PEMBINA institute

Offshore wind in Canada

Potential sites, cost and emissions reduction impact

by Raidin Blue and Binnu Jeyakumar | May 27, 2022

Summary

There is significant potential for offshore wind development in Canada, with a large number of appropriate sites in Canada's seas and lakes. This potential will increase further in the coming years as the technology for floating offshore turbines matures.

Average life cycle greenhouse gas (GHG) emissions for wind power (both offshore and onshore) remain amongst the lowest, second only to hydropower. However, while costs associated with the construction and operation of offshore wind turbines are currently higher than other renewable sources of energy, the costs for offshore wind are projected to significantly decline in the coming two decades.

As Canada moves towards a net-zero electricity grid by 2035, this primer provides some context on the potential for offshore wind and its cost and GHG implications.

Potential

Wind power has been scaling up globally over the last two decades. It is the world's second-largest source of renewable energy, with 698 gigawatts (GW) installed in 2020. The majority of global wind production is onshore, with offshore global capacity at 34 GW.[1] One of the advantages of offshore wind is that it typically has a higher and more consistent output than onshore wind facilities.

Figure 1 illustrates the modelled offshore wind potential in Canada and the United States. Areas with competing uses (fishing, defence, oil and gas exploration and production, environmental protection) are excluded.

[1] IRENA, "Wind energy," 2022. https://www.irena.org/wind

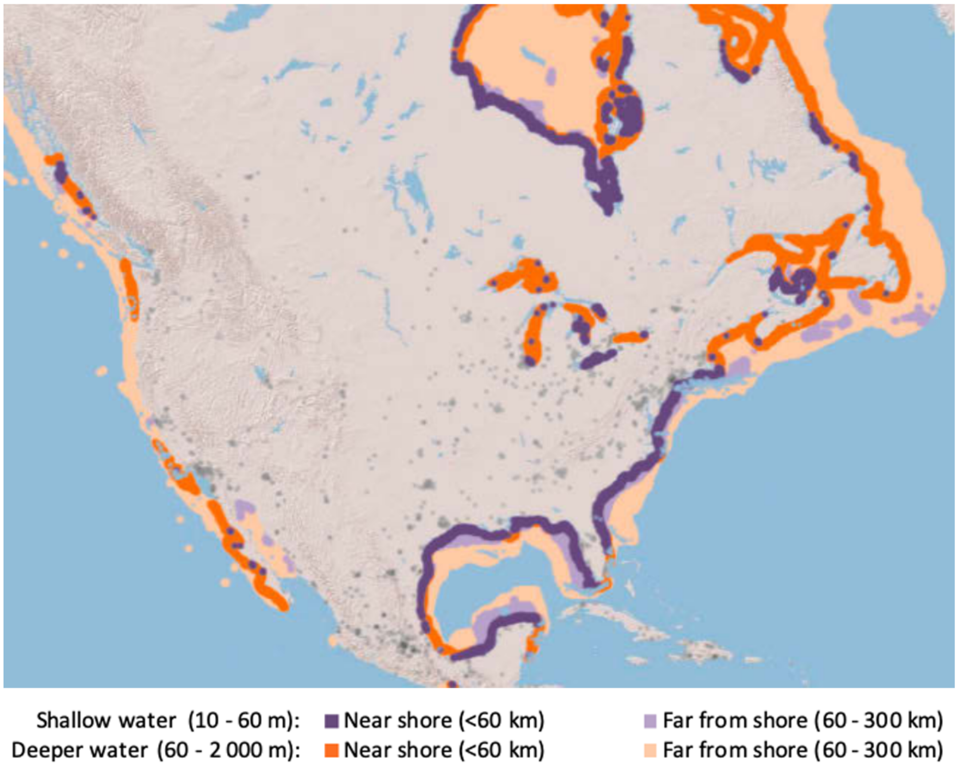

Figure 1. Modelled offshore wind potential in Canada and the United States

Adapted from: International Energy Agency[2]

No offshore wind farms exist in Canada, but more than 3.6 GW have been proposed.[3] The lack of investment is not due to poor potential, but likely to the nascency of the industry. Estimates for the potential for offshore wind will increase in the coming years as technologies advance and turbines are able to be built farther from shores (more than 60 km) and in deeper water (60-2,000 m). Typically, offshore wind turbines are "fixed", meaning they are built with a sturdy foundation embedded into the floor of the water body. However, the technology to facilitate floating offshore turbines, which are anchored and float semi-submerged, has been advancing in recent years. The U.S. National Renewable Energy Laboratory projects that floating offshore wind will be at utility-scale deployment by 2024.[4]

[2] International Energy Agency, *Offshore Wind Outlook 2019: World Energy Outlook Special Report* (2019), 52. https://www.iea.org/reports/offshore-wind-outlook-2019

[3] Canada Energy Regulator, "Canada's Adoption of Renewable Power Sources – Energy Market Analysis," July 20, 2021. https://www.cer-rec.gc.ca/en/data-analysis/energy-commodities/electricity/report/2017-canadian-adoption-renewable-power/canadas-adoption-renewable-power-sources-energy-market-analysis-emerging-technologies.html

[4] National Renewable Energy Laboratory, "Floating Wind Turbines on the Rise," April 2, 2020. https://www.nrel.gov/news/program/2020/floating-offshore-wind-rises.html

As shown in Figure 1, the development of offshore wind in Canada has the greatest potential in the Hudson Bay, the Labrador Sea and within the Great Lakes. Analysis remains to be done for other large lakes in Canada. The Canada Energy Regulator recently explored pathways to a net-zero electricity grid and modelled onshore wind becoming the primary source of electricity in Alberta, Saskatchewan and Nova Scotia by 2030, and New Brunswick by 2050.[5] However, this modelling excluded offshore wind. The inclusion of offshore wind could increase the proportion of renewable energy in the electricity grid.

Cost

The cost of offshore wind has declined significantly over the last ten years, but still has some catching up to do with onshore wind. Figure 2 shows the levelized cost of energy (LCOE) for offshore wind, globally, from 2010-2020. Broadly, LCOE indicates the average total cost of building and operating an energy asset, per unit of total electricity that the asset will generate over its lifetime.

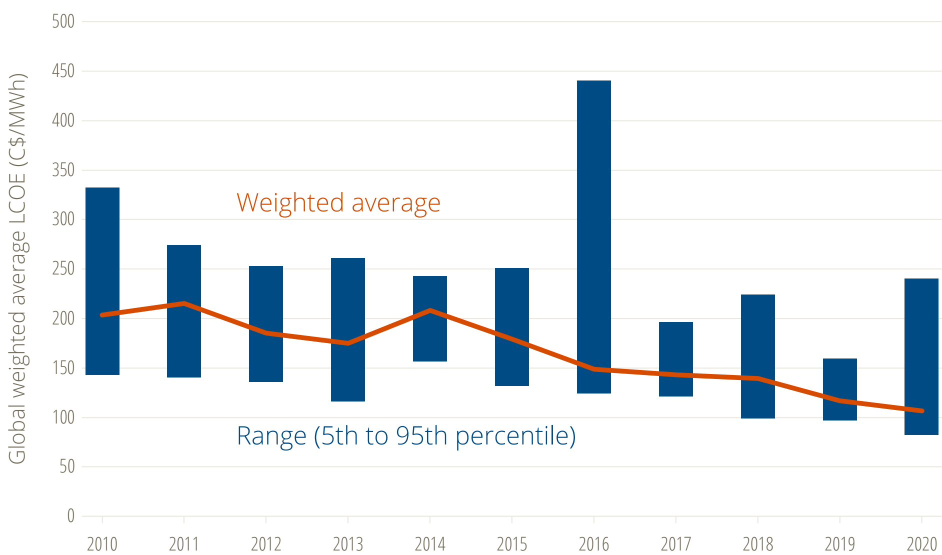

Figure 2. Global LCOE of offshore wind (range and weighted average)

Data source: IRENA[6]

[5] CER, "Towards Net-Zero: Electricity Scenarios," April 11, 2022. https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2021/towards-net-zero.html

[6] IRENA, *Renewable Power Generation Costs in 2020* (2021), 91. https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020

Costs converted to 2020 C$ at a rate of US$1 = C$1.26.

Offshore wind is currently more expensive than other renewable energy sources. Figure 3 shows the LCOE for various generation options. (These other options are described in the Appendix at the end.)

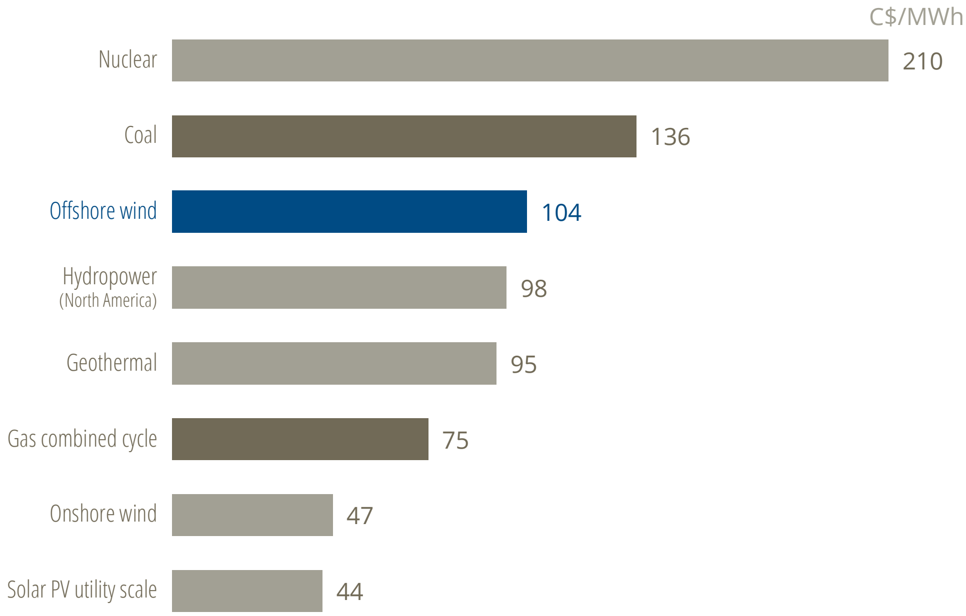

Figure 3. LCOE for various generation options (not region-specific)

Data sources: Lazard, IRENA [7]

The LCOE of offshore wind is estimated at approximately C$104 per megawatt-hour (MWh). This is comparable with the LCOE for hydropower (C$98/MWh), but remains significantly higher than for onshore wind (C$47/MWh) and utility-scale solar photovoltaics (PV) (C$44/MWh). The LCOE for offshore also varies regionally depending on meteorological conditions.[8]

It should be noted that the International Energy Agency estimates that the LCOE for offshore wind will drop to C$74/MWh by 2030 and C$56/MWh by 2040.[9]

Impact on emissions

The life cycle greenhouse gas (GHG) emissions of offshore and onshore wind are the same, and are comparable with both hydropower and nuclear (Figure 4). Life cycle GHG emissions are

[7] Lazard, *Lazard's Levelized Cost of Energy Analysis – Version 15.0* (2021), 2.
https://www.lazard.com/media/451881/lazards-levelized-cost-of-energy-version-150-vf.pdf

For hydropower: IRENA, *Renewable Power Generation Costs in 2020*, 131.

[8] *Offshore Wind Outlook 2019*, 42.

[9] *Offshore Wind Outlook 2019*, 42.

much lower than traditional generation types, even if these are paired with emerging carbon capture and storage (CCS) technologies.

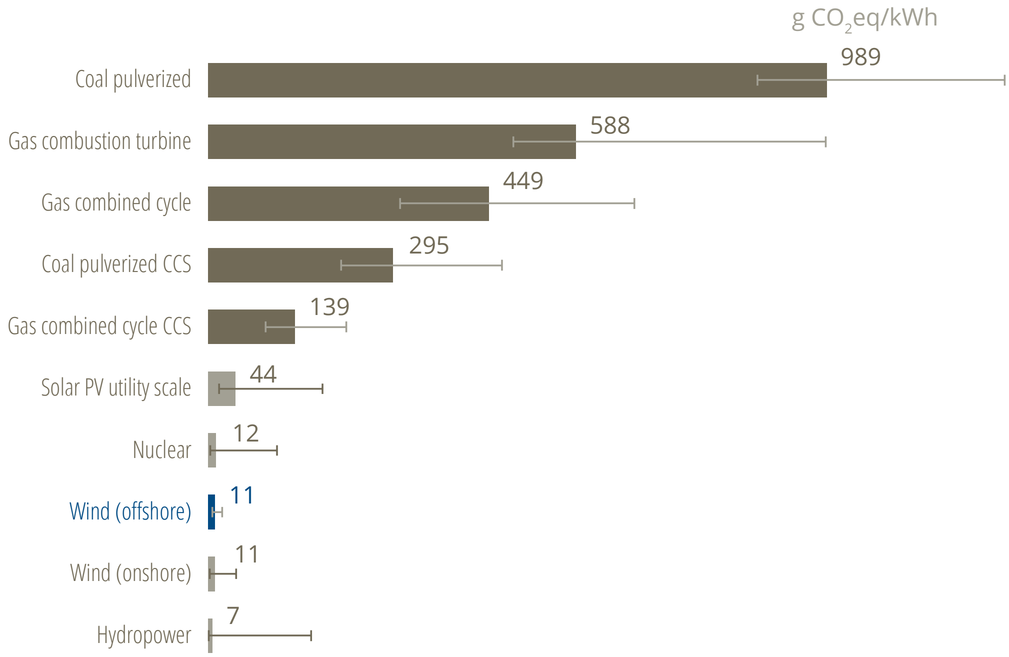

Figure 4. Global average life cycle GHG emissions

Data source: UNECE[10]

For offshore wind, virtually all of these emissions are embodied, i.e., they result from the manufacturing, transportation, installation, maintenance and disposal of building materials. Around 58% of offshore wind emissions arise from the foundation, tower and generator, while more than a quarter arise from construction operations[11] (for example, construction is notably more carbon intensive for offshore wind, as operations occur on boats rather than on land). However, even though offshore wind is more emissions intensive to build than onshore wind, the life cycle greenhouse gas emissions are similar, because offshore wind typically operates at higher capacity factors than onshore. The capacity factor of a power generation method can be understood as a measurement of the consistency with which it generates power (which, for wind, is partly reliant on the wind blowing — and therefore more consistent offshore).[12] Life cycle GHG impacts for offshore projects could drop further in coming years as the technology for floating offshore turbines matures.

[10] UNECE, *Life Cycle Assessment of Electricity Generation Options* (2022), 74. https://unece.org/sed/documents/2021/10/reports/life-cycle-assessment-electricity-generation-options

[11] *Life Cycle Assessment of Electricity Generation Options*, 28.

[12] IEA, *Offshore Wind Outlook 2019: World Energy Outlook Special Report* (2019), 20. https://www.iea.org/reports/offshore-wind-outlook-2019

Appendix: Other electricity generating technologies

Coal: Coal is burned in a furnace to generate heat, boil water, create steam, turn a turbine, and generate electricity. The coal LCOE figure represents a benchmark of operating coal plants across the U.S.

Coal pulverized: Coal is crushed to a powder and burned in a furnace which creates heat to boil water, generate steam, turn a turbine, and generate electricity.

Coal pulverized, with carbon capture and storage (CCS): The same system as coal pulverized, with the addition of carbon capture and storage technology — where carbon dioxide that is created during the burning process is captured before it is emitted into the atmosphere, and stored (often underground).

Gas combustion turbine: Compressed air is mixed with methane (natural gas) and burns the product to create heat, which turns a turbine and generates electricity.

Gas combined cycle: A similar method of electricity generation as gas combustion turbine with additional electricity generated by capturing exhaust heat with a heat recovery steam generator.

Gas combined cycle, with CCS: The same system as gas combined cycle with the addition of carbon capture and storage technology.

Geothermal: The natural heat of the Earth's crust is used to boil water, create steam, and turn a turbine to generate electricity.

Hydropower: A reservoir of water is collected with a hydroelectric dam that can be released to turn a turbine and generate electricity.

Nuclear: Uranium atoms are split to produce heat. The heat is transferred to pressurized water to create steam, turn a turbine, and generate electricity. Newer, small modular nuclear reactors (known as SMRs) were excluded from this analysis because the LCOEs vary greatly between technologies, and they are still maturing.

Solar photovoltaic (PV) at utility scale: Solar energy is captured by photovoltaic power stations and used to generate electricity; these figures are generalized between various types of semiconductors.