Policy Insights

POWERING FORWARD

Accelerating the Binational Great Lakes Region's Clean Energy Transition

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ACKNOWLEDGEMENTS

The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the official policy or position of the Council of the Great Lakes Region or the funder of this project, Ontario Power Generation. The authors would like to thank the government, industry, academic, and non-profit experts who provided input into this paper, particularly Brandon Hofmeister, Senior Vice President, Governmental, Regulatory, and Public Affairs, Consumers Energy; Tom Stanton, Principal Researcher, Energy and Environment, National Regulatory Research Institute; Howard Learner, President and Executive Director, Environmental Law and Policy Center; and, Joe DeFors, President, Leelanau Energy. The insights they shared were very valuable.

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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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CHICAGO, LAKE MICHIGAN

EXECUTIVE SUMMARY

The binational Great Lakes Region enjoys a multitude of shared sectors and socio-economic strengths, as well as integrated assets such as inter-state and cross-border supply chains and energy systems between the United States and Canada, that connect, unify, and advantage the eight states and two Canadian provinces that make-up this Region. Consequently, as a North American and international hub of manufacturing, scientific discovery, and technological innovation, the Region, with the world's largest freshwater system at its center, is well positioned to leverage its incumbent strengths, assets and natural resources to capture the full benefits the global transition to a clean energy economy will bring.

However, in order lead the clean energy transition and economy, integrating clean energy resources into the regional transmission and distribution system will require cooperation and collaboration among policymakers, power system managers, utilities, and public utility commissions as well as the successful navigation of the complex array of federal, state, and provincial regulations. If this can be achieved, an expanding "smart grid," integrating highly distributed advanced energy resources, energy storage, and microgrids, assisted by artificial intelligence and advanced analytics, can improve the quality, resiliency, and reliability of the regional power system.

But it must be said that transitioning to a clean energy future in the Great Lakes goes beyond the need to find cleaner ways to power our homes, institutions, and industries. The clean energy transition also provides tremendous economic opportunities. For example, the region's vast multi-modal transportation network, which move the region's goods and people, is responsible for a large portion of the region's greenhouse gas emissions. This being the case, decarbonizing and greening the transportation system, such as through vehicle electrification where feasible, has to be a regional imperative. Fortunately, the Region, already a global leader in battery technology and designing and manufacturing passenger vehicles as well as light and heavy-duty trucks, can lead the development of next generation, zero-carbon mobility solutions

Decarbonizing industrial processes, as well as building heating and cooling systems, also pose a significant challenge and opportunity for the Region. Again, the binational Great Lakes Region has the industrial prowess, academic might (one-third of both countries engineering schools are in the Great Lakes), and centers of excellence (e.g. U.S. Department of Energy's Argonne National Laboratory in Chicago, Illinois and Natural Resources Canada's CanmetENERGY research centers in Ottawa, Ontario and Varennes, Quebec) to be a leader in the design of renewable and alternative energy technologies and solutions, such as small modular reactors, offshore wind energy, green hydrogen, and the redesign of industrial and built systems that reduce energy consumption. Linking Canadian clean energy to the eight states through high-voltage direct current transmission also presents a tremendous opportunity to decarbonize the region's cities and sectors.

Corporations, consumers, and policymakers are beginning to understand both the benefits of transitioning to a clean energy economy and the socio-economic and climactic risks of inaction. The inevitable market shift to clean energy technologies and solutions and the urgency of addressing climate change represent an extraordinary opportunity to leverage the Region's incumbent economic strengths and natural resources to maintain and enhance the economic and environmental vitality of the Great Lakes Region. This paper analyses the state of the clean energy transition in the Great Lakes. More important, it identifies where we need stronger commitments and action, as well as more dynamic collaborations, to propel the region's clean energy transition forward – together.

FREIGHTER, WELLAND CANAL

INTRODUCTION

The Great Lakes Region is a powerful binational center of global commerce, endowed with an abundance of economic, environmental, and agricultural resources that are the envy of the world. The eight states and two provinces that comprise the Region enjoy a dynamic, deeply integrated economy making it an economic powerhouse and an engine of the North American economy.

Containing 21 percent of all surface freshwater in the world and 84 percent of all surface freshwater in North America, the five Great Lakes are the heart of the region, deepening the common bond between the U.S. and Canada and the multifaceted cooperation and collaboration that is required to protect and restore this globally significant ecosystem.

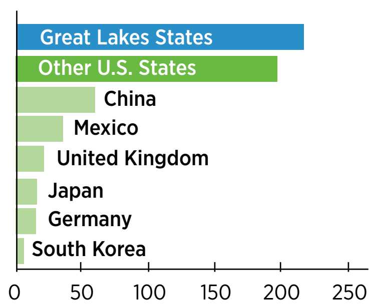
Powering the Region requires enormous amounts of energy, historically supplied by coal, nuclear, natural gas, and hydropower. Today, dramatic reductions in the cost of clean energy technologies couple with an increasing strategic focus on sustainability by business and the urgency of addressing climate change, are disruptive forces spurring energy sector innovation, redirecting energy policy and investment and catalyzing the transformation of the global and Great Lakes energy system.

In the U.S. and Canada, a confluence of demand and supply side energy preferences, market forces, regulatory mandates, and climate concerns is accelerating the clean energy transition. Studies are consistently showing that a dramatic transformation of the energy system is not only technically and economically feasible, the transition to a clean energy economy will also deliver an array of monetizable economic, health and environmental benefits while fulfilling future regional energy needs at less cost.

As the world faces the challenges of climate change, resource depletion, and increasing water scarcity, the incumbent assets of the Great Lakes Region can serve to advantage the Region and provide new opportunities for its states and provinces. The Region already has an array of clean energy resources and its states and provinces have strong policy-based commitments to build the foundation of an advanced energy future. Accelerating the clean energy transition can help position the Region for continued global leadership in advanced manufacturing, engineering, and material sciences, while providing the clean power that businesses and consumers increasing demand and ensuring long-term economic and environmental benefits for future generations.

- **GDP of US$6 trillion (2017 est)**
- **Population of 108 million (2017)**
- **30% of Canadian/ U.S. economic activity**
- **52 million jobs**
- **30% of Canadian/ U.S. workforce**
- **More than half of Canada U.S. cross-border trade**

ONTARIO AND QUEBEC'S TRADING PARTNERS
(2017 total trade in C$ blns)



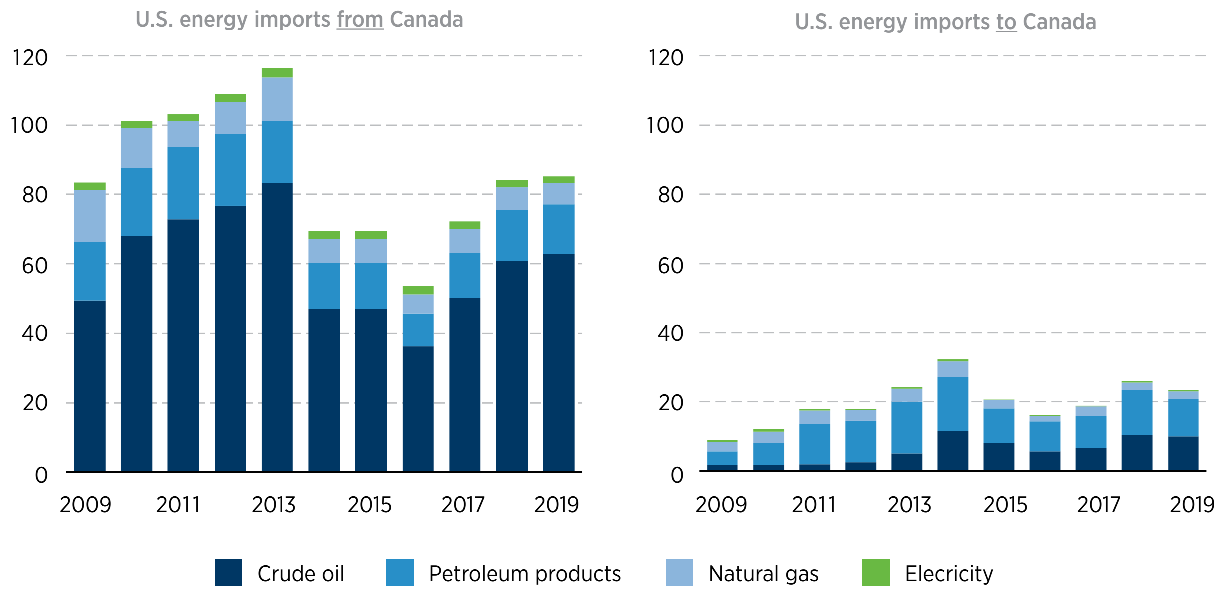
Source: BMO Financial Group

4 BINATIONAL COOPERATION – POWERING THE GREAT LAKES REGION'S FUTURE

The United States and Canada are linked by more than a common border; the Region shares a common social, cultural, and institutional heritage. We are a "macro-region," benefiting from long-established commercial and industrial relationships and common strategies for economic development.[1] Our two countries enjoy deep-rooted and mutually beneficial relationships in trade and commerce with the exchange of goods and services valued at an estimated $718.5 billion in 2018.[2]

CANADA IS THE LARGEST SOURCE OF U.S. ENERGY IMPORTS

Value of selected energy trade between Canada and the U.S., 2009 – 2019, billions



Source: U.S. Energy Information Administration

In energy trade, Canada is the largest source of U.S. energy imports and the second largest recipient of U.S. energy exports. While primary energy resources in the U.S. and Canada remain predominantly fossil fuels, all Great Lakes states have renewable energy standards and goals for higher levels of future zero-carbon electricity production. Ontario and Quebec, however, are better positioned, having deployed significant zero-carbon electric generation resources.[3]

Quebec, the largest generator of electricity in Canada with over 46 gigawatts of installed capacity, derives 95 percent of its electricity from hydropower and 4 percent from wind energy.[4] Ontario, the second largest producer of electricity in Canada, derives 96 percent of its electricity from zero-carbon emitting sources: 60% from nuclear power, 26% from hydropower, 7% from wind energy, and 2% from solar energy.[5] Ontario Power Generation's *Climate Change Plan* has set a goal of net-zero emissions from electricity production by 2040 and a net-zero energy economy by 2050.[6]

CONNECTING CLEAN POWER

The diversity of energy resources in the Great Lakes Region offers the potential for optimization and achieving higher efficiency in the use of clean energy resources through greater grid interconnection and grid integration. Canada's abundant supply of hydropower for example, and its potential for expansion, offers opportunities for Great Lakes states to accelerate their clean energy goals.[7] In addition to helping states achieve their clean electricity targets, hydropower provides operational flexibility in terms of augmented grid services, reserve storage capacity, and enhanced security, reliability, and grid resiliency.[8]

The U.S. and Canada are already connected by 37 major transmission lines.[9] To enhance grid integration and energy trade between the countries will require more generating capacity, transmission infrastructure, and cooperation among independent system operators (ISOs) and regional system operators (RTOs). Capital requirements for building new capacity will also require financial commitments for the offtake of energy supplies. The accelerating retirement of coal generating units across the Region will free up much needed transmission capacity to serve large scale clean energy projects.

New projects, however, must navigate a complex system of local, state, provincial, and national regulations. While the U.S. Department of Energy (DOE) and Natural Resource Canada (NRCan) have executed a Memorandum of Understanding to enhance bilateral "understanding of cross-border permitting regimes for electric transmission facilities,"[10] an elaborate, time-consuming array of political, environmental, and policy barriers must be overcome before new projects are able to break ground.[11]

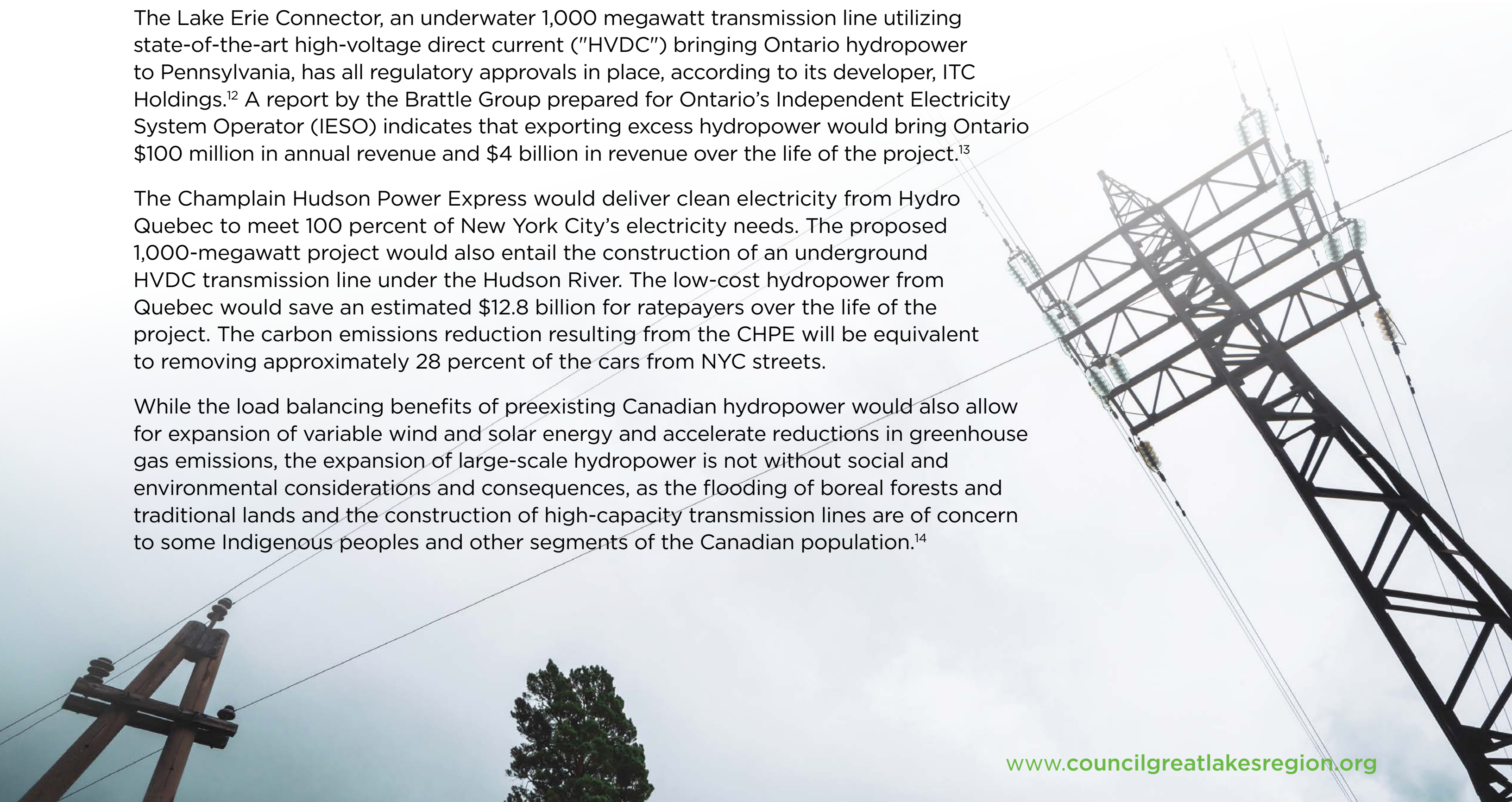
Regional efforts to calibrate regulatory policy and improve communication and collaboration among state and provincial energy authorities, therefore, are fundamental measures in accelerating integration of the regional power system. The latter was reinforced in U.S. DOE's 2015 QER, which suggested that collaborative programs in each country should be established for academic institutions and not-for-profits to develop legal, regulatory, and policy roadmaps for harmonizing regulations across borders. Notwithstanding the challenges associated with planning, permitting, and building major cross-border projects, progress is being made.

The Lake Erie Connector, an underwater 1,000 megawatt transmission line utilizing state-of-the-art high-voltage direct current ("HVDC") bringing Ontario hydropower to Pennsylvania, has all regulatory approvals in place, according to its developer, ITC Holdings.[12] A report by the Brattle Group prepared for Ontario's Independent Electricity System Operator (IESO) indicates that exporting excess hydropower would bring Ontario $100 million in annual revenue and $4 billion in revenue over the life of the project.[13]

The Champlain Hudson Power Express would deliver clean electricity from Hydro Quebec to meet 100 percent of New York City's electricity needs. The proposed 1,000-megawatt project would also entail the construction of an underground HVDC transmission line under the Hudson River. The low-cost hydropower from Quebec would save an estimated $12.8 billion for ratepayers over the life of the project. The carbon emissions reduction resulting from the CHPE will be equivalent to removing approximately 28 percent of the cars from NYC streets.

While the load balancing benefits of preexisting Canadian hydropower would also allow for expansion of variable wind and solar energy and accelerate reductions in greenhouse gas emissions, the expansion of large-scale hydropower is not without social and environmental considerations and consequences, as the flooding of boreal forests and traditional lands and the construction of high-capacity transmission lines are of concern to some Indigenous peoples and other segments of the Canadian population.[14]

> *"Well-informed and forward-looking decisions that lead to a more robust and resilient infrastructure can enable substantial new economic, consumer service, climate protection, and system reliability benefits."*
>
> Quadrennial Energy Review (QER) 2015



GRID DESIGN FOR THE 21ST CENTURY

The future promises a new architecture for our North American and Great Lakes power system. Large central powerplants, over time, will increasingly be displaced by highly localized, interconnected distributed energy resources (DERs), potentially resulting in greater efficiencies and enhanced system resilience and security. Localized energy generation resources like wind and solar energy, supported by energy storage technologies that enable a constant flow of reliable energy, are already the most cost-effective new energy supply solution in almost all world markets.[15] Long-term, seasonal energy storage capacity for heating and cooling presents a greater technology challenge for variable energy sources like wind and solar.

The U.S. National Renewable Energy Laboratory (NREL), in collaboration with NRCan, has launched the North American Renewable Integration Study (NARIS), an effort aimed at identifying "pathways to modernize the North American power system through the efficient planning of transmission, generation, and demand."[16]

Building out new transmission pathways allows for expansion of the overall "balancing area" and greater interconnection of grid resources, mitigating the effects of variable, intermittent power. NARIS will analyze power system requirements to integrate higher contributions of DERs like wind and solar energy, hydropower, and energy storage technologies, and will help determine the infrastructure needs for the future electrification of the transportation, industrial, and heating and cooling sectors.

Designing the grid to accommodate exponential increases in renewable energy, demand response, electric vehicles, and other DERs and energy services should be the present focus of energy resource planning in the Great Lakes. Connecting and integrating renewable energy systems across the Region so that energy resources and reserve capacity can be shared would improve power quality, operational efficiency, reliability, and system resilience while lowering overall system costs. A dynamic, optimally designed modernized grid will accommodate expansion of next generation energy technologies and services, accelerating the inevitable transformation of the Region's power system.

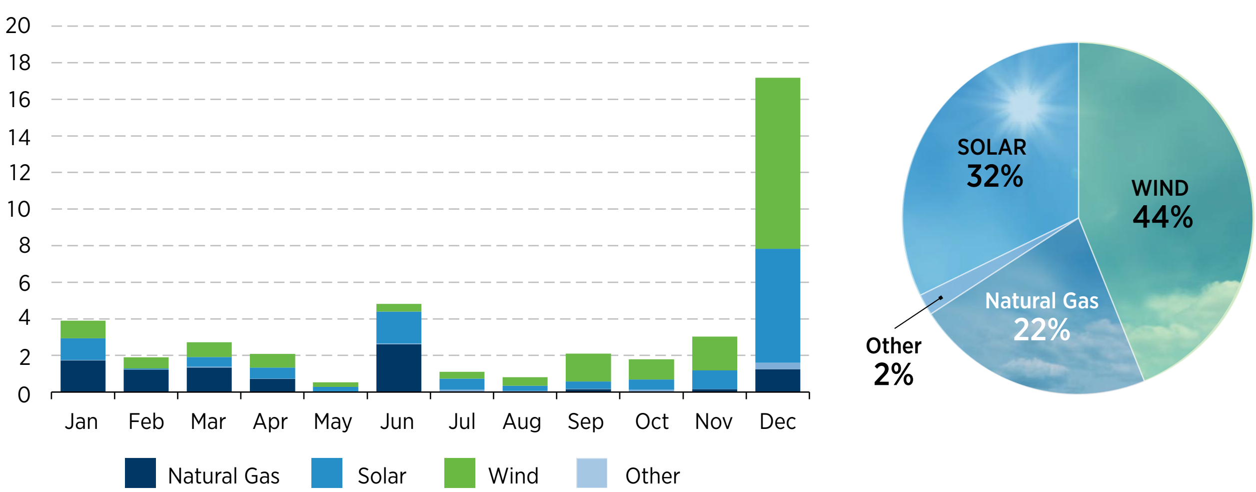
With the completion of the Great Northern Transmission Line in June 2020, Minnesota Power began receiving 250 megawatts of hydropower from Manitoba Hydro, enabling Minnesota to soon meet its goal of deriving 50 percent of its electricity from renewable sources.

"The Great Northern Transmission Line is a testament to the wonderful, longstanding relationship between our two companies and two countries."

Manitoba Hydro CEO Jay Grewal

NEW ELECTRIC GENERATING CAPACITY IN 2020 WILL COME PRIMARILY FROM WIND AND SOLAR

Planned U.S. electric generating capacity additions, 2020 GW



Source: U.S. Energy Information Administration

INTEGRATING DISTRIBUTED ENERGY RESOURCES

The future Great Lakes energy system will harmonize and orchestrate a diverse symphony of energy inputs and outputs while leveling demand and reducing peak loads. A smart grid utilizing self-optimizing automated controls, managed by artificial intelligence and advanced analytics, will modulate and synthesize thousands of simultaneous energy inputs and outputs from a diverse array of localized DERs and energy resources.

Recently, the Federal Energy Regulatory Commission (FERC) issued Order 2222, allowing aggregated DERs to fully participate in U.S. energy, capacity and ancillary services markets operated by RTOs and ISOs. DERs like distributed solar energy, energy storage technologies, and EVs will now be able capture additional value for the services they provide to the grid.

Developing microgrids, a novel but yet to proven concept on a larger scale, could help integrate and systematize DER technologies, providing an assemblage of valuable energy services. Operating independently, the promise microgrids is that they can power critical, local infrastructure, such as medical centers, industrial parks, and university campuses, while supporting the grid during storm events and outages. Furthermore, the self-contained energy systems, capable of delivering reliable, resilient power locally, can also be called upon to provide power to neighboring geographic areas in the event of power losses.

The ability to shift electric loads during periods of high demand and store, rather than curtail, excess energy from variable resources like wind and solar will be an essential feature of the future power grid. Balancing the power system, through automated "demand response" controls will provide grid managers with the nuanced capability of controlling demand with as much ease and flexibility as controlling energy supply.

Designing, engineering, and managing the next generation grid-related technologies and services represent promising new business opportunities for electric utilities as electricity consumption increases with the further electrification of the economy. Public utility commissions (PUCs) have a critical role to play in assuring that utilities are prepared to accommodate, deliver, and manage advanced energy resources. PUCs can use their regulatory powers to assure that grid design is a first priority and utilities are moving in the right direction by building capacity and making the right investments, though the structure, oversight and regulatory authority of PUCs differ across the Region.

Regional Energy Storage Innovation

The Great Lakes Region is the center of a rapidly growing, highly innovative energy storage industry. Variable renewable energy resources must be modulated by means of energy storage to enable a reliable, continuous daily and seasonal flow of electricity. The Region's cutting-edge energy storage industries manufacture and deploy a full array of state-of-the-art storage technologies. Collaborating with universities and national laboratories in public/private partnerships, the Region is a source of lithium-ion and "flow" batteries and is developing new and improved energy storage chemistries. Regional research and development "clusters" are bringing to market other energy storage solutions like compressed air, flywheels, liquid to gas storage, thermal energy, and hydrogen storage. The Region also hosts the Ludington Pumped Storage Plant on Lake Michigan – the 4th largest pumped storage facility in the world.

LUDINGTON PUMPED STORAGE PLANT, LAKE MICHIGAN. Wikipedia photo

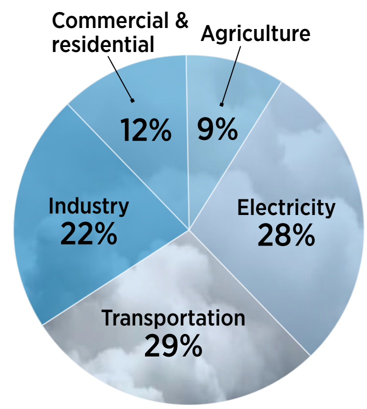
CORPORATE AND CONSUMER DEMAND MORE CLEAN POWER

Growing preferences for clean energy resources and increasing carbon sensitivity by businesses are dramatically increasing corporate demand for access to zero-carbon resources. Clean energy procurement by corporations is skyrocketing, reaching 19.5 gigawatts in 2019, accounting for 10 percent of added global electric generation capacity, and surpassing record corporate clean energy purchases in 2018 by 44 percent.[17]

The "big four in tech" – Google, Amazon, Facebook, and Apple, are on record with ambitious clean energy goals for their companies, competing among themselves to set the most aggressive carbon emission reduction targets. Microsoft recently reset the bar by announcing that it will not only be "carbon negative" by 2030 in all its global operations, it pledged to go much further and "remove from the environment all the carbon the company has emitted, either directly or by electrical consumption, since it was founded in 1975."[18]

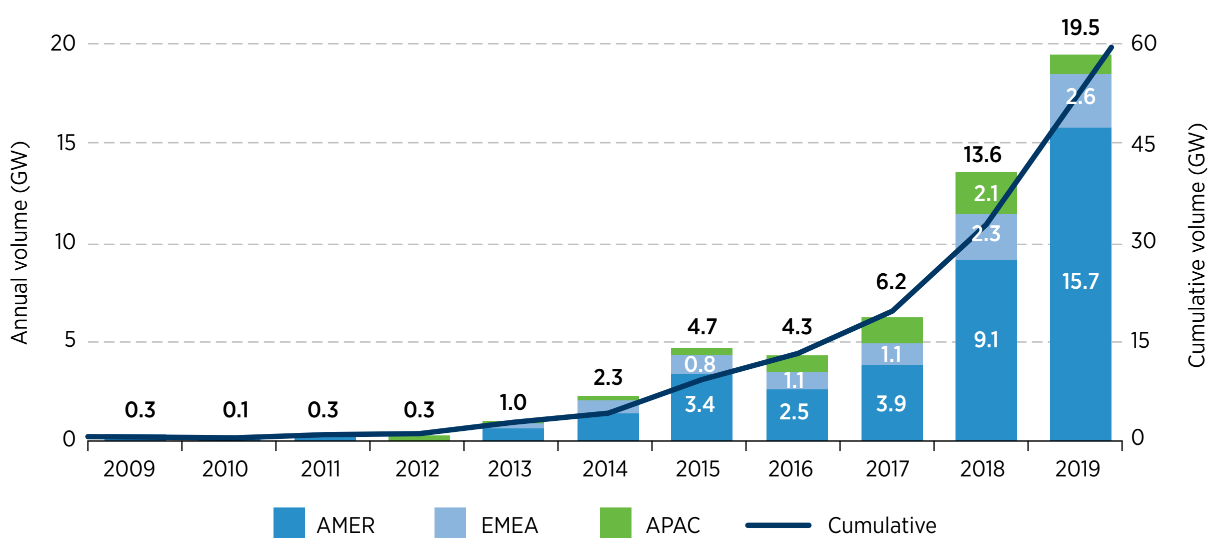
Numerous Fortune 500 companies have adopted 100 percent clean energy goals including major binational corporations in the Great Lakes Region. General Motors, Ford, Dow Inc., and General Mills are but a few of the many corporations with headquarters and/or manufacturing facilities located in the Great Lakes that have made public commitments to clean energy procurement, clean-tech adoption, and sustainability. Importantly, businesses are also making locational site selection and investment decisions based upon the availability of carbon-free power.

U.S. GREENHOUSE GAS OUTPUT BY SECTOR (2017)



Source: U.S. Environment Protection Agency

GLOBAL CORPORATE PPA VOLUMES



Source: BloombergNEF. Note: Data are through 2019, reorted in MW DC capacity. Onsite PPAs are not included. Australia sleeved. PPAs are not included. APAC number is an estimate. Pre-market reform Mexico PPAs are not included.

EMERGING CLEAN ENERGY TECHNOLOGIES

Clean energy technologies have become the most prudent, cost-effective, and environmentally benign choice for both public and private investment in energy infrastructure. The global clean technology market is predicted to reach $2.2 trillion by 2022.[19] Goldman Sachs forecasts investment in renewable energy will overtake capital outlays in oil and gas in 2021, projecting $16 trillion in clean energy investment opportunities between now and 2030.[20] The International Finance Corporation (IFC) estimates that the commitments made in emerging market economies under the Paris Agreement represent $23 trillion in investment opportunities through 2030.[21]

Transitioning to advanced energy technologies presents an unprecedented opportunity to leverage the Region's R&D advantage, advanced manufacturing capacity, and engineering strengths. The Region's sophisticated supplier network and industrial clusters supported by outstanding research universities and technology accelerators provide both the capacity to accommodate growing corporate and consumer demand for zero-carbon energy resources within the Region, and the opportunity to participate in the technology push and associated market opportunities for the coming global, low-carbon economy.

The economic and environmental advantages of energy efficiency and clean energy are clear and increasingly understood by business leaders, consumers, and policymakers. The market shift to a low carbon economy will bring significant benefits to the Great Lakes Region, but maximizing regional opportunities entails aligning energy policy, capital investment, R&D resources, and an integrated, "intelligent" power system across the Region.

> ***"The scale of Great Lakes regional innovation is already remarkable. The U.S. portion of the region accounts for 24% of total American R&D funding and 26% of patents in the United States, while the Canadian portion accounts for roughly 72% of R&D funding and 68% of patents in Canada."***
>
> Great Lakes. Great Minds

CANADA'S CLEANTECH SECTOR

- **Canada ranks fourth on the Global Cleantech Innovation Index**
- **The cleantech industry contributed $59.3 billion to Canada's GDP in 2016**
- **Canada's cleantech industry employs an estimated 274,000 Canadians**
- **Nearly 80 percent of Canadian cleantech firms are exporters, and together they generated $11.5 billion in exports in 2016**
- **Canada is ranked fourth worldwide and first in the G20 in terms of potential to produce cleantech start-up companies over the next decade**

Source: Generation Energy Council

WIND TURBINES, LAKE ERIE

ELECTRIFYING EVERYTHING

"Electrification of everything" may be the most important and promising transformative maxim of the 21st Century. Avoiding the most catastrophic effects of a rapidly changing climate is the greatest economic and environmental challenge of our times. An overwhelming scientific consensus points directly to the decarbonization of the global energy system as the only means of meeting the existential threat of a warming world.

Meeting future clean energy demand for space heating and cooling, industrial and manufacturing operations, and transportation requires transitioning to zero-carbon energy sources within an aggressive timeline and entails the fundamental restructuring of the energy supply. These energy intensive sectors can derive substantial benefits from technology improvements and implementations directed at increasing energy efficiency and capturing waste heat. The electrification of these energy sectors will also require the introduction of new clean energy business, financial and regulatory models and will challenge grid managers to ensure reliability and resiliency in all operations.

The binational Great Lakes Region is the global center of automotive innovation, research, and development. The electrification of vehicular transportation by the region's original equipment manufacturers requires the rapid development of improved battery chemistries and energy storage technologies that will also have valuable future applications for a wide array of grid support services.

The electrification of light duty vehicles connected to the grid, providing energy during periods of peak demand and storing surplus wind and solar energy, promises to provide the future backbone for a zero-carbon, hyper-resilient grid. Integrating EVs into the grid provides power system balancing capabilities far exceeding that of stationary storage and at a fraction of the cost.[22] Tesla, Honda, and Nissan are already engineering vehicle-to-home (V2H) and vehicle-to-grid (V2G) capabilities into their product lines.[23]

The electrification of transportation is already proceeding apace with almost all global automotive OEMs announcing plans to transition from internal combustion engines to electric drivetrains for light duty vehicles. Tesla, Rivian, Lucid and other disruptive EV startups are challenging incumbent automakers in the quest to make early EV market gains. The decarbonizing benefits of vehicle electrification correlate directly with the availability of clean power on the grid, underscoring the importance of the clean energy transition.

The Region's automotive sector is looking forward at "advanced mobility" and autonomous vehicles that promise to bring new modalities, efficiencies, and greater safety to both commercial and passenger transportation. UPS, Amazon, and other companies with established vehicle routes are ordering tens of thousands of electric delivery vehicles. Municipal, transit, and school buses and specialty vehicles are targets for early electrification which will reduce GHG emissions, eliminate sources of particulate pollution, improve air quality and public health, and cut costs for governmental units and schools by reducing maintenance costs and eliminating fuel purchases.[24]

Electrified, autonomous shipping may be coming to the Great Lakes Region as soon as sensor and automated navigation systems continue to improve and battery costs decline.[25] Aviation, not to be left behind, forecasts electrification of aircraft first serving regional routes and then expanding to greater distances as energy storage technologies and the prospect of hydrogen fuels improve.[26]

The electrification of energy intensive sectors will pose unique challenges. Steel, iron, and cement production, industrial boilers, and high temperature processing of chemicals and plastics use tremendous amounts of energy. Nevertheless, McKinsey & Company estimates that 50 percent of all fuel-based primary energy consumption by industry could be replaced by electricity with existing technologies.[27] Today's electric-arc furnaces and evolving technologies that capture and minimize waste heat could sharply reduce energy demand while shrinking carbon emissions.[28]

> ***'Electrify everything' isn't just a good slogan. It's the fastest way to decarbonize and create tens of millions of jobs."***
>
> *The Economic Case for Electrifying Everything*, Rewiring America

ELECTRICITY GENERATION AND USAGE IN THE GREAT LAKES REGION

TOPIC	Ontario	Quebec	Minnesota	Wisconsin	Illinois	Indiana	Michigan	Ohio	Pennsylvania	New York
Total Electricity Sales (GWh)	135,100	174,000	65,011	69,208	137,196	97,286	100,377	145,525	145,014	144,400
Total Electricity Generation (GWh)	154,400	213,700	57,975	62,851	181,668	103,021	116,767	119,804	231,732	134,536
Storage (GWh)	(100)	-	-	-	-	-	(696)	-	(566)	(316)
Electric Generation (GWh)	-	-	-	-	-	-	-	-	-	-
Wind (GWh)	11,000	8,548	11,040	1,649	13,831	6,206	5,813	2,029	3,549	4,850
Solar, Utility Scale (GWh)	700	200	1,513	51	65	337	162	160	88	650
Solar, Small Scale (GWh)	6,100	100	100	100	188	127	110	194	487	1,855
Hydro (GWh)	36,400	201,947	887	1,993	131	194	1,291	255	4,040	29,541
Other (GWh)	-	1,496	401	184	541	2,746	2,808	1,664	1,629	1,459
Natural Gas (GWh)	9,500	-	10,372	21,137	18,916	32,218	34,640	50,999	98,401	49,315
Coal (GWh)	-	-	18,206	26,349	48,842	60,782	37,363	46,795	38,776	422
Nuclear (GWh)	90,400	-	14,105	10,030	98,735	-	32,909	17,011	83,230	44,865
Biomass (GWh)	400	1,282	1,351	1,358	419	410	2,369	697	2,098	1,895
Electrifying Transportation										
Transportation Fuels (Trillion BTUs)	884	673	464	453	1,014	611	765	921	938	1,135
Transportation if Electrified (GWh)	51,151	38,929	26,840	26,203	58,636	35,343	44,268	53,257	54,263	65,653
Building and Industrial Heating Fuels (Trillions BTUs)										
Natural Gas	763	239	447	434	985	684	745	871	955	966
Other	-	-	22	19	40	24	23	34	42	40
Building and Industrial heating if Electrified (GWh)	63,357	19,846	38,936	37,599	85,104	58,798	63,789	75,132	82,846	83,510
Total Additional Electricity Needed to Electrify Transportation, Buildings, and Industrial Heating										
	114,509	58,775	65,776	63,802	143,741	94,141	108,057	128,389	137,109	149,163

SOLAR PANEL ARRAY, NEW YORK

Fully electrifying all transportation, building cooling and heating, and industrial processes would roughly double the amount electricity consumption for all states and Ontario. As Quebec is already heavily reliant on clean electricity in these sectors, it would only require increasing electricity generation by 28 percent.

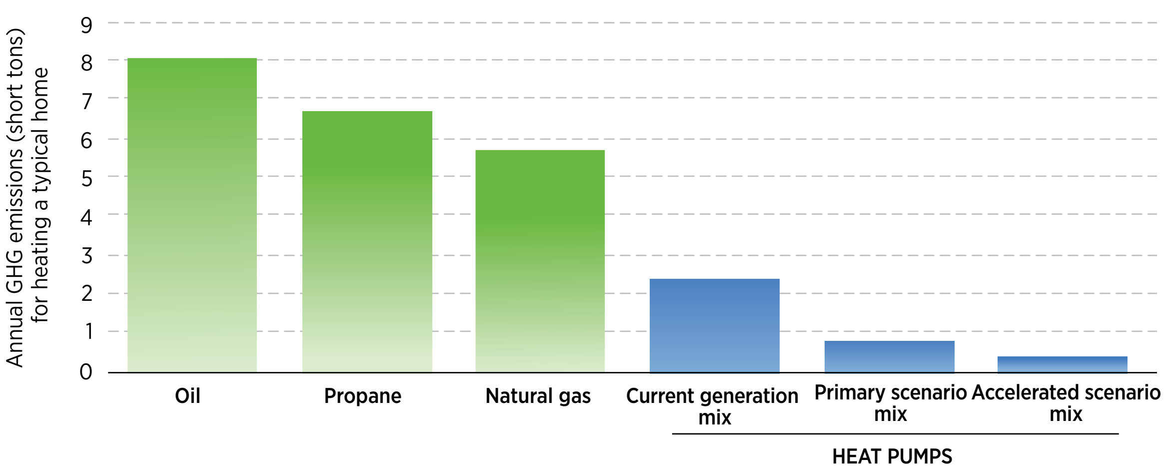
Buildings reliant on onsite heating and cooling account for 30 percent of fossil fuel-based emissions. Improving the efficiency of building envelopes and installing LED lighting can significantly reduce energy use. Electrifying heating and cooling using super-efficient heat pumps can also reduce energy consumption by 50 percent. The use of air heat pumps becomes more challenging in cold climates and remains more expensive than other heating options – but the recent improvements in efficiency and performance have been considerable. The use of smart meters and smart appliances coupled with time-of-use electricity pricing will reduce energy consumption and save ratepayers dollars. Employing intelligent energy management systems for industrial, commercial, and institutional facilities maximizes the potential for operational energy efficiency and allows for more economical use of energy.

Electrification will bring changes in periods of high energy demand and load shapes. In the Great Lakes Region, the electrification of building heating will create high demand curves in winter months. Electrification of heating will require the broad penetration of heat pumps, the retrofitting of existing building stock, and robust energy efficiency implementations.

Electrification of transportation, industry, and buildings would greatly enhance the ability of power system managers to implement demand response capabilities, allowing real time load shifting broadly across multiple end uses.

Policy changes across the energy system in the form of new building energy code requirements, performance-based utility regulation, targeted government subsidies, and infusions of new capital to incentivize innovation would help speed the transition.

COMPARISON OF EMISSIONS FROM HEATING TECHNOLOGIES



Source: Acadia Center

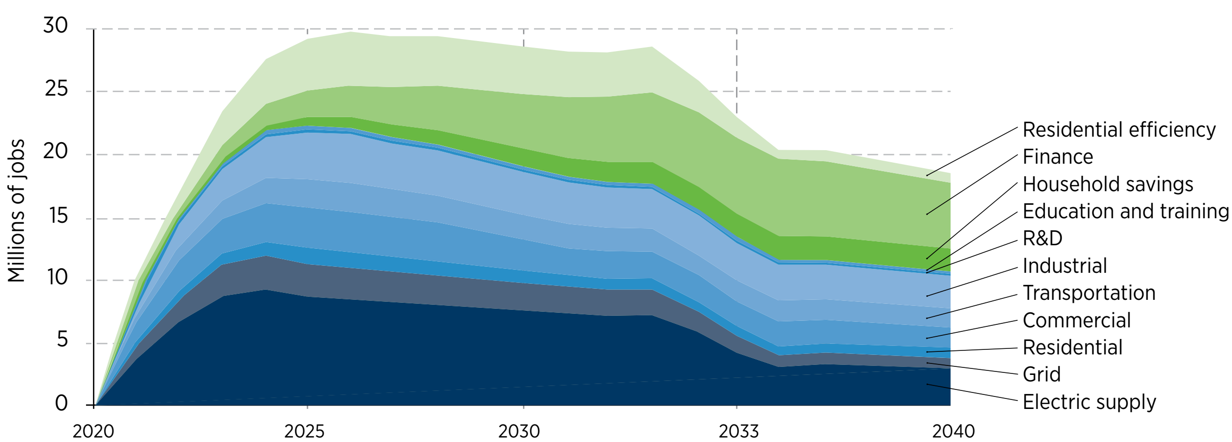
OTHER BENEFITS OF ELECTRIFICATION

Electrification is also predicted to create many new jobs. A recent analysis by Rewiring America indicates that aggressive decarbonization eliminating 70 percent to 80 percent of U.S. carbon emissions by 2035 of the U.S. economy would create 15 million to 20 million jobs, 5 million of which would be permanent.[29] Stanford University researches calculate that a 100 percent clean energy transition would create 28.6 million more jobs than are lost by eliminating fossil fuels.[30] A report by *Energy Innovatio*n found that transitioning to 90 percent clean electricity in the U.S. would create 530,000 more jobs annually, avoid at least $1.2 trillion in cumulative health and environmental damages, and would reduce economy-wide greenhouse gas emissions by 27 percent.[31]

Widespread electrification of end-use services across the transportation, buildings, and industrial sectors would increase electricity consumption by up to 38 percent in the U.S. by 2050.[32] At the same time, electrification will reduce primary energy demand. For example, electric motors used in electric vehicles are almost 80 percent efficient in converting power from the grid to mechanical energy at the wheels, while vehicles powered by internal combustion engines have a fuel-to-wheels conversion efficiency of 12 to 30 percent. The U.S. National Renewable Energy Laboratory (NREL) projects that if state-of-the-art, high efficiency motors are used in transportation, industry and buildings, primary energy consumption could be reduced by 21 percent.[33] Analyses by Stanford University indicate that a 100 percent transition to zero-carbon energy sources would reduce worldwide primary energy demand by 57 percent, and reduce energy, health, and climate costs by 91% compared with a business-as-usual analysis.[34]

The benefits of electrification are substantial; but when coupled with decarbonization of the U.S. electric energy supply at rates comparable to what has already been achieved by Ontario and Quebec, the benefits are multifaceted and transformative. Decarbonization of the electrical supply would reduce negative health impacts by 80 percent and help make it possible to limit global warming to below 2° Celsius.[35] Reducing the airborne deposition of acid gases, heavy metals, and particulates would greatly benefit our Great Lakes by improving water quality and by protecting the Region's commercial and recreational fisheries.

NEW CLEAN ENERGY JOBS



Source: Rewiring America

EVOLVING NEW CLEAN ENERGY TECHNOLOGIES – AN OPPORTUNITY FOR THE GREAT LAKES REGION

Existing clean energy technologies will continue to improve both in performance and economic efficiency, however, decarbonizing transportation, heating and cooling, and industrial processes may require further innovation in producing zero-carbon electricity and fuels. Promising new technologies are on the horizon but face obstacles to broad market penetration in terms of cost, commercialization, and public acceptance.

Small Modular Reactors (SMRs)

The challenges of decarbonizing the global economy and avoiding the worst effects of climate change require continuous efforts to develop new and improved technologies that promise reliable sources of carbon-free electricity. Among the new technologies in development are SMRs – small modular reactors currently being developed by Canada and the U.S.

SMRs bring simple, less complex designs, fewer parts, and failsafe, self-contained passive cooling systems that automatically shut down in the event of any service disruption. They promise to reduce the cost of nuclear energy and achieve economies of scale through use of standardized, factory produced components.

Both Canada and the U.S. are investing in SMR research and development in collaboration with innovative start-ups and nuclear industry experts. Canadian Nuclear Laboratories (CNL), together with Natural Resources Canada, have developed a SMR Roadmap with the goal of siting Canada's first SMR by 2026 and entering early into an emerging global market estimated at $150 billion a year by 2040.[36]

SMR development is also the focus of a collaboration involving the U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) in partnership with the Massachusetts Institute of Technology, GE Research, GE Hitachi, and the Electric Power Research Institute that also seeks to reduce SMR operation and maintenance costs.[37]

These binational efforts have come together in advancing the SMR design of a new startup – NuScale Power. NuScale's 60-megawatt SMR is designed to help smooth variable renewable energy from wind and solar projects, as well as providing supplemental carbon-free power that can also be deployed in remote areas. NuScale Power has signed an agreement with Ontario's Bruce Power to deploy its SMR design in Canada and has completed submissions to the Canadian Nuclear Safety Commission for pre-licensing review.[38] The U.S. Nuclear Regulatory Commission (NRC) has also issued a finding that the design met all safety requirements for the design certification stage of the licensing process.[39]

Offshore Wind

Offshore wind in the Great Lakes Region holds promise for the future as technology improves, wind turbines become larger, and as costs continue to decline. The total offshore wind potential in the Great Lakes is over 700 gigawatts, representing approximately one-fifth of the total offshore wind potential in the United States.[40] The greater constancy and speed of winds in the Great Lakes result in higher capacity factors and improved turbine efficiency.

> *"Canada has a window of opportunity to lead as it has all the necessary elements – a strong international brand, flexible and performance based regulator, world class nuclear laboratories and demonstration sites, a mature supply chain and domestic uranium mining industry, extensive nuclear operating experience, and strong science and technology in related areas."*
>
> Canadian SMR Roadmap

The cost of offshore wind energy has fallen sharply. In 2019, the cost of offshore wind fell 32 percent. On the Atlantic coast, power purchase agreements (PPAs) for the two-phase Vineyard offshore wind project were set at $74 per megawatt-hour (MWh) for phase one and $65 per MWh for the second phase.[41] The 804 megawatt Mayflower Wind project offshore from Massachusetts has contracted to produce power at 5.8 cents per kilowatt-hour.[42] Costs for European offshore projects have fallen to $50 per MWh.[43] Costs may decline further as turbines become more powerful. Siemens Gamesa intends to deploy a 14-megawatt model with a 222-meter rotor diameter while GE's Haliade-X 12 MW turbine capable of producing enough power for 10,000 homes is already setting new power production records.[44]

The Great Lakes Offshore Wind Project: Utility and Regional Integration Study[45] – a comprehensive power system integration study undertaken by U.S. DOE, General Electric, PJM, and Case Western Reserve University, identified the technical issues that would have to be addressed to successfully integrate and optimize Great Lakes offshore wind into the regional power system

Despite reduced costs and improving economics, offshore wind in the Great Lakes faces many hurdles including accessibility for construction and service vessels, lack of specialized port infrastructure, seasonal ice, and concerns from Great Lakes shipping industry. Coastal communities are likely to raise aesthetic concerns. Potential avian impacts along migration routes also need to be further investigated.

Still, interest in deploying offshore wind in the Great Lakes is growing with multiple projects in the planning stage.

Zero-Emission Hydrogen Fuels

Industrial processing by heavy industries like steel and cement producers, and those who use industrial boilers pose special challenges for an all-electric future. The high energy demand by these processes as well as the energy storage requirements of long-distance freight transportation would test the limits of "conventional" renewable energy sources like wind and solar energy.

Hydrogen fuels cells represent a promising means of meeting the high-power demand of the industrial sector. Hydrogen gas has three times the energy density of gasoline and diesel fuel and could power industrial furnaces and boilers as well as long distance trucking.

While hydrogen gas has been typically derived from fossil fuels, "green hydrogen" can be produced from electrolysis using renewable energy. Using excess wind and solar energy to power electrolysis could soon become a practical and cost-efficient solution. The need for an exponential increase in renewable energy resources will result in increased periods where supply of wind, solar and hydropower energy exceeds demand. Rather than curtailing energy production, the excess clean energy can be stored by conversion to hydrogen fuel.

Both Canada and the U.S. are well positioned to take advantage of the growing market for hydrogen fuels and hydrogen-based fuel cells, with the Great lakes Region host to many innovative companies pursuing hydrogen fuel applications and perfecting hydrogen technologies. Xcel Energy, for example, has received a grant from the U.S. DOE to produce hydrogen from the utility's Monticello nuclear plant in Minnesota, potentially improving the economics of nuclear energy while avoiding the use of fossil fuels.[46]

> ***"For over four decades, Canada has pioneered and developed a sector-leading position in advanced hydrogen and fuel cells. This know-how is critical as the world shifts to electrification. And as industries aim to decarbonize their sectors, the markets for hydrogen and fuel cell are expanding."***
>
> Canadian Hydrogen and Fuel Cell Association

THE CLEAN ENERGY TRANSITION – A KEY TO FUTURE PROSPERITY AND GLOBAL HEALTH

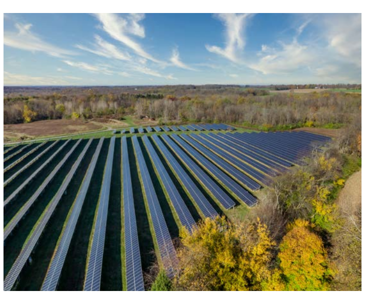
Cost reductions in renewable energy technologies have been phenomenal, falling far faster than the projections of energy experts. In 2013, wind and solar energy were the least expensive electric generation resource in one percent of energy markets.[47] Today, these technologies are the cheapest source of *new* power in two-thirds of global energy markets. By 2030, newly procured wind and solar energy resources are projected to produce power at rates cheaper than power produced by *existing* coal and natural gas plants worldwide.[48]

Performance improvements and dramatic reduction in cost have, in a remarkably short time, established clean energy technologies as the preferred choice of utilities and corporations. The promise of further technology improvement and cost reductions will keep the clean energy transition on track, helping to ensure a future decarbonized energy system.

Clean energy brings other quantifiable benefits as well. Climatic, environmental, and human health benefits represent trillions of dollars of additional benefits and avoided harm. The International Renewable Energy Agency (IRENA) 2019 report, *Global Energy Transition, Roadmap to 2050*, estimates the economic benefit of the global energy transition would range from $65 – 160 trillion by 2050.[49]

> "For every USD 1 spent for the energy transition, there would be a payoff of between USD 3 and USD 7 – or, put in cumulative terms over the period to 2050, a payoff of between USD 65 trillion and USD 160 trillion.... The level of additional investments needed to set the world on a more climate-friendly path above current plans and polices is USD 15 trillion by 2050 – a significant sum, but one that decreased by over 40% compared to the previous analysis due in large part to rapidly falling renewable energy costs."

Moreover, according to a recent analysis by the Harvard Center for Climate, Health, and the Global Environment, investing in the deployment of wind and solar energy in the Great Lakes Region would have greater monetizable economic and health benefits than comparative investments in other U.S. regions. The analysis indicates that installing 3,000 megawatts of wind energy in the Upper Midwest would provide $2.2 trillion in climate and health benefits to the region. Solar energy deployment at a like scale would provide similar benefits.[50] Early indications of regional deployment trends suggest that future penetration of utility scale wind and solar energy projects will easily exceed 3,000 megawatts in the near term.[51]



SOLAR FARM, OHIO

WOLF ISLAND, LAKE ONTARIO

Installing 3,000 megawatts of wind energy in the Upper Midwest would provide:

$2.2 trillion

in climate and health benefits to the region

Source: Harvard Center for Climate, Health, and the Global Environment

PROTECTING THE GREAT LAKES

As it stands, the carbon-intensive, fossil fuel power plants operating in the Great Lake States have broad, but largely unaccounted for, adverse effects on the health of the Great Lakes, as well as negatively affecting regional commerce, tourism, and recreational opportunities. Accelerating the clean energy transition will benefit the Great Lakes as well as the economic and ecological services that the Lakes and their tributary rivers and streams provide.

To illustrate, according to a 2019 report from the International Monetary Fund (IMF), negative externalities from fossil-fuel combustion at various points in the energy value chain and in the economy represent *over $4 trillion* in annual costs absorbed by the global economy. The IMF found that if negative externalities were actually included in the price of fossil fuels, carbon emissions would be reduced by 28 percent, fossil fuel air pollution deaths would be reduced by 46 percent, and global government revenue would i*ncrease* by 3.8 percent of GDP.[52]

Furthermore, the availability of unlimited water resources made the Great Lakes an optimal location for operating thermoelectric powerplants. Over time, 583 thermoelectric power units – including 144 coal-fired plants were sited on the Great Lakes. Requiring approximately 26 billion gallons of cooling water per day, thermoelectric plants accounted for 76 percent of water withdrawals in the Great Lakes Basin.[53] In addition to requiring great quantities of water, coal-fired plants have been a primary source of carbon dioxide emissions as well as other acid gases and heavy metals – including mercury, a powerful neurotoxin that bioaccumulates and accounts for the fish advisories in the waters of the Great Lakes.[54] Cooling water intakes also entrain millions of fish, fish eggs, larva, and other aquatic organisms. The discharge of the heated water affects aquatic organisms and benthic communities[55] reducing dissolved oxygen levels and helping to propagate algae and pathogens.[56]

PICTURED ROCKS NATIONAL LAKE-SHORE, LAKE SUPERIOR

A BETTER WAY FORWARD

Our Great Lakes, with their connecting waterways and the St. Lawrence River, comprise the world's largest open border, where two nations share a common history and common heritage. Our binational relationships and affiliations define our people and culture, providing a strong foundation for commerce, trade, and mutually enriching ingenuity, innovation, and enterprise.

The Great Lakes Region, the third largest economy in the world, is endowed with the earth's largest, most productive, and most valuable freshwater system. In an era of increasing water scarcity, our regional water wealth will be to our competitive advantage as global business, consumer and institutional interests come to better understand the economic, environmental, recreational, and aesthetic amenities our Region offers.

Accelerating the regional clean energy transition can both safeguard and protect the Region's unparalleled natural resource heritage, help us both mitigate and adapt to climate change, and attract the most innovative businesses and inventive entrepreneurs.

Our ambitions must be commensurate with the challenges of transitioning our energy supply and decarbonizing our economy. The Great Lakes Region has the talent and tools to lead the global energy transition – now we must find the tenacity and resolve to move forward boldly.

PORT BURWELL, LAKE ERIE

RECOMMENDATIONS FOR GOVERNMENT POLICYMAKERS, PUBLIC UTILITY COMMISSIONS AND GRID MANAGERS

GRID INTEGRATION

- Convene experts on power system design and management comprised of grid operators, utility representatives, public utility commission staff, technical experts, and policymakers to develop a vision for regional power system planning.
- Per the U.S. DOE's 2015 QER, establish collaborative programs for academic institutions and not-for-profits to develop legal, regulatory, and policy roadmaps for harmonizing regulations among Great Lakes states and provinces: In partnership with universities, qualified not-for-profits, and relevant Canadian and U.S. energy regulatory authorities, state and provincial, and local energy regulations will be compared to identify gaps, best practices, and regulatory inconsistencies.
- Develop a grid integration study for the Great Lakes Region evaluating power system needs to accommodate rapid electrification of all sectors with high levels of variable renewable energy and distributed energy resources that are able to participate in wholesale markets.
- Structure transmission, distribution, and electricity commodity rates in ways that incent users to shift consumption away from peak demand periods and make better use of surplus capacity.
- Streamline DER interconnection processes and modernize requirements to allow built-in smart inverter anti-islanding technologies to be utilized.
- Model future zero-carbon generation and transmission infrastructure needs to meet target goals for electrification and determine the most cost-effective and reliable means to integrate variable renewable energy sources and DERs.
- Use "performance regulation" to integrate DERs, catalyze grid design and innovation, and accelerate deployment of zero-carbon energy resources.
- Replicate the Ontario Energy Board's *Innovation Sandbox*[57] that provides innovators with a testbed for validating advanced energy technologies that promise to improve energy services.

ELECTRIFYING TRANSPORTATION

- Urge policymakers to:
  - Require 10 percent of all vehicles sold by 2025 be zero emission battery electric, plug-in hybrids, or hydrogen fuel-cell models.
  - Phase-out the sale of light duty vehicles powered by ICEs after 2035.
  - Accelerate the electrification of public transportation. Municipalities and school districts should require that all purchases of transit buses utilize electric drivetrains after 2027. States and provinces should provide transit agencies with financial and technical assistance to help them make the transition to electric buses while maintaining or increasing service.
- To meet consumer concerns, develop a regional vision for accelerating the expansion of electric vehicle charging stations that will inform public and private investment in charging infrastructure.
- Offer streams of low interest financing for infrastructure projects that electrify transportation and industry.
- Provide consumer EV incentives to reduce the upfront cost of purchase.

INDUSTRIAL PROCESSES AND BUILDINGS

- Provide stronger incentives for intelligent energy management systems, advanced energy technologies, and energy efficient retrofits.
- Support replacement of high carbon fuels in industrial processes with clean hydrogen, especially in applications where direct electrification is difficult. Support replacement of natural gas, propane, and oil heat with highly efficient heat pumps, geothermal systems, appliances, and air conditioning systems.
- Create planning incentives for new residential communities that incorporate carbon-free district heating and cooling systems.
- Develop end use load profiles for Great Lakes states and provinces; require utilities to optimize demand response capacity and provide time-of-use and/or dynamic pricing. Many utilities and jurisdictions in the region are in some stage of deployment of advanced metering and of advanced rate designs to more accurately charge for cost of service and incent cost-reducing customer behavior.

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