in Illinois and Michigan. In Ontario and Quebec homicides for 2019 were 1.3 and 1.32 respectively. The aggregate value for the Great lakes Region is 3.9 homicides per 100,000. The global target is 3.05 homicides per 100,000 people; compared to the current estimate of 6.1 homicides per year.

Confidence in data is suggested at '4 stars' as robust and annual values are published by most municipalities. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

VIOLENT CRIME RATE
Violent crime rates are routinely collected by municipalities. Values range in the United States' states between 243 violent crimes per 100,000 people per year in Minnesota to 459 crimes in Michigan. In Ontario and Quebec, violent crime rates for 2019 were 977 and 1067 respectively. The aggregate value for the Great lakes Region is 500 violent crimes per 100,000.

Confidence in data is suggested at '4 stars' as robust and annual values are published by most municipalities. For participating municipalities this metric is routinely published (and defined) with ISO 37120.

HEALTHCARE INDEX
The Healthcare Index is an estimation of the overall quality of the health care system, health care professionals, equipment, staff, coverage and relative cost. The index, as draft, is provided on city-sustainability.com. The index captures health service provision across municipal borders, and integration of public health aspects. The index is one of the six indices within city-sustainability.com (under development).

The healthcare index for US states is estimated at 0.8 and for Canadian provinces 0.88. The Great Lakes region has an aggregate Healthcare Index of 0.82.

This indicator is under development and confidence in data is '1 star'.

SUBJECTIVE WELL-BEING
Subjective well-being as a concept gained traction over the last decade. In 2020 the eighth edition of the *World Happiness Report* was published. The report's partners include the Ernesto Illy Foundation, Unilever, Gallup, the Sustainable Development Solutions Network, the Center for Sustainable Development at Columbia University, the Centre for Economic Performance at the LSE, the Vancouver School of Economics at UBC, and the Wellbeing Research Centre at the University of Oxford (see worldhappiness.report.com)

In 2020, Canada ranked 9th happiest country (score of 7.278) and the United States ranked 19th happiest country (score of 6.892). The Great Lakes region had an aggregate *score of 6.94.*

The World Happiness Report is considered the authoritative ranking of subjective well-being and has been published for eight consecutive years. This year values were differentiated by city. This indicator is one of the more robust indices, confidence in the data is '3 stars'.

TABLE 2: SOCIO-ECONOMIC INDICATORS, GREAT LAKES REGION

INDICATORS	UNIT	GOAL	CURRENT VALUE	CONFIDENCE
Youth Opportunity				
Under 5 mortality	per 1000 live births	<17	6	✪✪✪✪
Gender inequality index	0 - 10	<3	0.16	✪✪✪✪
Females in schools	%	>95	99	✪✪✪✪
Students completing primary school	%	>95	98	✪✪✪✪
Students completing secondary school	%	>90	93	✪✪✪✪
Youth unemployment rate	%	<12	11	✪✪✪✪
Average life expectancy	years	>80	80	✪✪✪✪
Economy				
Unemployment rate	%	>6	4.4	✪✪✪✪
Gini Coefficient	Index	<0.2	0.4	✪✪✪✪
Population living in slums/homeless	per 100,000	<1000	84	✪✪✪✪
Gross Domestic Product	$/cap	>20,000	53,495	✪✪✪✪
Material circularity	%	>50	7.5	✪✪
Energy Access and Intensity				
Authorized electrical service	%	100	100	✪✪✪✪
Access to clean energy for cooking	%	100	100	✪✪✪✪
Energy Intensity	MJ/$	<20	5.4	✪✪✪✪
Share of low-carbon in total energy	%	>80	22	✪✪
Total energy use	GJ/cap	50-150	281.9	✪✪
Mobility and Connectivity				
Personal automobiles	vehicles/cap	<0.2	0.7	✪✪✪✪
Daily public transport trips	trips/cap/day	>0.35	0.21	✪✪✪✪
Number of internet connections	% population	>50	72.4	✪✪✪✪
Commuters using a travel mode other than personal vehicle	%	>50	24.5	✪✪✪✪
Transportation fatalities	per 100,000/year	<8.6	7.6	✪✪✪✪
Commercial air connectivity (non-stop destinations)	#	>150	350	✪
Institutions				
Ease of doing business	Rank 1 - 195	<50	7.7	✪✪✪
Corruption convictions by city officials	per 100,000/year	<50	3	✪✪✪
Tax collected as a percent of tax billed	%	>95	97	✪✪
Institutional strength and support	Index (1-5)	1	2.1	✪
Basic Services				
Regular solid waste collection	%	>50	100	✪✪✪✪
Served by wastewater collection	%	>80	100	✪✪✪✪
Potable water supply	%	>81	100	✪✪✪✪
Physicians	per 100000	>175	275	✪✪✪✪
Nurses and midwives	per 100000	>800	1050	✪✪✪✪
Health security (www.ghsindex.org)	Index (1-100)	>50	80.7	✪✪
Food security	Index (1-100)	>50	83.1	✪
Security and Public Safety				
Number of fire related deaths	per 100,000/year	<0.5	0.88	✪✪✪✪
Number of homicides	per 100,000/year	<3.05	3.9	✪✪✪✪
Violent crime rate	per 100,000/year	<500	500	✪✪✪✪
Healthcare provision	Index (1-5)	<1	0.82	✪
Subjective well-being	Index (1-10)	>7	6.94	✪✪✪

ANNEX 1

Sustainable Development Goals

Agreed at the 48th session of the United Nations Statistical Commission in March 2017, the SDGs are made up of seventeen goals with 169 targets and 231 unique indicators (several repeat in various goals).

End poverty in all its forms everywhere

End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Ensure healthy lives and promote well-being for all, at all ages

Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Achieve gender equality and empower all women and girls

Ensure availability and sustainable management of water and sanitation for all

Ensure access to affordable, reliable, sustainable and modern energy for all

Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Reduce inequality within and among countries

Make cities and human settlements inclusive, safe, resilient and sustainable

Ensure sustainable consumption and production patterns

Take urgent action to combat climate change and its impacts

Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

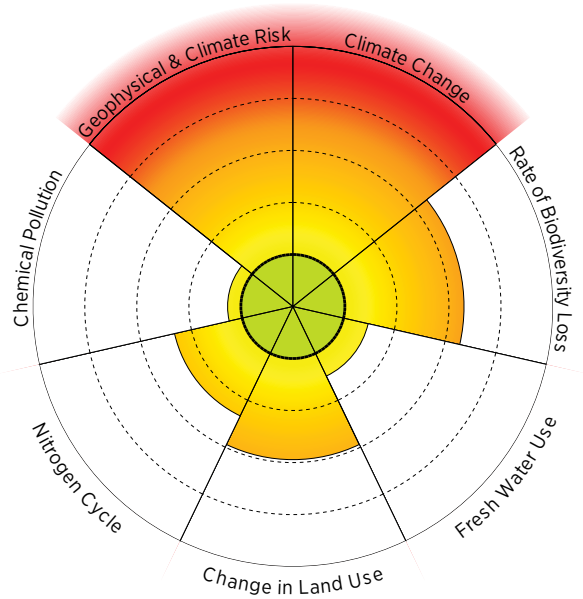
Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

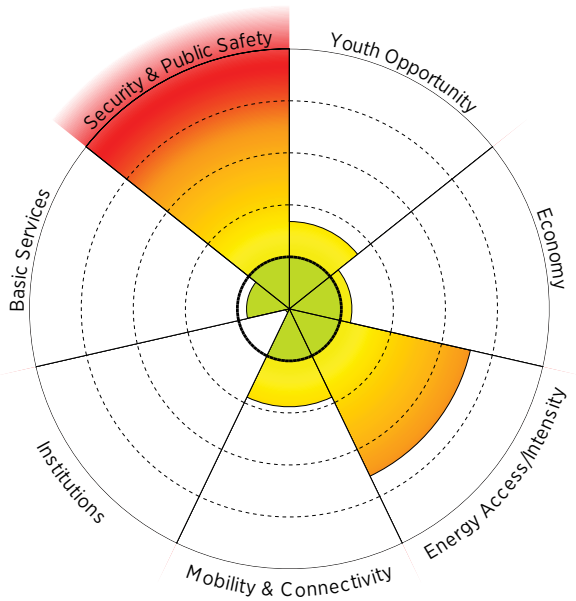
Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development Governance

ANNEX 2

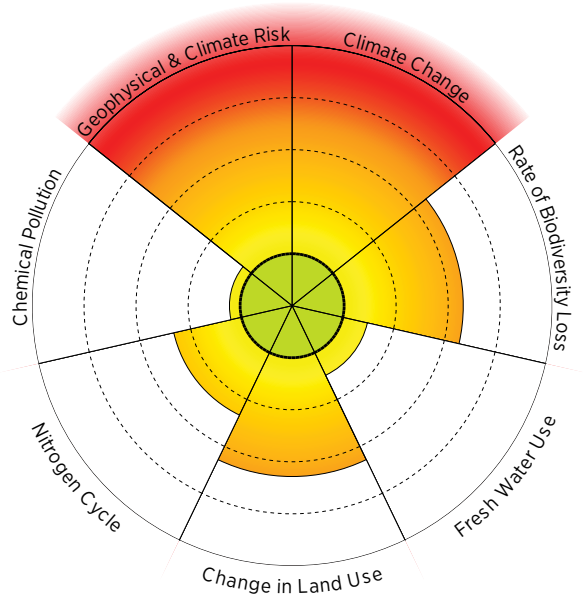
Sustainability Assessment of Cities within the Great Lakes Region

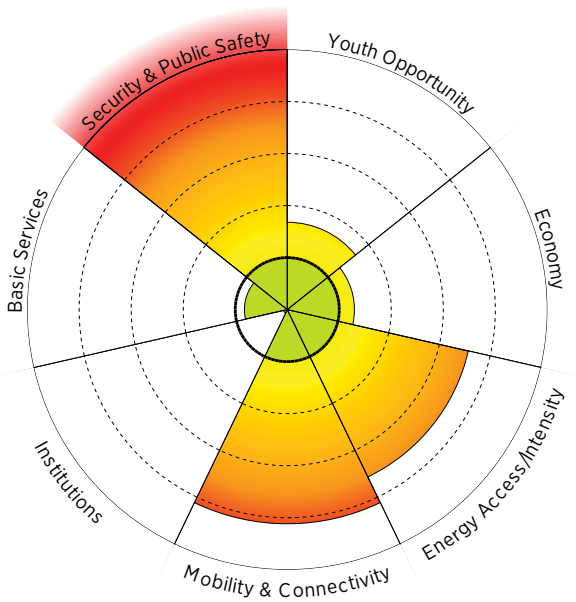
CHICAGO: BIO-PHYSICAL AND SOCIO-ECONOMIC





DETROIT: BIO-PHYSICAL AND SOCIO-ECONOMIC

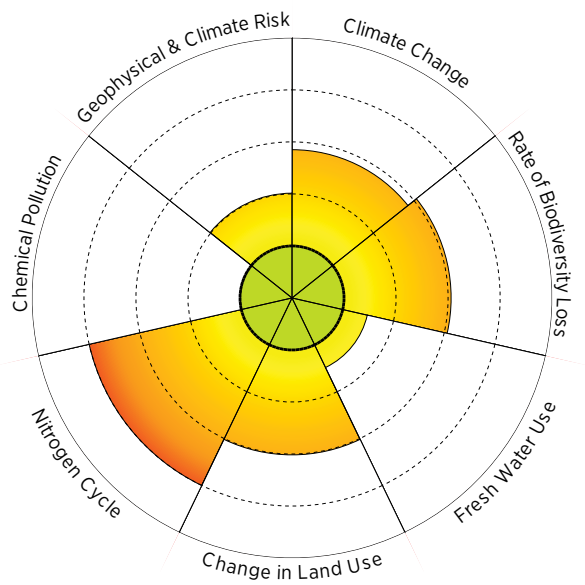


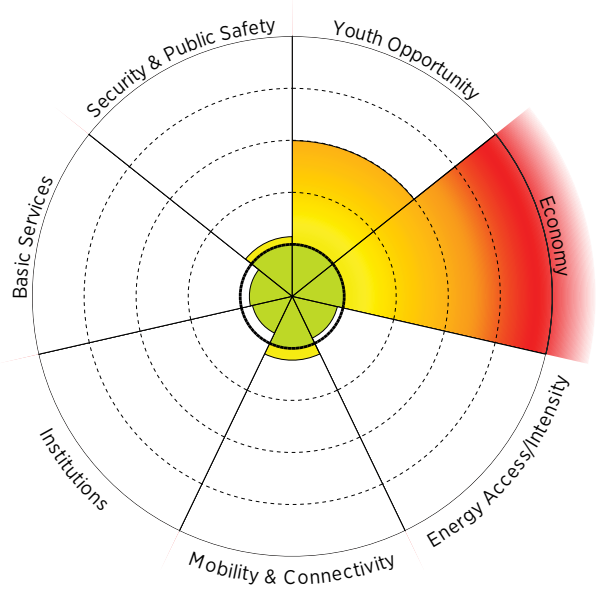


Source: https://www.city-sustainability.com/

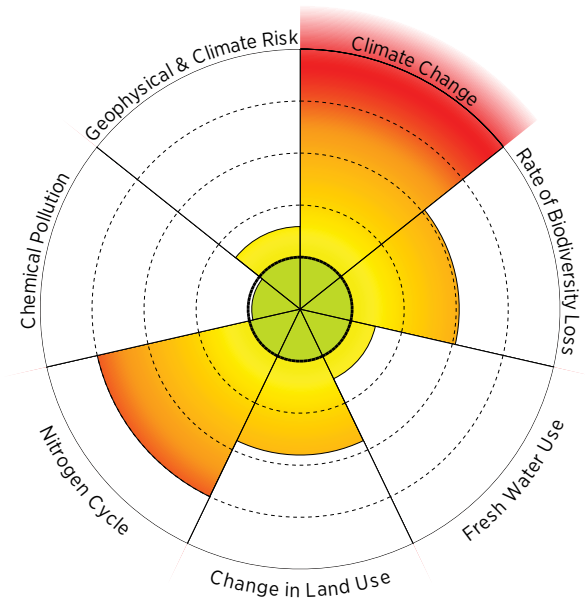
ANNEX 2 (CONTINUED)

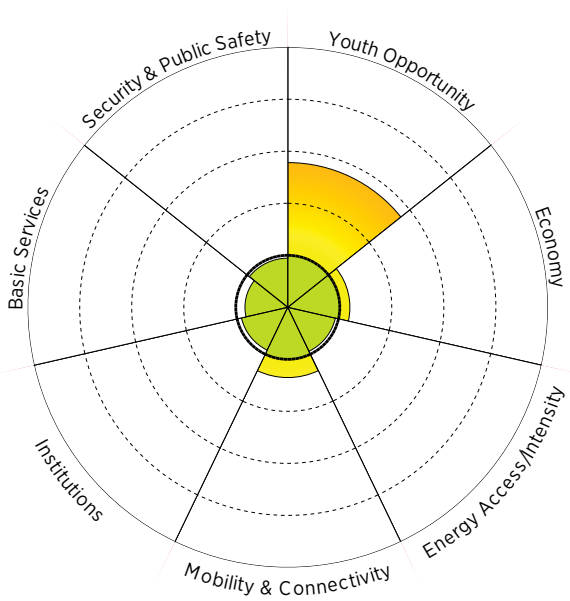
MONTREAL: BIO-PHYSICAL AND SOCIO-ECONOMIC





TORONTO: BIO-PHYSICAL AND SOCIO-ECONOMIC





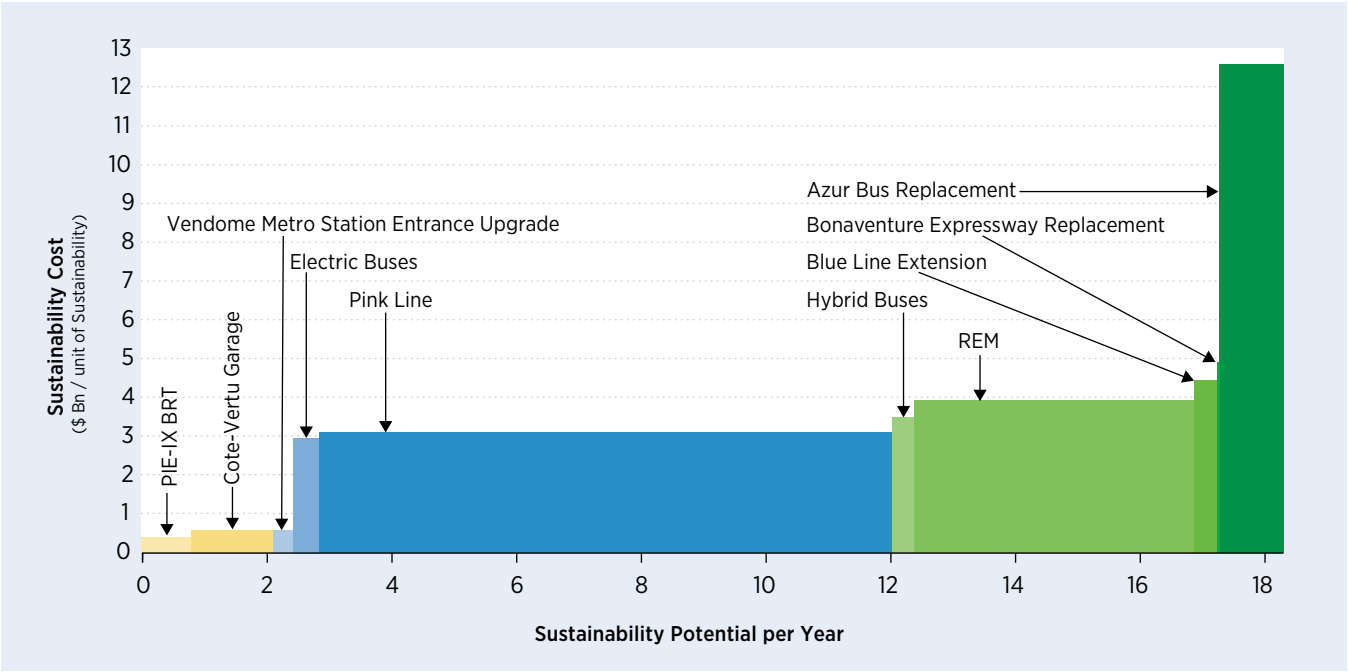
Source: https://www.city-sustainability.com/

[NB, the above cities sustainability assessment is illustrative. Metrics needs to be updated]

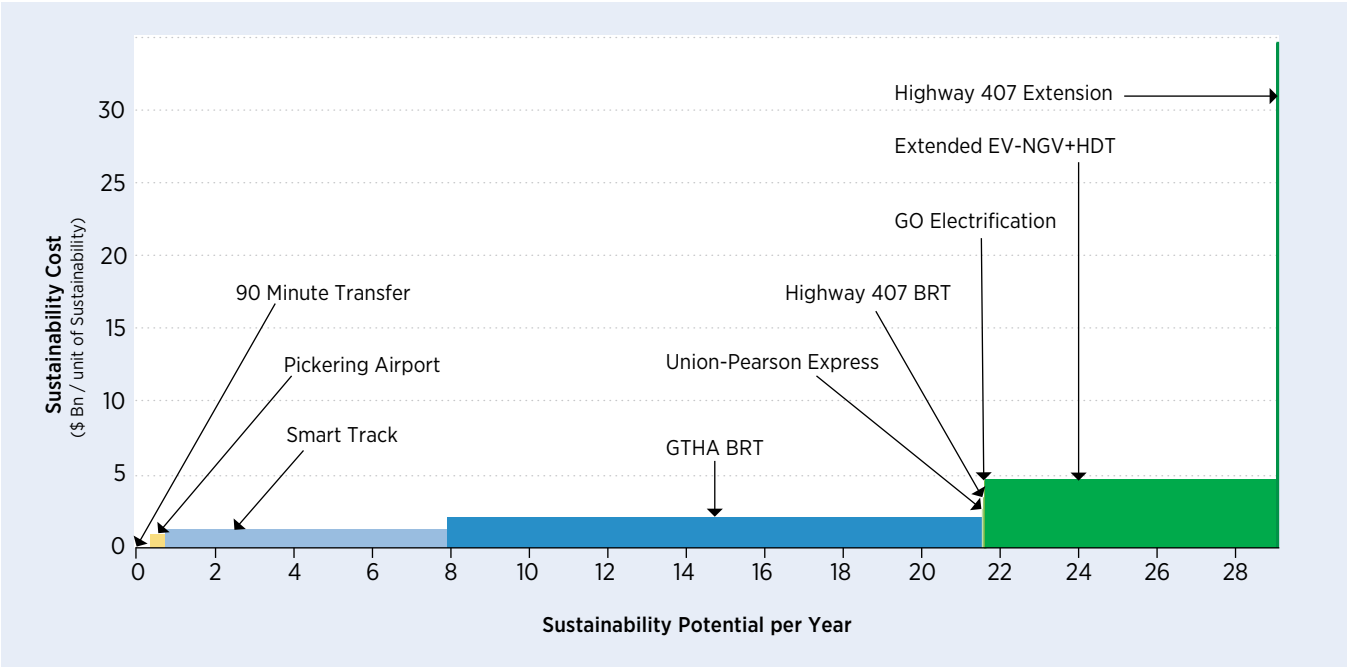
ANNEX 3

Using Sustainability Cost Curves to Evaluate Urban Transportation Infrastructure in Canada

SUSTAINABILITY COST CURVE: MONTREAL, CANADA



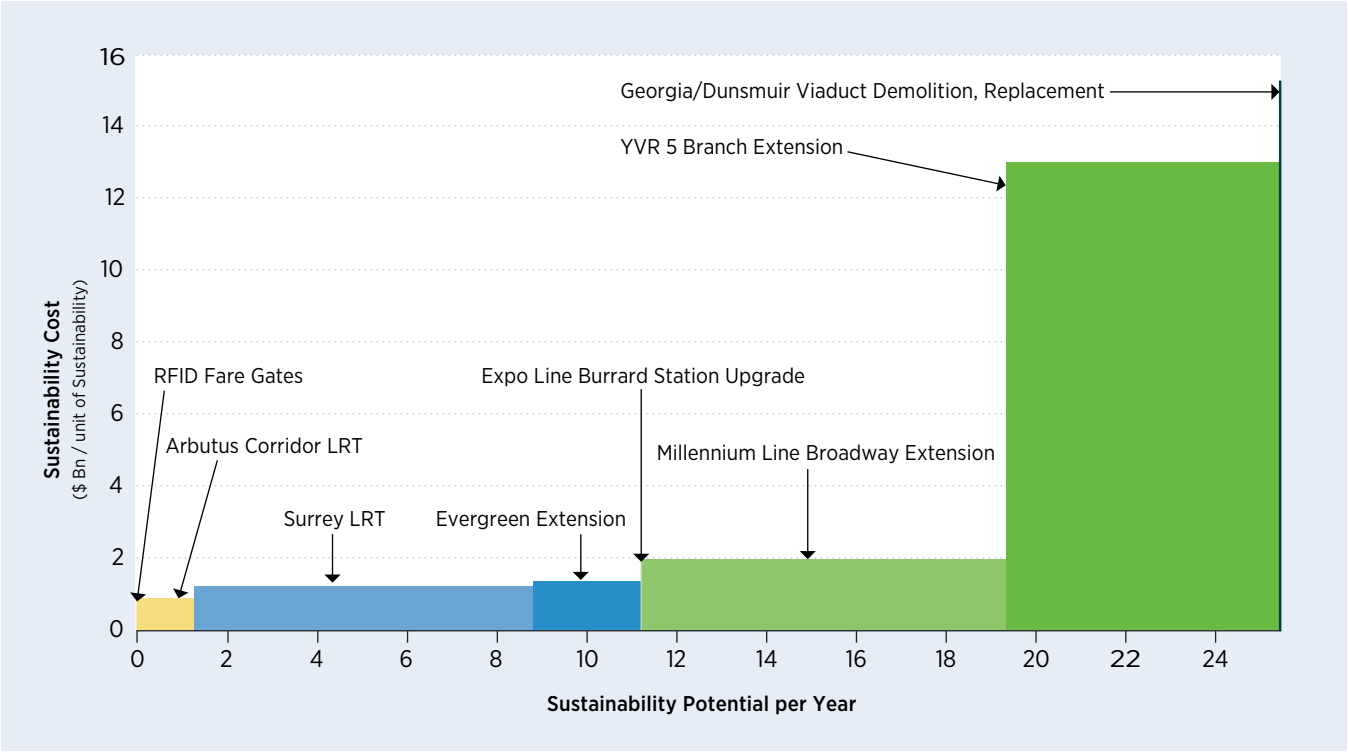
SUSTAINABILITY COST CURVE: TORONTO ,CANADA



Source: https://www.city-sustainability.com/

ANNEX 3 (CONTINUED)

SUSTAINABILITY COST CURVE: VANCOUVER, CANADA



Source: https://www.city-sustainability.com/

SUSTAINABILITY COST CURVES – Methodology[1]

Sustainability cost curves can help decision-makers select among a variety of long-term investment options. Policy-makers can apply sustainability cost curves as merit order curves, to prioritize investments for greater sustainability, at lowest cost.

Each activity, or wedge, along the curve represents an additional opportunity to increase sustainability. The width (x-axis) of each wedge represents the increase in 'sustainability potential' that the opportunity could deliver to a specified date, say 2050. Sustainability potential is derived from the aggregate contribution of the fourteen bio-physical and socio-economic indicators.

Changes that help to improve sustainability have a positive value for the change in sustainability indicator. The area of the wedge represents the activity's total expenditure, which is the product of sustainability potential and unit cost of sustainability (UCS).

The height (y-axis) of each wedge represents the average net present cost of that activity, per unit of sustainability potential. Net present cost includes capital and operating costs – less operating revenues (but not increased land value). Costs include expected expenditures to 2050 (benefits only start accruing from the year of commissioning). Cost estimates are based on expected government or utility financial outlays for the activity. The approach closely aligns with public expenditure in local governments and utilities. The curve is ordered left to right from lowest cost to the highest cost opportunities.

SCCs provide an overview of available development alternatives, and offer a starting point to prioritize options. Sustainable development involves more than choosing between options with least cost or largest sustainability potential, however SCCs provide a quick way to gauge the relative merits of activities, as well as enable comparisons between sectors and cities.

Cost curves require a specific future date to evaluate costs and benefits against; 2050 is selected in this analysis. A relatively long planning horizon of 30+ years is used as this helps evaluate larger-scale long-lived civil works that may require 35 years or more to amortize investments. The longer time-frame also encourages a more comprehensive analysis of options, combining capital and operation costs. Long lead times are also necessary to bring about large-scale changes in sectors such as energy and transportation. Many of the options being evaluated, e.g. power plants and subway lines can take more than a decade to plan and build. Also, much of the critical infrastructure in today's cities is older than 35 years; roads, rail and ports typically can last more than a century.

1 Adapted from Cities and Sustainability: A New Approach, Hoornweg, 2016

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c/o 3247 Clearwater Crescent,
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11075 East Boulevard, Room #245A,
c/o Canada-US Law Institute,
Case Western Reserve University,
Cleveland, Ohio, U.S.A. 44106

CONTACT:
Mark Fisher, *President and CEO*
Phone: (613) 668-2044
E-mail: mark@councilgreatlakesregion.org

www.councilgreatlakesregion.org