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# Living on the Edge: How we converted challenges into profitable opportunities

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ABSTRACT

In 2063, the Great Lakes–St. Lawrence River basin is Living on the Edge of system resilience, characterized by poor governance yet good environmental/economic balance. The Great Lakes region benefits from and depends upon human choices and natural forces outside the region pushing and pulling it toward that balance. Choices within the basin are insufficient to maintain system resilience, and there is minimal government involvement in Great Lakes governance. The Great Lakes region perseveres like a pampered but powerless slave, contributing value but lacking liberty. The predominant drivers of change that have brought the basin to this perpetual knife's-edge existence of dependency are the global economy, societal values, and technological innovation. Climate change, energy, and demographics in turn drive those drivers on a global scale, but the region itself has evaded the most extreme climate-change impacts, which proved highly variable through space and time. Global changes in energy demand resulted in the most massive investment in green energy technology in planetary history, dramatically shifting the global demand for wind, solar, wave, and nuclear power. Coupled with aggressive pro-business North American policies and endemic private-sector intellectual capital, the Great Lakes region reemerged as an economic engine to serve the demand. This shift occurred despite the death of cooperative federalism and after decades of ideological politics gutted science-based, citizen-participatory regulatory structures. Governance at local scales remains highly variable, so the Great Lakes region rides on the coattails of past policies. This scenario represents one of four described in the Great Lakes Futures Project.



## Introduction

In 2013, we cannot predict the future of the Great Lakes–St. Lawrence River basin into 2063 with confidence, but we can posit a scenario for the future state of the region as a system and provide a compelling narrative that unpacks plausible historical pathways leading to the future state of this system. Informed by the parameters of the Great Lakes Futures Project, we consider several drivers of change (aquatic invasive species, biological and chemical contaminants, climate change, demographics and societal values, economy, energy, governance and geopolitics, and water quantity). The drivers' prominence and significance ebb and flow through space and time like characters in a play but shape the state of the system and define its narrative (Appendix A). In this paper, we also add technological innovation as a driver because its narrative plays a critical role in shaping the Living on the Edge scenario.

We can consider regional policy frameworks as the props and scene setting with which our drivers interact. These are tools that either create connections or divisions among the drivers, directing the flow of the action but not fundamentally controlling our story's drama and conflict. The four main frameworks are the Great Lakes Restoration Initiative (GLRI), the Great Lakes–St. Lawrence River Basin Water Resources Compact (Compact), the Great Lakes Water Quality Agreement (GLWQA), and the Canada-Ontario Agreement Respecting the Great Lakes Basin (COA). In our scenario, which is characterized by poor governance, the GLRI, COA, and GLWQA are de-funded early on, minimizing their influence. The Compact, while dysfunctional, remains intact until the 2050s.

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[1] The Great Lakes Futures Project brought together graduate students and expert mentors from universities and institutions in Canada and the United States. Each paper required collaboration between a number of authors with many of them sharing co-leadership that we denote using a [1].

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We present a future history of the Great Lakes region in five acts, one per decade, looking back from 2063 over the past 50 years with an analytical and synthetic perspective (Fig. 1). We present a plausible narrative of how our system came to teeter on the edge of resilience, where resilience is the "capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Folke, 2006). The final act, set in 2063, includes an extended discussion on the state of affairs and a reflection on the historical evolution leading to the new normal.

Our future history, Living on the Edge, represents the scenario that occupies the upper-left quadrant of a two-dimensional coordinate plane, with the horizontal axis representing the human capacity for change and the vertical axis a balanced environment and economy (Laurent et al., in this issue). This scenario is characterized by poor governance and, more generally, a poor human capacity to effect change. External forces are responsible for the most significant changes within the Great Lakes region, and internal decision-making that does exist on the broadest scales is largely impotent. Another feature of this scenario is persistent reactivity to problems rather than proactive policies to prevent them. Our scenario also demonstrates poor governance in the collapse of cooperative federalism across the region. The Great Lakes region has essentially exported its governance; the predominant capacity for change-making inside the basin lies outside the basin.

Despite poor governance and an overall poor capacity for societal change, the Living on the Edge scenario displays good environmental and economic balance. The Great Lakes region experiences economic regeneration that does not disproportionately impinge upon internal environmental systems. Balance is maintained as the economic pressures that have historically impacted the environment negatively – resource extraction, dirty power production, urban sprawl, and industrial pollution – shift over time to become cleaner, less intensive, and more expensive, thus limiting negative externalities. However, the balance remains tenuous because it depends on spillover effects from the pursuit of profitable business. In this scenario, the private sector takes the lead.

So long as environmental benefit remains aligned with economic profit, so long as past policies push and global demand pulls the region forward, and so long as technological innovation pushes back the frontiers of the possible, our system enjoys good balance. Yet should any of these four forces slacken, we expect a rapid descent of the system from a precarious but prosperous life on the edge into the lower-left quadrant described in the Out of Control scenario. The system we describe in Living on the Edge performs well under certain conditions, but lacks an internal capacity to adapt to all possible changes.

## Future history

### *Act I: taking the government out of governance (2013–2023)*

*A flurry of government budget cuts and austerity measures in wake of the 2008 Great Recession combine with pro-business policies to deregulate the environmental and natural resource sector…*

Shifting demographics in the US contributed to a second term for President Barack Obama in 2012. However, proactive federal environmental policies continued to fall on deaf ears in Congress, led by Republicans who clung to power in gerrymandered districts and underwritten by powerful corporate interests resistant to regulation, uncertainty, and change — so long as superior economic opportunity remained a key societal value of the American electorate. These conditions had set the stage for the Tea Party movement, characterized by ideological extremists pulling the political discourse and policies to the right throughout the decade.

In Canada, the second consecutive Conservative government majority was won in 2015 and helped to further cement pro-business governance trajectories (Malakoff, 2013). Protective environmental policy took a back seat to a more business-friendly political agenda favoring natural resource development on both sides of the border. At the same time, the mass retirement of government bureaucrat baby boomers and an over-reliance on contractual staff and outsourcing to consulting firms considerably degraded government capacity for Great Lakes basin governance. This vacuum presaged the erosion of federal and subnational government leadership in the region's governance (Jetoo et al., in this issue), and proved a perverse catalyst leading to funding cuts to the GLRI, COA, and the GLWQA.

These trends were again seen in the US with the 2016 election of a Tea Party Republican president (Fig. 1). The Tea Party government returned to trickle-down economic policies inspired by Ronald Reagan that gave wider latitude to the largest corporations and weakened both environmental protections and scientific investment in the name of job creation and government downsizing. Canada followed suit with the changes in American environmental policies, as has historically been the case (Hoberg, 1991). With federal policies on both sides of the border providing no incentives for large corporations or utilities to internalize environmental or societal costs, individual corporate actors were left either to self-regulate or follow the markets wherever they

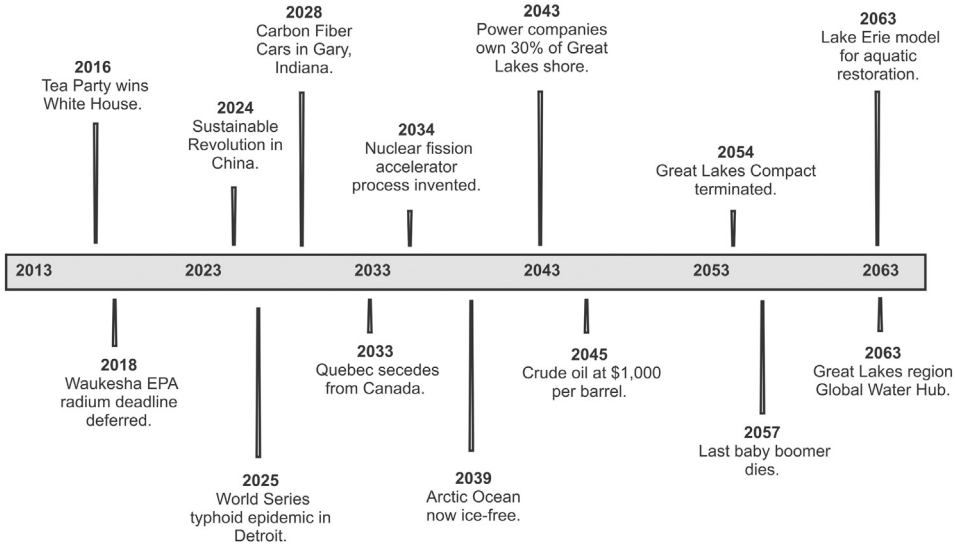


**Fig. 1.** Timeline of the events occurring from 2013 until 2063 within the Great Lakes–St. Lawrence under the Living on the Edge scenario.

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may lead. Through the 2010s, corporations in the Great Lakes region states and provinces responded to their new tax breaks and relaxed regulatory frameworks with higher profit margins but only mediocre job creation. Not until the next decade would this pro-business policy regime encounter the surge in foreign demand for non-petroleum energy solutions that caused domestic economic activity to explode.

The North American drought of 2012 followed by Superstorm Sandy brought the region's societal values back around to viewing climate change as a present threat (Abramson and Redlener, 2013). In his 2013 inauguration address, President Obama argued that the US must take the lead to innovate technological solutions to mitigate and adapt to climate change in order not to discount the welfare of the planet's future generations (WH, 2013). In Canada, Prime Minister Stephen Harper also lauded the necessity of private enterprise and green technology in climate change mitigation and adaptation (though in reality, more attention was given to oil sands development and exports). Industry and the public took little notice when the average global concentration of carbon dioxide in the Earth's atmosphere passed the 400 ppm milestone, but the more intense storms ravaging the region and overwhelming conveyance systems through the 2010s did not escape notice (Patz et al., 2008). These led to the spread of sewage contamination and disease, especially among children, the elderly, and vulnerable First Nations and Tribes with existing water infrastructure problems (NAHO, 2002).

The increasing frequency and severity of these extreme rainfall events and heavily localized sewage overflows triggered associations of climate change with biological contaminants in the public mindset (Cornwell et al., in this issue; Curriero et al., 2001). The result was that individual cities displayed local-level governance by adapting to climate change with greener infrastructure for stormwater control. In the absence of federal or subnational leadership and funding, existing municipal-level organizations and initiatives, such as the Great Lakes and St. Lawrence Cities Initiative, the Federation of Canadian Municipalities, and the US Conference of Mayors endeavored but failed to harmonize municipal adaption strategies across the basin. The region reacted well to points of crisis but failed to be proactive or comprehensive. One example of this was massive investment by the City of Montréal public- and private sectors in green stormwater infrastructure, including green roofs and urban tree canopy improvements in response to recurring boil water advisories of the 2010s.

The situation in the sprawling suburban community of Waukesha in Wisconsin proved a fascinating counterpoint, but one still demonstrating how government was stepping out of regional governance for better or worse. Facing a 2018 US Environmental Protection Agency (USEPA) deadline to remove radium contamination from its groundwater-derived drinking water, the community had been the first to apply for an out-of-basin diversion under the Compact. When it became clear that other states party to the Compact would not allow Waukesha's diversion request because of dissatisfaction with the inadequacy of its proposed water conservation plan, the president intervened by issuing an indefinite stay of the EPA radium deadline. Eschewing regulation, he instead provided a financial compensation package for the city to offset the anticipated radium treatment costs. Coupled with Congressional de-funding of the EPA, this executive countermand signaled the end of the era of EPA regulatory influence in the US. It also effectively deferred Waukesha's Great Lakes diversion request indefinitely, preventing the Compact from functioning as intended and leaving its parties in limbo without a clear precedent with which to judge future diversion requests (Fig. 1). Still, the cost of extracting water from the deep aquifer beneath Waukesha, already drawn down from historic development, increased dramatically. The concomitant water rate increases served to curtail sprawl, driving people and investment out of the suburbs back to the water-rich Midwestern coastal cities. Ultimately, people only responded to base economic motivations. Facing the choice to adapt or die, Waukesha itself finally adapted. In a case of poor governance on multiple levels leading to good environmental and economic balance, Waukesha, though still reliant on groundwater, ultimately implemented bolder conservation measures that proved worthy of emulation by water-scarce communities everywhere.

In the 2010s, aquatic invasive species were also still on the public agenda because of their ongoing impacts to the Great Lakes basin environment and economy (Pagnucco et al., in this issue). For some time into the 21st Century, industry and government both rode the coattails of the successful ballast water exchange policies, such as the Ballast Water Control and Management regulations that were added to the Canada Shipping Act in 2006, the similar St. Lawrence Seaway Development Corporation's regulations of 2008 in the US (Bailey et al., 2011), and the stricter measurable International Maritime Organization D-2 equivalent standards agreed to in 2013 (USEPA, 2011, 2013). Implementation of a consistent standard of rules after almost two decades of push and pull between governments and industry finally incentivized a new burgeoning industry of ballast water treatment systems developed in the Great Lakes region. However, by the mid-2010s, the war against invasives had shifted from the eastern to the southern front (Lynch et al., 2010). Migrating up the Mississippi River system, Asian carp had become so widespread in the region's rivers (Cooke and Hill, 2010) that establishment in the Great Lakes region themselves was no longer deemed the worst case scenario — simply inevitable. Private-sector innovations in new electric barriers and more sophisticated environmental DNA tracking stemmed the tide in the Chicago River, but it was only a matter of time until the barriers failed. Moreover, climate change continued to push open other niches vulnerable to invasion by species migrating over land or through river systems, and stricter ballast water standards did nothing to guard against these routes.

With governments no longer as willing to foot the bill for invasive species control, private industry took on more of a leadership role. For example, until the 2020s the ubiquitous reed *Phragmites* dominated roadside drainage ditches and colonized post-industrial right-of-ways wherever they remained derelict of human intervention. *Phragmites* also choked out native wetland plants throughout the Great Lakes basin (Tulbure et al., 2007). A large biotechnology firm patented a gene in 2019 that targeted the plant's immune system and developed a lucrative herbicide for the control of this invasive plant and its associated ecological impacts. This development and others like it signaled the private sector's entrance into the emerging market of restoration ecology.

### *Act II: epoch of international corporate responsibility (2023–2033)*

*The continuance of pro-business and deregulatory policies in North America lead to increased corporate influence over governance processes at all scales…*

Hurricane Leonard swamped the northeastern coast of North America in 2023. With their capital offices flooded, politicians of all stripes suddenly resolved to tackle climate change — a cap on carbon emissions was not yet palatable, but tax breaks for energy companies on both sides of the border to invest significant portions of their portfolios in alternative energy or electric vehicles were an easier sell. These tax breaks combined with subsidies to incentivize net-zero-carbon emissions set the stage for massive industrial capitalization in green technology throughout the Great Lakes region. This was less a proactive choice of binational regulatory harmonization under the 2011 Beyond the Borders Action Plan than kowtowing to private interests. The US and Canadian governments also threw their weight around in the global marketplace, imposing new tariffs on foreign green technology and next-generation vehicle imports. These tariffs were designed to boost domestic demand, though the ultimate policy aim was to bootstrap domestic companies with sufficient capital so they could successfully compete in foreign markets, which promised the greatest long-term opportunities for growth due to ballooning consumer populations. This tilting of the economic playing field was criticized for being

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inequitable and ratcheting up geopolitical tension — yet it benefited the Great Lakes region economy.

Suburban sprawl continued throughout the region until 2025, when it simply became too expensive for the majority of the population to live too far removed from the greatest cultural and economic centers. Utilities passed rising energy costs along to consumers. As the true costs of traditional sources of energy (e.g. coal) were finally incorporated due to fear-based market forces motivating the corporate boardroom, demand ratcheted down, as consumers grew increasingly unwilling and unable to pay these increased costs. Petroleum-based fuel costs continued to rise and people drove less often and shorter distances because they could no longer afford the cost of fuel. Thus followed an era of inevitable contraction. Extended family units came to live together again in cities, rekindling hyperlocal urban communities. For instance, the suburban and exurban havens of commuters surrounding the City of Toronto, like those in Durham and York Region, had the requisite population bases to establish their own economic centers beyond mere business and industrial parks. This fostered considerable densification efforts, the breakdown of commuter culture, and the disassociation of the Greater Toronto Area as a singular geographic entity.

The year 2025 also marked a transition in approach to the region's neglected ailing infrastructure, which contributed to the Detroit Typhoid Fever Epidemic (Fig. 1). Two hundred thousand people got sick and almost a hundred died after water main breaks during unseasonably heavy storms contaminated Detroit's water supply with human sewage (Lambertini et al., 2012), notably impacting visiting guests at Comerica Park during the World Series. In response, policymakers created a nationwide series of pipe rehabilitation projects modeled after the post-recession federal stimulus act, and state and municipal governments applied for project funds to rehabilitate infrastructure. This helped to push climate change and institutional and infrastructure readiness into the mainstream, but as with the contamination episodes of the previous decade, the event saw successful reaction but a failure to be proactive (AWWA, 2012; USEPA, 2009). Responsibility for environmental governance remained shifted to the local level and not every community was able to access funds to shore up its infrastructure.

Globalization remained king in the 2010s. The late 2010s and early 2020s are now seen as the dawn of an era of international corporate responsibility, when corporations seized the world stage as actors of greater stature than most governments — for better or worse. This trajectory was cemented by the failure of several legal challenges to *Citizens United*, the landmark US Supreme Court ruling that extended the precedent of treating corporations as persons whose freedom to spend money on speech was protected (Liptak, 2010). Most corporations did not shy from exerting their influence. To maintain their profit margins, North American corporate giants had to earn (or buy) the confidence of North American publics the way politicians of earlier eras did. Green brand positioning was seen as a key competitive advantage to ensuring regulatory and popular favor, and hence shareholder value.

The global transition that buttressed the supremacy of large corporate interests in the Great Lakes region came as a result of actions outside the basin. In 2024, the Chinese government rolled out sweeping and decisive policies to invest in non-fossil-fuel energy production to meet the demands of its rapidly expanding middle class and stem the tide of climate change. The "Sustainable Revolution" coincided with a strategy within North American- and European-owned big oil companies to diversify their portfolios into green energy in order to ensure long-term profitability, as oil grew increasingly costly to extract (Fig. 1). Permissive federal policies promoting unrestricted big business growth, the unprecedented surge in foreign demand for specialized manufacturing products and services, and shifting corporate strategies from "Drill, Baby, Drill" to "We Also Do Oil" resulted in the ballooning of industrial activity and economic resurgence throughout the Great Lakes region. This built on the region's historic but underutilized industrial capacity.

A powerful counterpoint to the Chinese-led Sustainable Revolution was heavy-handed North American economic interventionism, particularly in Latin America and Southeast Asia, which transformed the automotive industry by opening up global markets to carbon-fiber electric cars manufactured in the Great Lakes states and Ontario. The US and Canada used their leverage as imperial and military powers to negotiate favorable economic agreements with the developing nations in which domestic corporations perceived burgeoning markets. International trade agreements (Smith, 2010) and import tariffs (Gopinath, 2013), proved the true weapons of global market impact, as they have historically. Strong-arm North American trade negotiations and heavy domestic subsidies incentivized the widespread production and distribution of a new wave of less-carbon-intensive vehicles made by the next generation of Rust Belt automakers. The poster-child enterprise was Carbon Fiber Cars Co. The company opened in 2024, symbolically locating its production facilities amid the rusted hulk of the US Steel plant in Gary, Indiana (Fig. 1).

Given these economic trends, it was no surprise in the 2020s that the energy future for the Great Lakes region differed from 2013 Energy Information Administration and National Energy Board outlooks (EIA, 2012; NEB, 2011). Most notable was their overestimation of the role of coal-fired energy and underestimation of the private-sector's role in advancing renewable energy production. Unconventional natural gas sources, particularly hydraulic fracturing (referred to as "fracking"), experienced a short boom followed by a decline in the 2020s. This decline was expedited by the Ohio and Michigan aquifer contamination fiasco in 2025. In fact, this decline may have been even further exacerbated by growing awareness, both scientific and public, of unexpected levels of methane released from the extraction process. Despite these environmental consequences and obvious negative societal perceptions around hydraulic fracturing, the boom in energy production from unconventional sources of natural gas did play a critical role in easing the eventual shift from coal to renewables (Kelly et al., in this issue).

A business-friendly policy environment spurred the private-sector action described above that was to dominate the following decades. There was a loosening of regulation and standards for energy developments in place of direct incentive-based policies. Lessons learned from the shortcomings of early incentive programs like Ontario's feed-in-tariff program around supply management coupled with technological advancements in energy storage propagated private-sector investment in wind and solar. These incentive programs have since ended, and today in 2063 the government presence in the energy policy arena is negligible. However, the policy inertia from these programs along with the response of global markets to the unpalatable costs of fossil fuels enabled the private energy sector to largely push fossil fuels out of the basin.

### *Act III: the collapse of federalism and the scarcity of water (2033–2043)*

*Decades of erosion of federal government programs lead to the collapse of federalism across the Great Lakes region as global climate-change impacts expose the world's scarcity of freshwater resources. The region retains these resources in abundance due to historic policies like the Great Lakes Compact, and it attracts both global climate refugees and regional immigrants…*

Decentralization and poor alignment between federal and subnational governments have always been a challenge facing governance in the basin (Jetoo et al., in this issue), and ultimately in the 2030s the ideal of cooperative horizontal federalism (Hall, 2006) officially failed. Hall (2006) defines horizontal federalism as "…an approach in which states jointly develop common minimum legal standards…to manage a shared resource, but leave the individual states with the flexibility and autonomy to administer those standards under state law." By the 2030s, the Compact and GLWQA were no longer federal priorities in the US and Canada. This generated a race to the bottom in environmental policy among subnational governments. Institutional fragmentation

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ensued, as policy implementation and eventually policy making were continually downloaded to local governments, who showed at best a variable capacity for governance. While local cases (e.g., municipalities) did arise as scarce and scattered examples of good environmental governance, region-wide harmonization and ecosystem-based binational governance were non-existent. Additionally, in 2033, after two decades of Parti Québécois provincial leadership, the sovereignty movement triumphed and Québec separated from Canada, causing a monumental change to its national identity (Fig. 1). Subsequent tensions between Ontario and Québec negated any future prospects for cooperative horizontal federalism on the Canadian side of the Great Lakes region. Since basin-wide governance was already in a degraded state, geopolitical tension rose dramatically when suddenly three nations shared Great Lakes basin resources. Hydropolitics among the three nations continued to darken, and future transboundary conflict over Great Lakes water was feared. With the US Southwest exerting the greatest pressure and growing dependence on water diversions to support their population and agriculture, the conditions were ripe for scarcity conflicts comparable to those for less stable regions like the Nile River system (Homer-Dixon, 1994).

The loss in scientific capacity of federal and subnational governments also became apparent in the 2030s. In particular, budget cuts and gradual decentralization of Great Lakes basin governance laid ruin to the science and policy capacity of Environment Canada and the USEPA, and therefore much of the federal presence in the region. The International Joint Commission (IJC) was also permanently de-toothed in the 2030s due to continuing reduction in funding and capacity. Since the expert boards of the IJC were historically critical components of participatory governance (Botts and Muldoon, 2005), the loss of governance capacity was drastic and the science-policy gap widened. Accountability, transparency, and public participation within the Great Lakes basin governance structure worsened, and the environment eventually became an almost entirely privatized commodity. The lobbying power of interest groups, both private-sector and environmental, over the IJC and Great Lakes Executive Committee underscored the precariousness of the environmental and economic balance. Money talked.

In the 2030s, the question of water quantity impacts from diversions paled in comparison to the growing realization that climate change was perturbing the natural fluctuations of Great Lakes levels (Bartolai et al., in this issue; Hanrahan et al., 2010). Trends in lake water levels documented by the National Ocean Service of the National Oceanic and Atmospheric Administration (NOAA, 2013) continued with lake temperatures and evaporation on the rise and ice cover on the decline. Up to that point, there was considerable policy involvement and subnational government regulation in water-supply management. This began changing in the 2030s, due to persistent high variability in lake levels, especially in Lakes Michigan and Huron (Maghrebi et al., in this issue). Due in part to alarmist rhetoric that overstated likely impacts, policymakers, industry, and the public feared a future where the lakes dried out like the Aral Sea, yet they were unable to adequately prepare for dramatic year-to-year lake level fluctuations that hampered coastal commerce, recreation, and industry. While the Compact was meant to prevent the actualization of these fears via diversions or bulk water exports (Squillace, 2006), by the mid-2030s the Compact began to fall off the government agenda as climate change seemed to be diverting much more water from the lakes than unaccounted-for human uses. Climate-change fears spurred the rallying of both public and private capital in a major cross-border initiative to build the long-anticipated Great Lakes structural control on the St. Clair River at Stag Island (Mackrael, 2013) in 2038. This moved the lakes one step further along their trajectory as a managed system.

The regional energy narrative advanced in the 2030s as well. Though the technology to harvest the Great Lakes region's great wind resources existed in the 2000s, breakthroughs in wireless transmission methods made their rapid proliferation economically viable in the early 2030s since industry and governments no longer had to solve the costly transmission problem. As a spillover of their new revenue and investment spoils, forward-looking utilities also invested in coastal rehabilitation across the region, seizing and holding thousands of acres of shoreline property, initially catering to environmentalists who feared the wind turbines would lead to massive bird kills (Drewitt and Langston, 2006) and act as another vector for invasive species establishment (Petersen and Malm, 2006). Utilities needed these shorelines free of development to facilitate the wireless transmission of power, but they also wanted to placate local communities. Wind farms changed the esthetic of the lakes, particularly in the southern basin of Lake Michigan and the Golden Horseshoe area of Lake Ontario, but also resulted in the enhanced protection of wind power free regions in the northern stretches of Lake Superior, whose northern shore's change in climate opened up the region into a veritable mecca of tourism and commerce. Lake Superior became linked overland to the expanded trade and transit routes between Duluth/Superior, Sault Ste. Marie, and the new northern frontier in the resource-rich Canadian Territories, which were opened up to development and resource extraction by a warming climate and proximity to the ice-free and navigable Arctic Sea (Fig. 1). Superior's renaissance was yet another example of successful environmental stewardship being aligned with economic interest that continued to lay the foundations of regional environmental and economic balance.

At the same time that the Great Lakes region built up its wind energy capacity, the nuclear industry was also transformed. Persistent nuclear waste leakage from power plants along the shores of Lakes Michigan and Huron on both the American and Canadian side of the border raised the collective alarm and strained cross-border relations throughout the 2010s and 2020s. But nuclear power was still heralded by many as having a prominent role in a sustainable and carbon-free future. The invention in 2034 of a low-cost fission accelerator process (Fig. 1) allowed the conversion of spent reactor fuel into a safely exportable resource of high economic value, powering a new wave of smaller reactors (Borges Silverio and Lamas, 2011). This both reduced contamination risks to the Great Lakes region and eased global energy demand: one generation's toxic waste became the next generation's resource.

### *Act IV: after peak oil, an epoch of realignment (2043–2053)*

*Global economic shocks related to Peak Oil, climate change catastrophes, and the shift to serving Chinese and Indian consumer demand leads to an industrial boom of green energy and blue technology designed and manufactured in the Great Lakes region…*

By the 2040s, demand in the energy and transportation sectors remained strong, but another global sector joined them: water technology. The late 2030s through 2040s featured global water shortages and regional water conflicts exacerbated by population growth, intensive agriculture, and climate change. The increased demand for safe and reliable water supplies shifted the Great Lakes region industrial capacity from serving mainly the demand for green energy to also creating and exporting smarter blue infrastructure, such as self-healing pipes, aquaponics systems, novel genomic techniques, and – critical for millions around the planet – low-technology water treatment, micro-irrigation, and shallow groundwater pump and aquifer monitoring systems for developing nations affected by severe drought or conflict (Burney et al., 2013). This surge in blue technological innovation at once helped insulate the Great Lakes region from the most severe water quality and quantity problems, while the profitable export of those technologies mitigated the worst of those problems in the hardest hit regions globally. Oil prices hit $1,000 a barrel in 2045 (Fig. 1), causing global economic and geopolitical shocks that further increased the value of the region's alternative energy and water technology exports. The economic tide rose because the Great Lakes region itself enjoyed access to freshwater and was insulated against the global oil shocks due to sufficient domestic supplies of fracked natural gas and coal, sufficient local agricultural food stuffs, the influx of battery-powered carbon-fiber cars,

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and a growing regional wind, bioenergy and nuclear portfolio already weaning the Great Lakes region off its fossil-fuel dependence.

Due to historic remediation efforts that reduced legacy contamination in Great Lakes region Areas of Concern (e.g., the Milwaukee Estuary, Sheboygan River, and St. Louis River and Bay; Cornwell et al., in this issue) combined with the aforementioned private-sector interests in ecological restoration, biological and chemical contaminants were far less severe in the Great Lakes basin than at the turn of the century, though their legacy on public perceptions of the Great Lakes region fisheries continued. For example, by the 2040s most consumers had become accustomed to avoiding sport fish due to well-founded fears of mercury contamination. At the same time, the demand for domestic aquaculture had risen by orders of magnitude. The Great Lakes region's cities were actually engaged in profitable commercial urban aquaculture operations that also provided local food sources free of contamination and with significantly lower environmental costs than in the 20th Century. Out in the open waters, the pervasiveness of Asian carp in the region spawned the development of a new sport and commercial fishery, with the latter serving the increasing population of Asian immigrants who valued carp not only as food but also as a source of alternative medicines.

The human adaptation to the carp invasion helped to shift the public perception about invasive species and emphasized the leading role that societal values can play as a driver of change. Invasive species were globally accepted as a reality. Incidentally, in 2045 the Great Lakes basin could no longer boast the title of the world's most invaded freshwater system — that title being passed on to the Yangtze system in China. Given the effects of climate change and global trade in the past century, the concept of native species had the gone the way of the dodo (along with beliefs in the theory of ecosystem equilibrium). In the end, the established Asian carp populations proved an incredibly hardy introduced species — one member of a new unnatural ecosystem with integrity by proxy. Over the previous 30 years the carp's environmental consequence was realized but then forgotten. The Asian carp altered Great Lakes basin food webs and what fish species predominated; but importantly, the system still functioned sufficiently to deliver a set of ecosystem services with anthropogenic utility, which was what society valued.

*Act V: a common tragedy — the commodification of Great Lakes water (2053–2063)*

*As the capacity for governance is continually degraded in the Great Lakes region over the 2050s, the looming global threat of climate change and water scarcity leads to an even greater erosion of tri-national, region-wide cooperation in resource management and the eventual failure of the Compact…*

The death of any type of cooperative horizontal federalism and the increasing demand for water and private-sector competition in water governance caused the eventual failure of the Compact to prevent out-of-basin diversions and bulk water exports (Fig. 1). The absence of region-wide collaboration on policy implementation and a total lack of enforcement presence on behalf of the federal government led to a collapse in water quantity governance. The final nail in the coffin of the Compact was hammered in 2054 when the political backlash that lawmakers feared from repealing the Compact (Hall, 2006) was outweighed by panic and fear outside the basin and economic opportunism within the basin. Droughts, intensive agriculture, and overexploitation of aquifers regionally, nationally, and internationally led to insatiable demand for the basin's water.

Without federal policy leadership and authority, state and provincial governments became increasingly self-serving. Through the 2050s, the Great Lakes basin saw increasing commodification of water resources. Under conditions of institutional fragmentation, the age-old pitfalls of the tragedy of the commons and the myth of abundance ran rampant across the fractured jurisdictions and localized governance regimes. As a result of the increasing frequency and severity of extra-regional growing-season droughts in combination with poor agricultural land management practices in the Canadian Prairies, Great Plains, and the US Southwest, the Great Lakes region experienced an increasing demand for bulk water exports. This strained international relations and increased geopolitical tension across the border as both subnational and local governments and industries served their own economic interests regarding water governance. Importantly, the water diversions that were increasingly being approved in response to this rising demand have not yet translated into any major effects on lake water levels. As a scarce commodity in various regions outside of the Great Lakes basin, water was priced at a premium that economically benefited the Great Lakes region, but these economic gains were highly dependent on uncertain and external economic and climatic drivers and thus opened up considerable vulnerabilities for future water governance.

Attention must also be given to the strong divergence of regional versus global effects of climate change. It became apparent that the Great Lakes region was spared from the most severe impacts that were experienced globally — especially in the drier and high-latitude regions (IPCC, 2007). This succeeded in bringing international attention to the Great Lakes basin as a freshwater source in a time of scarcity. Economically, the region, especially private-sector innovators within, began to establish dominance in blue infrastructure and technology. Demographically, the stream of immigration to the region so vital to the growth of Toronto and Montréal at the turn of the century (Hou and Bourne, 2006; Méthot et al., in this issue) was now happening in most major urban centers in the Great Lakes region, including on the US side of the border. These immigrants were frequently referred to by the media and the environmental and international development communities as climate refugees, because their places of origin were often countries ravaged by the changing climate. The infusion of this diversity of cultures into urban hubs within the Great Lakes basin and its effect on societal values within remained unapparent and uncertain, though widening cultural divides were feared. These displaced and vulnerable populations represented a case of distress migration in place of economic migration (Johnson and Krishnamurthy, 2010). Consequently, in the absence of government-led social protection to help climate refugees resettle and integrate, a real threat of isolation in the immigrant populations existed. These climate refugees did not constitute one single voting or consumer bloc, and therefore the region's demographic heterogeneity remained a societal asset. Immigrant assimilation into the North American mainstream actually became easier than in previous generations due to the mediation of technology, as personal connective devices were commonly available for even the poorest people and English had become accepted as a de facto global language. Technological social networking evened the playing field and societal unrest remained minimal as long as green-collar labor was in demand. The strength of the region's green industrial economy sent feedbacks through the still predominantly service-based economy, enabling the region, on balance, to absorb the influx of immigrants.

## Discussion — the final act: Great Lakes region emerges as a global water hub (2063)

*In the 2000s, Milwaukee businesspersons envisioned their city reinvigorated as a global hub of water industries; in 2063, the entire Great Lakes region has emerged as such a hub, serving water-scarce regions of North America and the world hit hardest by climate change with innovative and profitable technological solutions that underwrite humanity's new bargain with the planet…*

Humans are creatures of change. History illuminates how human innovation consistently and unpredictably defers and transforms the hardest choices facing society. New technology alters what society values as normal because it pushes back the frontier of the possible, ushering in new challenges and opportunities even as it addresses those problems that led to innovative responses in the first place. Innovation

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changes not only the winners and losers of the game but can change the nature of the game itself. The Great Lakes region, due to its unique history and resources, capitalized on these accelerating waves of change (Fig. 2).

One example of this innovation is the hypoaerator. In response to disastrous nutrient- and mussel-related harmful algal blooms, this relatively simple technology is used successfully in 2063 to oxygenate patches of the hypolimnion, the bottom layer of the lake that can become anoxic, particularly in the summer with prolonged stratification and the decay of settling algae. The hypoaerator is deployed along with in-lake wind turbines and consists of a simple pump powered by each turbine that forces air down a tube to the lakebed footer where it is passed through a network of perforated tubes that release the air into the water. The premise is similar to aerating a fish tank, only here local sections of Lake Erie are the fish tank. The hypoaerator, which can be toggled on or off depending on conditions that promote algal blooms and constitutes a negligible drain on the productive capacity of each turbine, does not solve the underlying problem of eutrophication but it locally mitigates one of the worst symptoms impacting aquatic biota. Utilities, in this case, were motivated by branding themselves as environmental stewards.

Another example of transformative practices that would scarcely have been imagined 50 years ago involves the public/private effort to harvest the nuisance macroalgae *Cladophora*. Entrepreneurs in 2063 deploy and maintain algal sentry networks to harvest the sloughing macroalgae in the nearshore zones of the Great Lakes basin, converting waste into resource. Following the profit motive, they receive a percentage of municipal beach revenues as long as excessive *Cladophora* does not foul the shore; during seasonal slough events the same entrepreneurs collect the seaweed and sell it to be processed as a cheap biofuel or to be composted for marginal profit but enough to justify the cottage industry. These efforts are privateer but successful where sufficient investment is incentivized by local governmental jurisdictions ceding their control.

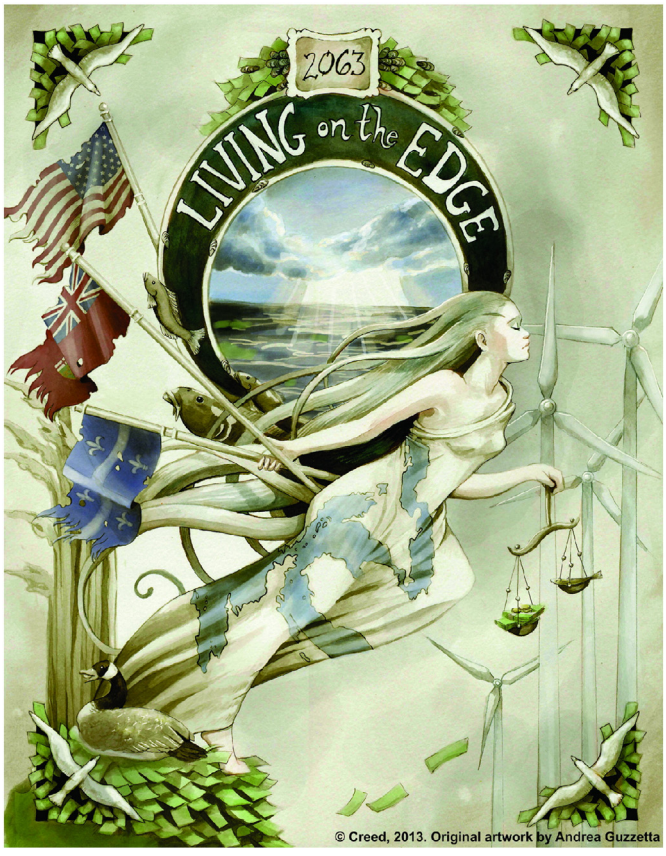


**Fig. 2.** Original artwork illustrating the outcomes of a Living on the Edge scenario for the Great Lakes–St. Lawrence River basin.

Such innovative solutions to wicked environmental problems were once faced with skepticism, public resistance, and a generational sluggishness to accept new ideas. The results speak for themselves and portray how, in many ways, the Great Lakes basin demonstrates resilience. Nuisance algae have been curtailed, fish and benthic populations have rebounded, and recreational waterfront commerce has increased. It is not a perfect world, but we have learned to profit from it. In the process Lake Erie in particular has been transformed into the planet's most well-regarded managed large-lake system (Fig. 1). Further, it has become a scalable laboratory on which to test and improve other innovative management strategies, coupled with local private-sector innovators capitalizing on the natural resource management opportunities in the region and beyond. But what happens to a region when progress toward a sustainable future is driven only by technological innovation and economic forces? Can these drivers herald the onset of a new and inclusive governance regime that pushes our social-ecological system toward a stronger trajectory of sustainability, or is a society so motivated endlessly trapped in a reactionary cycle of dependence?

A visually striking example of this debate involves the vast arrays of wind farms sprouting from the shallows of the Great Lakes basin. These wind farms were developed in spite of the lack of local buy-in from resistant lakefront communities, who feared the esthetic disruption of their lakes' scenic beauty. Technological innovation in the region was not in response to a call from the citizenry. Market forces, not a proactive response by the citizenry to the impending threats of climate change, drove the transition toward renewable energy innovation in the region. Energy utilities control a staggering 30% of the Great Lakes region shoreline in order to maintain adequate wireless power transmission from offshore wind turbines, though the interests of the utilities currently align with the interests of the public. The green space provides parkland as well as valuable coastal habitat. This land represents a managed system but also is an exponent of the corporate triple-bottom-line approach that is a matter of course today.

The economy was also a primary driver of change in the basin (Campbell et al., in this issue), especially external economic forces. Without the proactive, massive policy endeavors of the Chinese government reacting to the quality-of-life demands of its up-in-coming middle class in the 2020s, the Great Lakes region would not have had the sufficient influx of resources to make its tenuous transition into a global economic powerhouse predicated on the export of green and blue technology. This existence is still fueled almost entirely on foreign demand, and thus remains fickle. Much like deferring car repairs on an aging vehicle until crisis forces costly intervention, the world turned away from climate change mitigation until coastal cities were repeatedly faced with climatic extremes and natural disasters of increasing magnitude and frequency in the 2010s, 2020s, and 2030s. Governments worldwide finally took note that their metaphorical brake lines had ruptured, and they had no choice but to act because they were on a downhill road. Globally, it was too late to stave off the earliest impacts, and hundreds of millions lost access to clean water, particularly in poorer nations in Africa and Asia. This resulted both in global tragedies and an influx of climate refugees to the Great Lakes region. Because the region had continuing access to freshwater and a prospering economic and environmental balance, it proved a magnet for migrants.

Despite climate disasters elsewhere in the world, the Great Lakes region profited from initiatives to transition the developing economies (e.g. China and India) to alternative fuels and a low-carbon economy. The shift in China, specifically, demanded cooperation with and investment by US industries, which profited from meeting the demand and helped to reverse the historic trade imbalance between the two nations, and thereby increased their geopolitical connectivity. With the help of economic interventionism abroad, North American green jobs experienced a boom and local economic welfare increased.

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Pockets of local proactive governance throughout the Great Lakes region have emerged in response to these economic benefits, despite occupying a decentralized and institutionally fractured environmental policy arena. Localized proactive governance is also partly a reaction to the low-level persistence of terrorism as a modern reality and the mainstream awareness of global calamities like climate change. In response to events like the 2024 Toronto subway bombings, people pulled together into new local communities-of-caring. Many such communities proved ephemeral, but enough endured to make an impact on societal and environmental issues. They are widespread and decentralized — do-gooder networks in a sense. Despite lacking formal connective governance structures, these communities-of-caring, connected through technology, have developed a decentralized network of support throughout the tri-national region. In some localities, this connectivity has also facilitated a transition toward watershed-based planning. They cannot and do not plan for the entire Great lakes region, but some are excellent at managing their local watershed.

This style of communication and hyperlocal governance of variable quality sits in concert with the new social contract and emerging societal sense of individual groups as cellular participants in the global superorganism, as presaged by scientists and writers of the 20th Century like James Lovelock and Lynn Margulis (Onori and Visconti, 2012). Following the economic and sociopolitical shocks of the early 2000s (e.g. the September 11th 2001 terrorist attacks, Hurricane Katrina, and the Great Recession; Campbell et al., in this issue), it was ultimately the leadership of the aging Millennial Generation that steadied the ship through the early 21st Century and steered her on a global course. The Millennials also bore the brunt of the Baby Boomer retirement crisis, fallout from which led to a new social contract where fewer social services are expected from governments and greater financial self-reliance is incentivized. Today people expect less, but everyone gives more. While the old social contract was rooted in individualism and nationalism, the current social contract is much more decentralized and communalistic — both facets mediated by technology.

As ever, the future of Great Lakes region and indeed the entire planet remain plagued by uncertainty looking beyond 2063. Interestingly, a compelling narrative on the temporal dimensions of uncertainty is spreading across the Great Lakes region carried by the voices of scientists, social and environmental activists, and a subset of diligent business leaders, though it remains largely underground. Environmental and socioeconomic calamities triggered by climatic change occur with relative frequency outside of the Great Lakes region, in North America and globally, and nearly all of these have increased the demand for water. Although the Great Lakes region experienced more intense storms over the past 50 years than it had over the previous century, the human impacts to climate change here paled in comparison to drought in the developing world, which decimated populations and contributed to unplanned global migrations (Bernauer et al., 2012). The relative abundance of Great Lakes region freshwater has already translated into more frequent out-of-basin diversions and bulk water exports throughout North America, particularly to serve agricultural interests that historically relied upon the Ogallala aquifer. If water scarcity increases and demand for Great Lakes region water continues to grow unabated, the environmental consequences could be disastrous now that the Compact is no longer in place. In fact, if this future trajectory is deemed inevitable, then we have already exceeded a vital threshold when the Compact was repealed and water exports began. The fear is that there will be a time lag in the environmental consequences from these exports and even more so in the subsequent socio-political response to the consequences. Given the reactionary nature of the new hyperlocal governance regime in the Great Lakes region, these time-lagged effects could be disastrous to the tenuous environmental and economic balance that is currently held today.

The system we describe demonstrates resilience but is not completely resilient. If not for a specific future history where forces external to the basin keep it functioning in environmental/economic balance, the region would fall from this balance. It cannot adapt to the widest set of possible circumstances yet gains balance from a narrow set of actual circumstances. If China, for example, does not demand green technology, there is insufficient economic incentive for the Great Lakes region to thrive and the region falls. If in the absence of regulation energy corporations do not shift their portfolios to renewables driven by the profit motive, the region falls. If early local climate-change impacts were not less intense than feared, the region falls. Rather than sustaining the pressures from external forces due to an internal structure capable of adaptation, we argue here for a just-so-story future were external forces sculpt and maintain the system itself. The resulting system behavior described in the history is contingent upon a fortuitous alignment of interests, not the capability of the system to adapt to all stressors.

## Conclusion

The balance struck between economic welfare and environmental quality in this scenario shows that the Great Lakes basin demonstrates resilience. Resilience often has loose or contrasting meanings when applied to sustainability concepts (Pickett et al., 2014). Older definitions in the traditional ecology discourse saw resilience as the ability of ecosystems to return to a point of equilibrium when perturbed (Pickett et al., 2014). However, modern definitions of resilience in the context of social-ecological systems reflect the understanding that systems are adaptive and change over time; often those changes are a result of external forces (Folke, 2006). Indeed, resilience is increasingly used as a lens through which to understand and analyze social-ecological systems and their sustainability (Folke, 2006). The maintenance of basin-wide economic and environmental system functioning in response to external and indeed global forces exemplifies resilience.

Global market forces combined with decentralized environmental policy have made going green profitable and spurred technological innovation around renewable energy production. In our scenario, the private sector takes the lead, but the balance remains tenuous. It is dependent on spillover effects from the pursuit of profitable business, external economic drivers that are uncertain and volatile as ever, and regionally less-severe impacts of climate change. Moreover, in the absence of government leadership in Great Lakes basin research, the gap between science and policy is expanding. The Great Lakes region as a social-ecological system is complex, and if a time lag precedes the worst environmental and socioeconomic impacts caused by the current and historic state of our poor governance, then the tenuous balance of this scenario may be tilted. This balance may be an illusory echo and product of past choices, not today's — it may belie that our current path has already crossed the threshold of impending future environmental and economic disaster. Uncertainties or even disparities between social resilience and ecological and economic resilience exist (Adger, 2000). The lack of social capacity for change in this scenario arguably threatens the long-term sustainability of the Great Lakes basin.

Some economic impacts over the past 50 years remained consistent with earlier trends, such as swelling corporate and private-sector influence. Others have reversed their direction. For example, the historical misalignment between the profit motive and environmental stewardship has been reversed. This latter point is central to the environmental and economic balance of today and was driven in no small part by societal values and technological innovation. The cities of the Great Lakes basin enjoyed a decades-long boost in economic activity through the 2050s that, despite loosened environmental regulations, realigned with environmental protection. The regional economy was predicated upon less polluting externalities and entrance into the ecological restoration market. Today in 2063, the Great Lakes region has emerged as a world water hub and center of profitable technological innovation. However, without good internal governance, the system looms over the edge of a precipice — balanced today but dependent on external forces not to tumble into the abyss.

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## Appendix A. Drivers of change

**Table A1**
The state of each driver of change for the Great Lakes region in 2063.

| Driver | Description |
|---|---|
| Aquatic invasive species | New invasions attributed to climate change and global trade are abated somewhat by private-sector control and restoration, while society increasingly accepts invasives as commonplace. |
| Biological and chemical contaminants | Biological contamination in the form of waterborne disease continues to pose public health risks wherever infrastructure is most vulnerable, but health risks from emerging chemical contaminants mostly remain unstudied due to policies that decreased non-applied research capacity. |
| Climate change | Climatic change is less severe in the Great Lakes region compared to others, but external impacts are felt locally through increasing demand for water exports and an influx of climate refugees. |
| Demographics and societal values | Technology has redefined what it means to be human and our relationships to each other. Social networking mediated by more intimate and accessible devices increases the sense of collectivism at the same time incentivizing rapid gratification served by global markets. The death of the baby boomers ushers in a new social contract where individuals give more and expect less. |
| Economy | Global demand is king. China, Southeast Asia, and North America are inextricably entwined with local Great Lakes–St. Lawrence River basin service economies bolstered by regionally strong green and blue industries while domestic and foreign demand for freshwater rises. |
| Energy | Wind farms dot the shores of the Great Lakes and industry innovators continue to improve solar, wave, and nuclear energy production in the Great Lakes region in response to changing foreign markets. |
| Governance and geopolitics | Decentralization and deregulation increase in Canada and the US, leading to a breakdown of basin-wide water governance and the emergence of hyperlocal governance regimes. Geopolitical tension mounts as foreign and domestic demand for water increases. |
| Water quantity | Dropping lake levels transform the Great Lakes into an intensively managed system. Bulk water exports and diversions to more climate-afflicted regions occur, though major environmental and geopolitical impacts remain to be seen. |
| Technology | Innovation continues to solve old problems and create new ones. We are pushing back the frontiers of the possible to effect change, with the full force of the private sector attacking global challenges. |

### *A.1. Drivers of change in the year 2063*

#### *A.1.1. Aquatic invasive species*

The ecological and economic impacts of invasive species in the Great Lakes basin continued into the 2010s, though with decreasing severity. Governments rode the coattails of earlier successes with ballast water policies, but stagnated while climatic change facilitated new invasions from the south. Private-sector interests helped to stave off the impacts of invasive species; the growing profitability of the green economy spurred industries into the world of invasive species control and ecological restoration. In the altered climate and globalized economy that is so reliant on international trade, invasive species are accepted as normal. Society ceases to cling to concepts of native species and ecosystems, as is reflected in the burgeoning Asian carp fishery. Thus, the environmental and economic balance in regard to invasive species is dependent on both the biophysical reality and societal values of an ecosystem.

#### *A.1.2. Biological and chemical contaminants*

Chronic infrastructural neglect led to societal vulnerability to biological contaminants such as fecal pathogens that pose health risks to the most vulnerable populations. However, major episodes of diarrheal outbreaks led to a spotty yet effective political response resulting in government investment in stormwater, wastewater, and drinking water infrastructure improvements throughout the Great Lakes region that reduced societal vulnerabilities. Climate change exacerbated the rain-related disease risk by increasing the frequency and intensity of storms that taxed our infrastructure. In short, we got sick but we patched our underground pipe networks out of fear of getting sick again.

#### *A.1.3. Climate change*

Climate change remains a complex and uncertain global driver of change that, to some degree, influences all aspects of the Great Lakes region. The evolution of the most influential drivers shaping the Great Lakes region – economy, energy, technology – was arguably catalyzed by the changing climate. Impacts are spatially and temporally variable in their severity. Worldwide, the most severe climate change impacts were suffered in coastal, drier, and high-latitude regions, and also by more marginalized populations, leading to an influx of climate refugees to Great Lakes region cities. The Great Lakes region was spared from the most severe environmental change during the past 50 years. The Great Lakes region's abundance of freshwater resources attracts growing demand, both foreign and domestic, for Great Lakes basin water.

#### *A.1.4. Demographics and societal values*

Technological change had the most profound impact on the evolution of societal values over the past 50 years. Coupled with the die-off of the Baby Boom generation, the more community- and holistic-oriented values of the aging Millennial generation commanded North American society. The expectations of what it means to be human today have shifted over the past 50 years. We expect less from governments and give more to hyperlocal communities as a matter of course. These anti-individualistic values were promulgated through social networking technologies that became more and more integrated with individuals at the same time private corporations grew savvier in appealing to these values in order to maximize their profit—hence brewed a seductive alignment that increased the appeal of alternative energy and water efficiency technologies.

#### *A.1.5. Economy*

Increased global demand for green energy and blue technology pulled the Great Lakes region out of a major recession. Population explosions in China, India, and elsewhere coupled with those countries' proactive governance and fears about climate impacts fueled the demand for non-fossil-fuel energy and transportation solutions. Combined with pro-business federal and subnational policies in North America that subsidized big business and loosened regulatory strictures – plus trade protectionism abroad that tilted global markets toward buying North American products – the Great Lakes region ratcheted up industrial production of green and blue technologies. The biggest corporate actors, including those steering the oil industry, held the strings of the global economy but saw that in order to remain profitable in a post-oil future, they would have to adjust their business models. Thus, the

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Great Lakes region prospered at the expense of the global community who, at least for now, grew dependent on our technological and intellectual capital exports as we grew equally dependent on their demand.

*A.1.6. Energy*

The Great Lakes region has emerged as a global leader in the manufacturing and adoption of green and blue energy technology, and has largely moved away from fossil fuel sources. Energy and the economy are intimately linked as both global and regional drivers of change. By and large, the economic thrust and demand for new low-carbon energy sources occurred in Asian markets — most notably China. Importantly, the market forces pushing the shift toward green energy sources in the Great Lakes region are external to the region and therefore unstable. Given the above, climate change cannot be ignored as a key catalyst of energy innovation.

*A.1.7. Governance and geopolitics*

Great Lakes basin governance in 2063 is largely deregulated and decentralized, with corporations instead of government taking a leadership role. Turn-of-the-century deregulation and widespread slackening of environmental policy were supplemented by a plethora of incentive-based policies to encourage private-sector innovation in green technology and resource development. A breakdown in cooperative horizontal federalism between subnational governments meant increasingly self-serving jurisdictions. This combined with climatic change and demand for water exports triggered the repeal of the Compact. Geopolitical tension among nations continues to rise, while some fear scarcity-driven conflict over Great Lakes region water.

*A.1.8. Water quantity*

The Great Lakes basin in 2063 is an intensively managed system. Falling lake levels and the growing acceptance of climatic change spurred both public- and private-sector action for increasing control of lake levels with the addition of another structural control on the St. Clair River. Regardless, basin-wide water quantity governance deteriorated significantly over the following decades, culminating with the failure of the Compact to prevent out-of-basin diversions and bulk water exports. Major geopolitical and environmental consequences of this failure remain to be seen, but the increasing demand for water in drier parts of North America make the situation in the region unstable.

*A.1.9. Technology*

Replication of the Milwaukee "Global Water Hub" model throughout the Great Lakes region created a unique niche and brand for profitable innovation focusing on solving problems in water-related industries. Wicked environmental problems like large-lake eutrophication and invasive species were mitigated by speculative but profitable approaches. The private sector sustained its own investment in innovation, largely unfettered from government regulation and aligned with the profit motive. More broadly, society continued to salivate after more intimate personal connective devices that set new trends for what it meant to work, communicate, and play. Those responsible for actually developing said technologies grew more and more specialized, even as their democratizing products were disseminated globally en masse.

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