



ENERGY FUTURES GROUP



# Levelized Cost of Energy (“LCOE”) Calculations

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On behalf of Ontario Clean Air Alliance Research Inc.

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## 1. SUMMARY

Energy Futures Group (“EFG”) was asked by the Ontario Clean Air Alliance Research Inc. to evaluate the levelized cost of energy (“LCOE”) for several resource technologies, including offshore wind, onshore wind, solar, and nuclear resources. LCOE is a measure of the average cost for a generator over its lifetime. The LCOE calculation includes the lifetime costs of a plant (capital, financing and construction costs, fixed operation and maintenance (“O&M”), transmission costs, variable O&M, and fuel)<sup>1</sup> divided by the energy production over the lifetime of the generator. The accompanying workbook to this report shows the input assumptions and data sources that result in the LCOE calculations provided in this report. The accompanying workbook is also configured to allow users to develop alternative assumptions for two sensitivities where inputs into the LCOE calculation for each resource technology can be modified.

One important note about the LCOE results is that these systems are not entirely comparable. In order to compare wind or solar as a full replacement on a capacity factor or capacity accreditation basis, one would need to pair wind/solar with battery storage or develop a portfolio of resources including renewables, battery storage, and demand side management (“DSM”). Developing alternative portfolios of resources requires a more detailed analysis and was outside the scope of this report.

## 2. INPUTS TO LEVELIZED COST OF ENERGY CALCULATION (“LCOE”)

The following section outlines the data sources for each of the inputs into the LCOE calculations contained in the workbook that accompanies this report. The input sources for offshore wind, onshore wind, and solar are shown in Table 7 below. The two data sources<sup>2</sup> for these inputs are the Independent Electricity System Operation (“IESO”) Pathways to Decarbonization Report Appendix A<sup>3</sup> and the National Renewable Energy Technology Baseline (“NREL ATB 2023”).<sup>4</sup> The IESO Pathways to Decarbonization Report included transmission costs for several different locations for offshore and onshore wind resources. The IESO transmission costs and capacity factors reported for each zone were used to develop a zone specific LCOE, which results in a range of LCOEs for both offshore and onshore wind.<sup>5</sup> The IESO Decarbonization Report Appendix A did not indicate a transmission cost for solar so that was not included in the LCOE calculation for solar.

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<sup>1</sup> For the resource technologies evaluated, the variable O&M and fuel only applied to the nuclear resources.

<sup>2</sup> These data sources were used to be consistent with the IESO data sources.

<sup>3</sup> Retrieved from <https://www.ieso.ca/en/Learn/The-Evolving-Grid/Pathways-to-Decarbonization>

<sup>4</sup> NREL (National Renewable Energy Laboratory). 2023. "2023 Annual Technology Baseline." Golden, CO: National Renewable Energy Laboratory. <https://atb.nrel.gov/>.

<sup>5</sup> The zones included in this report and the LCOE calculation are for locations in Ontario south of 53 degrees latitude.

**Table 1. Data Source for Wind and Solar Resources**

<b>Input</b>	<b>Offshore Wind</b>	<b>Onshore Wind</b>	<b>Solar</b>
Finance Factor <sup>6</sup>	NREL ATB 2023	NREL ATB 2023	NREL ATB 2023
Construction Factor	NREL ATB 2023	NREL ATB 2023	NREL ATB 2023
Capital Recovery Factor	NREL ATB 2023	NREL ATB 2023	NREL ATB 2023
Life	IESO Pathways to Decarbonization	IESO Pathways to Decarbonization	IESO Pathways to Decarbonization
Capacity Factor			
Capital Cost			
Fixed O&M			
Transmission			
Variable O&M			
Fuel			

The input sources for the nuclear LCOE assumptions include the reported costs for the Plant Vogtle AP 1000 nuclear reactors<sup>7</sup>, Tennessee Valley Authority's ("TVA") recent Integrated Resource Plan ("IRP") overnight capital costs for a Light Water Small Modular Reactor ("SMR")<sup>8</sup>, and the NREL 2023 ATB. The TVA costs for a Light Water SMR were developed for a First of a Kind ("FOAK") and Nth of a Kind ("NOAK") unit. It is important to note that the LCOE calculations presented in this report assume TVA's cost assumption from the FOAK to a NOAK, but that it is still unknown what level of cost reduction might happen once units are built. These different cost assumptions reflect a range of costs for nuclear technology. The cost estimate based on the Plant Vogtle reactors represents a potential book end value.

The capacity factor included in the LCOE for nuclear is based on the average historical performance of the Darlington nuclear units, which is 78.63%.<sup>9</sup> Three different life assumptions (60, 50, and 30 years) were evaluated for the nuclear resources to consider the potential need for nuclear units to require refurbishment to continue operating. The life assumption for a resource impacts the capital recovery factor ("CRF") that is included in the LCOE calculation. If a resource has a longer book life, then this will result in a lower CRF, which reduces the LCOE. Alternative life assumptions for nuclear resources were included in this analysis to try to reflect operating lives for nuclear units given that the units often have additional investments for refurbishment to extend the life of the units. The Darlington nuclear unit refurbishment started in 2016 and are under a planned refurbishment schedule

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<sup>6</sup> The tax rate assumption in the NREL ATB 2023 workbook was revised to reflect a Canadian corporate income tax rate.

<sup>7</sup> Retrieved from <https://www.worldnuclearreport.org/IMG/pdf/wnisr2024-v2.pdf>

<sup>8</sup> TVA 2025 Draft IRP, Appendix E – Utility Scale Resource Methodology, Table E-5 at E-8 – E-9. Retrieved from [https://tva-azr-eastus-cdn-ep-tvawcm-prd.azureedge.net/cdn-tvawcma/docs/default-source/environment/environmental-stewardship/integrated-resource-plan/2025/draft-2025-irp-volume-1-092324.pdf?sfvrsn=26f01b64\\_1](https://tva-azr-eastus-cdn-ep-tvawcm-prd.azureedge.net/cdn-tvawcma/docs/default-source/environment/environmental-stewardship/integrated-resource-plan/2025/draft-2025-irp-volume-1-092324.pdf?sfvrsn=26f01b64_1)

<sup>9</sup> Retrieved from <https://pris.iaea.org/PRIS/CountryStatistics/ReactorDetails.aspx?current=43>

to extend the life of each unit.<sup>10</sup> The LCOE calculations presented in this report do not reflect any additional investments needed for refurbishment but try to capture impacts on the LCOE by looking at three different life assumptions. Table 2 shows the data sources used to develop the LCOE for an AP1000 nuclear reactor and Light Water SMR.

**Table 2. Data Source for Nuclear Resources**

<b>Input</b>	<b>Nuclear</b>	<b>Nuclear SMR</b>
Finance Factor <sup>11</sup>	NREL ATB 2023	NREL ATB 2023
Construction Factor	NREL ATB 2023	NREL ATB 2023
Capital Recovery Factor	NREL ATB 2023	NREL ATB 2023
Life	60, 50, and 30 years	60, 50, and 30 years
Capacity Factor	Darlington Historical	Darlington Historical
Capital Cost	Plant Vogtle	TVA 2025 IRP First and Nth-of-a-kind
Fixed O&M	NREL ATB 2023	NREL ATB 2023
Variable O&M	NREL ATB 2023	NREL ATB 2023
Fuel	NREL ATB 2023	NREL ATB 2023

### 3. LCOE

A 2030 and 2040 LCOE was calculated for each technology and reported for three cases: without an Investment Tax Credit (“ITC”), assuming a 30% ITC, and assuming a 15% ITC.<sup>12</sup> The NREL ATB formula for the calculation of the LCOE for each resource was used to develop the calculations. Table 3 shows the LCOE results for a 2030 project cost in 2024 \$/MWh (US dollars) without the application of a 30% ITC and with a 30% ITC included. Table 4 shows the LCOE results for a 2040 project cost in 2024 \$/MWh (US dollars) under an assumption of no ITC, a 30% ITC included, and a partial ITC at 15%. These different ITC assumptions were included for the 2040 assumption to reflect LCOE results if there is an extension to the ITC beyond 2034. The ITC was applied as a straight reduction to the capital cost of each resource. A range of LCOE results are shown for offshore and onshore wind to represent the different zone locations. A range of LCOE results are also shown for the nuclear resources to represent the different life assumptions for 60, 50, and 30 years.

<sup>10</sup> Retrieved from <https://news.ontario.ca/en/release/42218/nuclear-refurbishment-begins-at-darlington-generating-station> and <https://www.opg.com/projects-services/projects/nuclear/darlington-refurbishment/>

<sup>11</sup> The tax rate assumption in the NREL ATB 2023 workbook was revised to reflect a Canadian corporate income tax rate.

<sup>12</sup> Retrieved from <https://www.canada.ca/en/revenue-agency/services/tax/businesses/topics/corporations/business-tax-credits/clean-economy-itc/clean-technology-itc/about-ct-itc.html>

**Table 3. LCOE (US 2024\$/MWh) Based on 2030 Cost**

<b>Resource</b>	<b>No ITC</b>	<b>ITC at 30%</b>
Offshore Wind	\$105 - \$113	\$86 - \$93
Onshore Wind	\$33 - \$51	\$27 - \$43
Utility-Scale Solar	\$54	\$41
Nuclear	\$279 - \$307	\$206 - \$226
Nuclear SMR FOAK	\$289 - \$319	\$211 - \$232
Nuclear SMR NOAK	\$214 - \$235	\$159 - \$174

**Table 4. LCOE (US 2024\$/MWh) Based on 2040 Cost**

<b>Resource</b>	<b>No ITC</b>	<b>ITC at 30%</b>	<b>ITC at 15%</b>
Offshore Wind	\$94 - \$103	\$78 - \$85	\$86 - \$94
Onshore Wind	\$30 - \$47	\$24 - \$39	\$27 - \$43
Utility-Scale Solar	\$41	\$31	\$36
Nuclear	\$279 - \$307	\$206 - \$226	\$242 - \$266
Nuclear SMR FOAK	\$244 - \$269	\$180 - \$197	\$212 - \$233
Nuclear SMR NOAK	\$182 - \$200	\$137 - \$149	\$160 - \$174