E

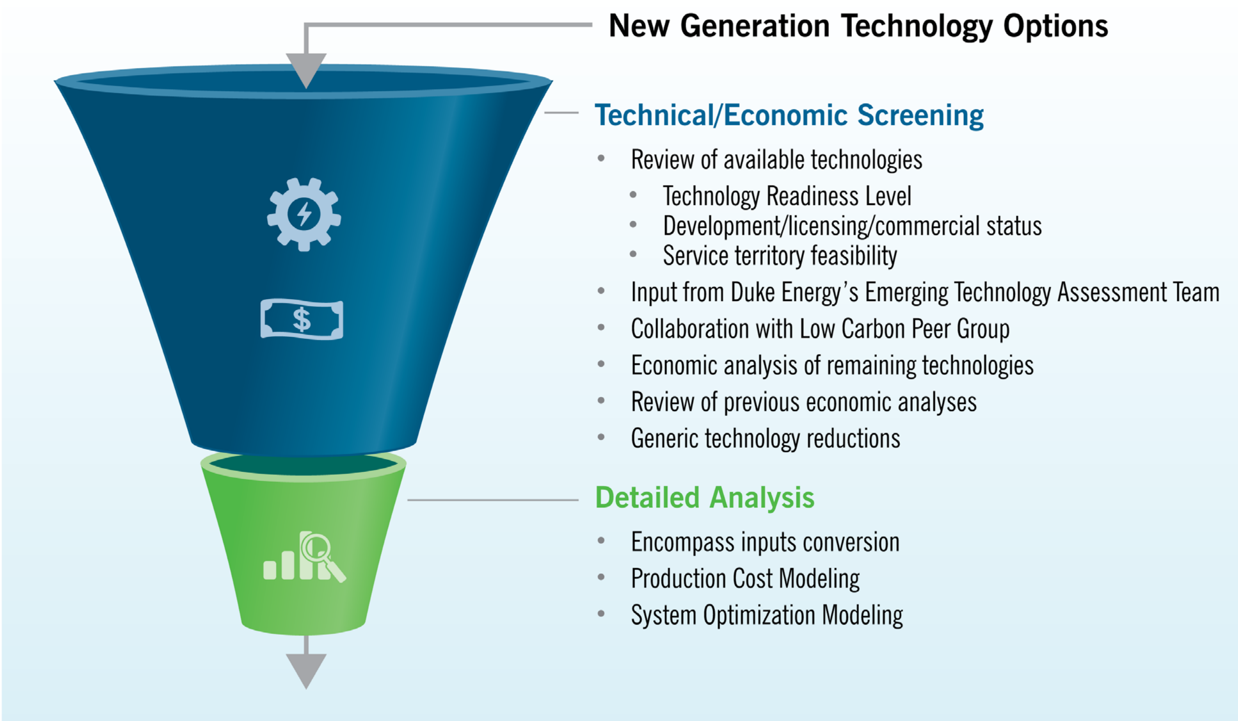
Screening of Generation Alternatives

Highlights

- Similar supply-side technologies were made available for selection in the 2023 Carolinas Resource Plan as in previous resource plan analyses, including advanced nuclear, combined cycle plants, combustion turbines, storage, wind and solar resources.
- Costs for all resource types increased due to inflationary pressures and supply chain constraints. Although future technology costs decline more aggressively, the beginning point in 2023 for all technology costs has increased since prior resource plans.
- Inflation Reduction Act of 2022 tax credits will reduce the cost increases for most technologies, and those cost reductions are accounted for in the resource plan modeling. However, that analysis is performed outside of the generic unit cost estimates addressed in this Appendix since the tax credits do not impact the expected overnight capital cost of each technology.

Duke Energy Progress, LLC ("DEP") and Duke Energy Carolinas, LLC ("DEC" and, together with DEP, the "Companies") screen generation technologies prior to performing detailed resource selection analysis to develop a set of possible supply-side alternatives. Generating technologies are screened from both a technical perspective as well as an economic perspective, shown below in Figure E-1. In the technical screening, technology options are reviewed to determine technical limitations, commercial availability issues, and feasibility in the Duke Energy service territory. Economic screening considers the potential for the technology to be cost-competitive against other available technologies. The technologies must be technically and economically viable to be passed on to the detailed analysis phase of the Carolinas Resource Plan development process.

Figure E-1: Screening Considerations



Technically and Economically Excluded Screening Results

The first step in the Companies' supply-side screening process is a technical screening of the technologies to eliminate those that have technical limitations, commercial availability issues, or are not feasible in the Duke Energy service territory. There are also technologies that are technically available but clearly unable to compete economically with other technologies from a similar class (e.g., baseload, peaking/intermediate, variable, or storage). The list of technologies being evaluated by the Companies but excluded due to technical or economic reasons is as follows:

Advanced Geothermal: Geothermal resources have traditionally been enabled by geology in the western half of the United States, shown in Figure E-2 below. However, advanced geothermal is under development and is in the demonstration phase. Advanced geothermal covers a variety of technologies but typically includes closed loop systems and deep borehole drilling to reach greater depths with higher temperatures. Recent developments in deep direct-use geothermal may expand geothermal's applicability into some of the least favorable geological formations. Although these technologies have not yet reached commercial status, the Companies continue to monitor ongoing pilots and demonstrations for potential future application within its service territory.

Figure E-2: Geothermal Resources of the United States

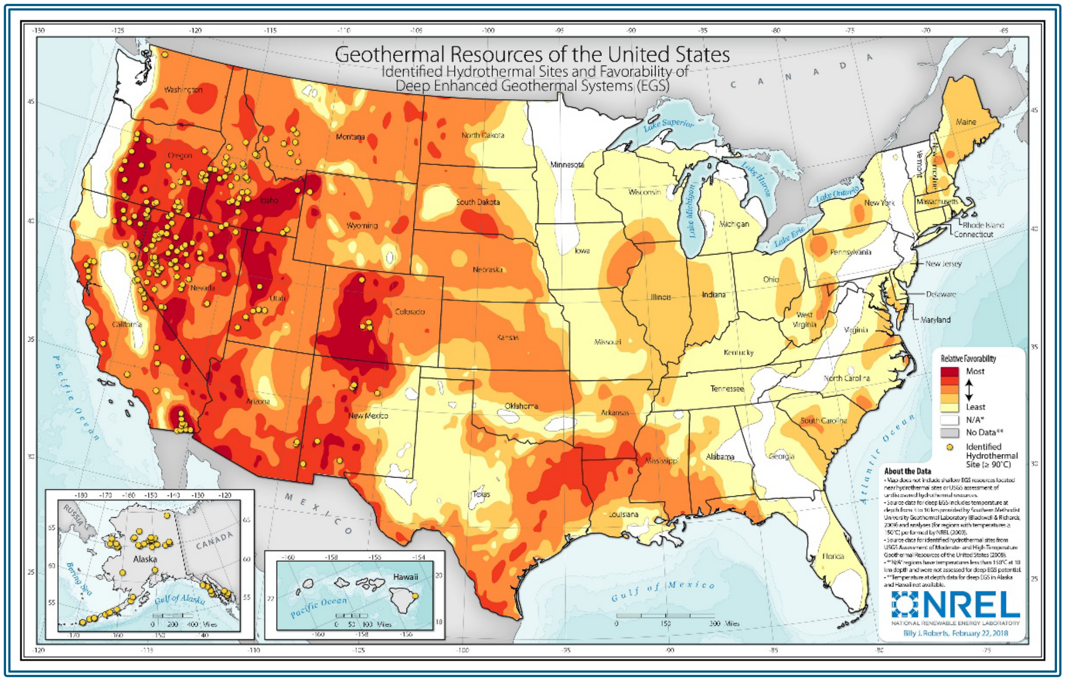


Figure source : National Renewable Energy Laboratory ("NREL")[1]

Bioenergy: There are various forms of bioenergy being developed and considered for power generation. Biofuels are mostly being considered as an alternative to natural gas with potentially lower emission rates than natural gas. Although there are some applications of biofuels already in use, those are mostly small-scale and dependent on specific agreements that are already in place (e.g., methane from animal waste products). Larger-scale biofuels that could be used for capacity expansion are still being developed and are not yet ready for the scale required, so the Companies will continue to monitor advancements in the biofuels area.

Coal: While coal facilities are technologically mature, increasing environmental regulations, decreasing fuel supply assurance, and labor supply issues threaten their ability to be developed and operated. Additionally, it is expected that any new coal facility would require inclusion of carbon capture and sequestration ("CCS") technology due to expected emission constraints, and the costs for a coal facility with CCS have both a high capital and operating cost. Coal has not been selected by the capacity expansion models as a new resource for many years even when the models had the option to choose coal without CCS. Given the challenges facing coal generation discussed in Chapter 1 (Planning for a Changing Energy Landscape), it is unlikely that any new coal facilities will be pursued in the United States.

[1] National Renewable Energy Laboratory, Geothermal Resources of the United States, February 22, 2018, available at https://www.nrel.gov/gis/geothermal.html.

Hydroelectric: Hydroelectric power is another technology that is mature enough to pass the technical screening process. However, hydroelectric power is extremely site-specific, requiring a relatively large water source and the ability to manage it through a dam or other structures. In addition to the lack of available new sites for development of hydro in the Carolinas, building new hydro reservoirs can have high costs and require significant amounts of permitting/regulatory work. Expansion and utilization of existing reservoirs would reduce the cost, risk, and permitting process.

Nuclear Fusion: Nuclear fusion energy has been researched for many decades as the technology holds significant promise for energy production. Additionally, nuclear fusion has made headlines more often lately as technology breakthroughs have come at a more rapid pace with a notable milestone reached in 2022 as the first fusion reaction achieved net power gain. However, commercial development of fusion will take many years to demonstrate and could take place only after the proper scientific breakthroughs have been achieved. Repeated net-energy gain, sustained net-energy gain, and commercial development are all required before fusion can pass the technical screening step. A commercial milestone was hit in 2023 as Microsoft signed a Power Purchase Agreement with Helion Energy, with expected first offtake in 2028. The Companies will monitor this and other commercial demonstrations to determine when fusion may be appropriate to include in the modeling effort.

Solar Steam Augmentation/Concentrated Solar: These systems utilize thermal solar energy to supplement a steam cycle similar to a fossil generating plant. The supplemental steam is integrated into the steam cycle and supports additional megawatt ("MW") generation similar in concept to the purpose of duct-firing a heat recovery steam generator. Instead of collecting energy through solar panels, solar steam augmentation/concentrated solar power utilizes mirrors to concentrate solar energy. This process requires specific weather conditions, mostly hot dry locations, and most current installations are in deserts like the North American Southwest. The Companies will continue to monitor developments in solar steam augmentation if there are changes to the technology in the future that change the assessment.

Supercritical Carbon Dioxide ("sCO_2") Brayton Cycle/Allam Cycle: In sCO_2 power systems, carbon dioxide ("CO_2") is utilized as the working fluid, replacing the air (Brayton Cycle) or water (Rankine Cycle) as used in traditional power generation systems. Just above the critical point, CO_2 is liquid-like, which dramatically reduces compression/pumping power (and cost) compared to air and nitrogen. Some sCO_2 Brayton cycles for fossil-fuel plants might achieve 100% CO_2 capture and zero emissions of conventional pollutants with little or no efficiency or capacity penalty. However, a low-CO_2-emitting sCO_2 Power Cycle facility would require carbon capture, transportation and storage (or, alternatively, utilization). This technology remains in the demonstration stage with some early pilot issues requiring correction before the technology reaches commercial status. This technology has the potential to be an improved option compared to a traditional natural gas combined-cycle plant with CCS due to the advantages named above, but both the commercial status of the technology needs to progress and the viability of CO_2 sequestration within the Carolinas needs to be proven. The Companies will continue engaging in industry efforts to follow the technology's status and determine when the sCO_2 power cycle should be considered as a selectable technology.

Wave/Tidal: Wave and tidal power systems are developing technologies focused on harnessing energy from the ocean. There are a few wave power systems currently operational today, but the technology is still far from being considered commercially viable and has not been a focus of development for the Companies. Tidal power typically requires large variation in tides, which does not exist within the Carolinas. There are companies pursuing the advancement of these technologies in the United States, and the Companies will continue to monitor these technologies in future updates.

Additional Storage Technologies: There are dozens of storage technologies and even more companies emerging on the market as larger amounts of variable renewable energy installations show the need for stationary energy storage. The Companies have represented in the modeling some storage technologies, and the majority of these additional storage technologies are still developing and have not reached commercial status. The technologies included in the model are meant to be representative of the Companies' current expectations for short to medium duration storage. The Companies will continue to evaluate the potential for long-duration energy storage technologies to reach commercial status and be included in the modeling. Refer to Appendix I (Renewables and Energy Storage) for additional information on storage technologies under evaluation. For 2023 representative technologies for storage, up to eight hours is included for modeling purposes.

Technically and Economically Screened-In Results

The technologies that are available for selection as a supply-side resource for the modeling process due to passing the technical and economic screening are presented in this section. The technologies are separated into categories based on their expected usage for the system. Baseload technologies are dispatchable resources with high-capacity factors for the system's daily needs. Peaking and intermediate resources typically fill the gaps in load and demand with greater ramping capabilities and lower capacity factors than the baseload options. Storage resources have a variety of uses and are beneficial to moving generation from periods of low demand to periods of high demand. Variable resources are options that do not consume or rely upon traditional fuels, and which have availability tied specifically to a factor outside the control of the grid operator (e.g., solar irradiance or wind speed). Economic screening considers capital costs, ongoing maintenance costs, ongoing capital costs, fuel costs, decommissioning costs and any other life cycle costs to determine whether each technology should be included as a supply-side resource or not. Figure E-3 below shows each supply-side resource and its classification.

Figure E-3: Generation and Storage Options – Winter Ratings

BASELOAD

- 300 MW, Small Modular Reactor Nuclear
- 300 MW, Advanced Small Modular Reactor Nuclear plus 150 MW of Thermal Storage
- 1,359 MW, 2x2x1 Advanced Class Combined Cycle (with Duct Firing)

STORAGE

- 100 MW / 4 Hour Lithium-ion Battery
- 100 MW / 6 Hour Lithium-ion Battery
- 100 MW / 8 Hour Lithium-ion Battery
- 1680 MW / 10+ Hour Bad Creek Pumped Hydro Storage Powerhouse II

PEAKING / INTERMEDIATE

- 850 MW, 2 x Advanced Class Combustion Turbines (CTs)

VARIABLE

- 75 MW Bifacial Single Axis Tracking (SAT) Solar PV
- 75 MW Bifacial SAT Solar PV plus 20 MW / 4 Hour Lithium-ion Battery
- 75 MW Bifacial SAT Solar PV plus 40 MW / 4 Hour Lithium-ion Battery
- 75 MW Bifacial SAT Solar PV plus 60 MW / 4 Hour Lithium-ion Battery
- 150 MW Onshore Wind
- 800 – 2,400 MW Offshore Wind

Baseload and Peaking/Intermediate Technologies

The baseload and peaking/intermediate technologies available as supply-side resources are listed above in Figure E-3. A combination of combined cycle, small modular reactor nuclear, advanced small modular reactor nuclear with thermal storage, and combustion turbine can meet the dispatchability requirements of the system. It is notable that the advanced small modular reactor with thermal storage has an expected commercial availability that is at or near the end of the 15-year planning window. Combined cycle with CCS was considered as a selectable technology, but it is unknown whether the Carolinas region can support sequestration of CO_2 from a CCS facility. It is possible that any CO_2 storage would require interstate pipelines with an unknown regulatory/permitting structure and cost adder along with agreements from another state to accept the CO_2.

Variable Technologies

The variable supply-side resources include a variety of solar photovoltaic ("PV") and wind configurations. Solar PV considers one racking option: single axis tracking ("SAT") and is assumed to use bifacial panel technology. All solar paired with storage options are assumed to be designed as SAT racking with bifacial modules, paired with a 4-hour lithium-ion storage. The paired storage ranges from approximately 25% of the solar output (20 MW) to approximately 75% of the solar output (60 MW) with the higher storage MW pairings based on stakeholder feedback received in conjunction with the engagement session held March 16, 2023. Wind includes options for onshore and offshore configurations.

Storage Technologies

Due to the wide variety of storage technologies that exist, the intent of the technologies included as supply-side resources is to ensure options that match the marketplace are available for selection. The new storage market is largely dominated by lithium-ion batteries, and in the near term all shorter duration deployments are likely to be lithium-ion. Lithium-ion at four, six, and eight hours is included as selectable by the models. A second powerhouse for Bad Creek pumped hydro is considered as a medium duration storage option. Although this project is not a generic unit option, it is noted here for completeness of supply-side technologies. Ongoing efforts continue to evaluate longer duration options for future modeling.

Modeling Technology Simplification

Due to the need to reduce supply-side technologies for modeling run times, a representative class from each technology is used rather than multiple available similar technologies. Due to this modeling simplification step, a number of technologies are not included as supply-side options despite passing technical and economic hurdles. Due to this simplification step, only advanced class turbines are modeled for both the combined cycle and simple cycle model options. F-Class combined cycle, F-Class simple cycle, and aeroderivative turbines would be considered for baseload and peaking needs during a more detailed procurement analysis if selected by the models. Due to this simplification and also due to the lack of sequestration locations in the Carolinas, the combined cycle with CCS technology was not included as a selectable technology. Fixed tilt solar PV was not included as a selectable technology due to the better economics of SAT solar PV. Storage has been represented by both short duration (4-hour and 6-hour) as well as medium duration (8-hour). 2-hour storage and the 10-hour advanced compressed air energy are not included as selectable technologies. 8-hour lithium-ion batteries are representative of single-day discharge options, and a similar value is represented by the 8-hour and 10-hour storage for the model. Since 8-hour lithium-ion has a lower capital cost and higher round trip efficiency the 8-hour lithium ion was chosen to be modeled. The planning execution will reintroduce the technologies that were eliminated for modeling simplification purposes as more detailed analysis will be performed during the execution phase.

Generic Unit Cost Information

A variety of sources are considered when determining the overall economics of each technology passing the technical screening. The primary resources used when considering the economics of each technology are an engineering study produced by Burns & McDonnell and a group of renewable and storage of tools created by Guidehouse. Burns & McDonnell has construction experience in the energy industry and recent projects lend credibility to estimating generic technology costs. Guidehouse prepares the renewable and storage tools to allow for flexibility in estimating a wide range of resource options and configurations. Both companies prepare cost estimates specific to the Carolinas region based on labor rates, geographical information, and other regional-specific factors. There is also internal Companies' data considered when creating the technology cost information (e.g., 2022 solar procurement information).

Other industry resources are also reviewed when preparing generic cost information. The Electric Power Research Institute ("EPRI") has a program dedicated to techno-economic analysis of energy systems, and there are a variety of reports that are useful when evaluating technology costs. EPRI also maintains the TAGWeb database, which shows technology costs for all pertinent supply-side resources and has annual updates for most technologies under consideration. EPRI information was directly used for some of the generic technology costs. Other public resources are considered when finalizing cost data — NREL's Annual Technology Baseline, Energy Information Administration's ("EIA") Annual Energy Outlook ("AEO"), Lazard's Levelized Cost of Energy ("LCOE") and various reports from Wood Mackenzie are all considered when creating the generic technology costs. EIA AEO's technology inflation factors are used in creating the long-term technology cost estimates.

Due to stakeholder requests from previous proceedings, the Companies have made an effort to make more generic unit cost information public to assist in transparency. The Companies have worked with Guidehouse to make renewable and storage forecast information publicly available information. The Companies have also made changes to the process to make some technologies aligned to more generic information that has no confidential limitations (e.g., advanced nuclear costs are now publicly available and not tied to any vendor-specific information).

Costs continue to experience significant volatility, and the technology costs used for modeling reflect this. Although material prices appear to be stabilizing, there is a significant lag between market data and real-time installations. The costs projections used for 2023 modeling have shown significant increases across all supply-side technology options due to these cost pressures. Contingency has also been raised in the near-term for all technologies since actual project installations have shown greater uncertainty in the ability to obtain fixed-price contracts. This contingency "penalty" is reduced each year before being completely eliminated in the 2030 cost projections.

Lithium-ion storage costs have been particularly difficult to forecast over the last several years. Due to the early technology adoption curve, it was expected that storage costs would drop drastically over the last several years, but due to supply constraints there has been a significant increase in lithium-ion storage costs during that time. Part of this increase in cost is due to the significant rise in lithium carbonate prices, a primary material used in the production of lithium-ion batteries. However, pricing for lithium carbonate saw a significant reduction between the fourth quarter of 2022 and the second quarter of 2023. Therefore, the Companies have reduced lithium-ion prices by 10% to account for feedback from the stakeholder process and the reduction in lithium carbonate prices.

The other primary factor recently affecting technology costs is the set of new tax credits available through the passing of the Inflation Reduction Act of 2022 ("IRA"). An analysis of the IRA impacts is performed elsewhere in the Carolinas Resource Plan, but the pertinent detail for technology costs is that all are presented without the inclusion of tax credits when considering overnight cost. The tax credits are included as part of the preparation of EnCompass inputs, but they do not affect the expected overnight capital cost of each technology since these credits are awarded after installation is complete.

Capital Cost Forecast

A capital cost forecast is developed to determine the overnight capital cost of each supply-side resource through 2050. The Companies' forecast uses a combination of 2023 costs, Guidehouse price decline curves, EIA AEO technology forecast factors, EPRI technology forecast factors and other near-term adjustments (e.g., removal of additional contingency) to develop the table of technology costs. This table is used to create technology-specific inflation rates used to project each technology cost through 2050. The 2023 EIA AEO technology forecast table is presented below in Table E-1 for reference. The EIA technology forecast table was created from EIA's estimated capital costs through 2050. The table converts the overnight capital costs into factors that can be used to project a technology's cost into future years. The factor represents the percentage cost expected in a given year compared to the initial starting point. For example, the Simple Cycle forecast factor for 2025 is .874, which means the technology cost is expected to be 87.4% of the cost assumed in the initial year. The table excludes all inflation and only reflects expected technology learnings over the period of consideration.

Table E-1: 2023 EIA AEO Technology Forecast Table

Year	Simple Cycle	Onshore Wind	Offshore Wind	Solar PV	Solar PV - Tracking w/ Storage	Battery Storage	Fuel Cell	Modified Pumped Hydro	Small Modular Reactor	Combined Cycle	Combined Cycle with CCS
2023	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2024	0.921	0.928	0.923	0.892	0.880	0.838	0.898	0.928	0.925	0.925	0.922
2025	0.874	0.887	0.866	0.821	0.799	0.723	0.826	0.887	0.881	0.881	0.876
2026	0.850	0.868	0.674	0.778	0.752	0.662	0.798	0.868	0.859	0.859	0.852
2027	0.836	0.860	0.663	0.746	0.721	0.631	0.780	0.849	0.849	0.848	0.839
2028	0.827	0.855	0.656	0.720	0.696	0.611	0.764	0.831	0.841	0.841	0.830
2029	0.815	0.850	0.648	0.702	0.677	0.590	0.749	0.826	0.833	0.832	0.819
2030	0.804	0.844	0.554	0.690	0.663	0.568	0.733	0.821	0.825	0.824	0.809
2031	0.793	0.838	0.546	0.681	0.653	0.554	0.717	0.815	0.816	0.816	0.798
2032	0.786	0.833	0.512	0.673	0.645	0.545	0.702	0.810	0.808	0.810	0.789
2033	0.780	0.829	0.505	0.665	0.637	0.537	0.688	0.806	0.801	0.805	0.781
2034	0.774	0.823	0.498	0.656	0.628	0.528	0.672	0.801	0.793	0.799	0.772
2035	0.767	0.818	0.491	0.648	0.620	0.519	0.657	0.795	0.785	0.793	0.763
2036	0.760	0.812	0.484	0.639	0.611	0.509	0.641	0.789	0.776	0.786	0.753
2037	0.753	0.806	0.474	0.631	0.602	0.500	0.626	0.784	0.768	0.780	0.744
2038	0.746	0.800	0.467	0.623	0.594	0.491	0.611	0.778	0.760	0.774	0.735
2039	0.739	0.795	0.460	0.614	0.585	0.482	0.596	0.773	0.752	0.767	0.726
2040	0.733	0.789	0.453	0.606	0.577	0.474	0.581	0.768	0.744	0.761	0.717
2041	0.726	0.784	0.446	0.598	0.569	0.465	0.566	0.762	0.736	0.755	0.709
2042	0.719	0.778	0.439	0.590	0.560	0.456	0.551	0.757	0.727	0.749	0.699
2043	0.712	0.772	0.432	0.581	0.552	0.447	0.536	0.751	0.719	0.742	0.690
2044	0.704	0.765	0.424	0.573	0.543	0.438	0.521	0.744	0.710	0.735	0.680
2045	0.697	0.759	0.417	0.564	0.534	0.428	0.506	0.738	0.701	0.728	0.670
2046	0.689	0.752	0.410	0.555	0.525	0.419	0.491	0.732	0.692	0.721	0.661
2047	0.682	0.746	0.402	0.547	0.517	0.410	0.476	0.726	0.684	0.714	0.652
2048	0.674	0.740	0.395	0.538	0.508	0.401	0.461	0.719	0.675	0.707	0.642
2049	0.667	0.733	0.388	0.530	0.499	0.392	0.446	0.713	0.666	0.700	0.633
2050	0.660	0.727	0.381	0.521	0.491	0.384	0.432	0.707	0.658	0.694	0.624

2023 Generic Unit Technology Costs

As discussed previously, the Companies have received stakeholder feedback recommending additional cost information to better understand generic technology costs used in modeling. The Companies have worked with Guidehouse and changed processes to enable most of the generic technology costs to be available publicly. The 2023 modeled overnight capital costs for all technologies except for simple cycle and combined cycle are shown below in Table E-2. To preserve confidentiality, a range of overnight capital costs are given for simple cycle and combined cycle units. Offshore wind costs are shown as a range due to the changing costs over the MW range assumed above in Table E-1. Costs represent overnight costs, are presented to the nearest $50/kW, and include a generic interconnection adder, expected owner's costs and the increased contingency factor. The costs shown in Table E-2 below do not include the generic proxies for transmission network upgrade costs described in Appendix L (Transmission System Planning and Grid Transformation). Costs are grouped by technology class (e.g., Baseload, Peaking/Intermediate, Variable and Storage). The effective load carrying capability ("ELCC") for each technology is also important when comparing costs, but ELCC is not included in the table below and instead should be referenced in Chapter 2 (Methodology and Key Assumptions).

The costs presented below in Table E-2 are expressed in 2023 dollars and represent the estimated overnight cost of installing a technology in 2023. Overnight costs exclude the inflation that would occur and the interest that would be accrued during construction. Overnight costs for future in-service years are projected using technology-specific inflation curves based on the general inflation rate and the expected technology learning curve through the modeling period. The 2023 overnight costs are the starting point for these forecasts. Since resources are installed at a future time (i.e., after 2023) and inflation and interest are added to the overnight costs, the modeled cost for each technology in the installation year will differ from the costs shown below in Table E-2. Recent inflationary pressures and supply chain challenges create significant uncertainty around the future costs of materials, labor, components and other items included in technology cost estimates. Forecasted technology cost declines are generally more aggressive than in previous years to account for the future easing of inflation, and the Companies will continue to evaluate the changing cost dynamic to update these curves in future proceedings.

Table E-2: 2023 Generic Unit Overnight Technology Capital Costs

Technology	Technology Class	Cost (2023 $/kW)	Notes
2x1 Combined Cycle	Baseload	$800-1,250/kW	Includes duct firing kW, high firm transport O&M adder, low near-term cost decline
Generic Small Modular Reactor	Baseload	$6,450/kW	Unavailable until mid-2030s, low near-term cost decline
Generic Advanced Reactor with Thermal Storage	Baseload	$6,850/kW	Unavailable until late-2030s, moderate near-term cost incline
Multi-Unit Combustion Turbine	Intermediate/Peaking	$750-$900kW	Multi-unit pricing, moderate firm transport O&M adder, low near-term cost decline
Solar PV SAT	Variable	$1,850/kW	Moderate near-term cost decline
Onshore Wind	Variable	$2,150/kW	Moderate near-term cost decline
Solar PV SAT + 20 MW/4-Hour Li-Ion Storage	Variable	$2,550/kW	High near-term cost decline
Solar PV SAT + 40 MW/4-Hour Li-Ion Storage	Variable	$3,200/kW	High near-term cost decline
Solar PV SAT + 60 MW/4-Hour Li-Ion Storage	Variable	$3,850/kW	High near-term cost decline
Offshore Wind	Variable	$4,150-$4,850/kW	Unavailable until early 2030s, moderate near-term cost decline
4-Hour Li-Ion Storage	Storage	$2,250/kW	High near-term cost decline
6-Hour Li-Ion Storage	Storage	$3,300/kW	High near-term cost decline
8-Hour Li-Ion Storage	Storage	$4,200/kW	High near-term cost decline

Benefits and Challenges of Levelized Cost of Energy

LCOE is a metric that can be used to compare generation resources to determine the lowest cost over a set period with a specific set of assumptions. The LCOE considers the full cost of the asset including capital, fuel and operating and maintenance ("O&M") expenses, and it also considers the expected capacity factor and operating life of the asset. However, LCOE has limitations when comparing technologies, which can create uneven results when considering different use cases (e.g., baseload vs. peaking), capacity values (e.g., ELCC) and/or operating life (e.g., 15 vs. 35 years). Although LCOE can be a useful metric for cost analysis, a full evaluation of costs and usage expectations using a capacity expansion model is needed in lieu of simple LCOE metrics.