Capacity Expansion Planning Under the Risk of Hurricanes: An Analysis of The US East Coast

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1. **Database Construction For The Florida Energy System**
2. **Database Construction For The North Carolina Energy System**

Section 2 details the data and considerations followed in the construction of the database for the North Carolina Energy System.

* 1. **Technologies**

Tables 2.1 and 2.2 provide a description of the existing and new energy generation technologies considered in our simulations, and Table 2.3 describes the non-energy generation technologies.

**Table 2.1:** Existing Generation Technologies Represented in The Model

|  |  |
| --- | --- |
| **Technology Code** | **Description** (Following EIA 860 Nomenclature) [1] |
| AB\_ST\_EXISTING | Steam Turbine Using Agricultural By-Products |
| BIT\_ST\_EXISTING | Steam Turbine Using Bituminous Coal |
| BLQ\_ST\_EXISTING | Steam Turbine Using Black Liquor |
| DFO\_CC\_EXISTING | Combined Cycle Combustion Turbine Using Petroleum |
| DFO\_GT\_EXISTING | Combustion Turbine Using Petroleum |
| DFO\_IC\_EXISTING | Internal Combustion Engine Using Petroleum |
| LFG\_GT\_EXISTING | Combustion Turbine Using Landfill Gas |
| LFG\_IC\_EXISTING | Internal Combustion Engine Using Landfill Gas |
| MWH\_BA1H\_EXISTING | Battery Storage- 1h |
| MWH\_BA2H\_EXISTING | Battery Storage- 2h |
| NG\_CC\_EXISTING | Combined Cycle Combustion Turbine Using Natural Gas |
| NG\_GT\_EXISTING | Combustion Turbine Using Natural Gas |
| NG\_ST\_EXISTING | Steam Turbine Using Natural Gas |
| NUC\_ST\_EXISTING | Nuclear Turbine |
| OBG\_IC\_EXISTING | Internal Combustion Engine Using Other Biomass Gas |
| SUN\_PV\_EXISTING | Solar Photovoltaic - Utility |
| WAT\_HY\_EXISTING | Conventional Hydroelectric |
| WAT\_PS\_EXISTING | Hydroelectric Pumped Storage |
| WDS\_ST\_EXISTING | Steam Turbine Using Wood Waste |
| WH\_ST\_EXISTING | Steam Turbine Using Waste Heat |
| WND\_WT\_EXISTING | Onshore Wind Turbine |

**Table 2.2:** New Generation Technologies Represented in The Model

|  |  |
| --- | --- |
| **Technology Code** | **Description** |
| BATT\_2H\_NEW | Battery Storage 2h (NREL ATB 2022 Technology) |
| BATT\_4H\_NEW | Battery Storage 4h (NREL ATB 2022 Technology) |
| BATT\_6H\_NEW | Battery Storage 6h (NREL ATB 2022 Technology) |
| BATT\_8H\_NEW | Battery Storage 8h (NREL ATB 2022 Technology) |
| BIOMASS\_CC90\_NEW | Generation From Biomass With 90% Carbon Capture (Technology from NREL ReEDS model Using BECC-mod) |
| BIOMASS\_NEW | Generation From Biomass (NREL ATB 2022 Technology) |
| COAL\_95CC\_NEW | Generation From Coal With 95% Carbon Capture (NREL ATB 2022 Technology) |
| COAL\_99CC\_NEW | Generation From Coal With 99% Carbon Capture (NREL ATB 2022 Technology) |
| COAL\_NEW | Generation From Coal (NREL ATB 2022 Technology) |
| NG\_F-FRAME\_CC\_95CC\_NEW | Combined Cycle Natural Gas Turbine F-Frame With 95 % of Carbon Capture (NREL ATB 2022 Technology) |
| NG\_F-FRAME\_CC\_97CC\_NEW | Combined Cycle Natural Gas Turbine F-Frame With 97 % of Carbon Capture (NREL ATB 2022 Technology) |
| NG\_F-FRAME\_CC\_NEW | Combined Cycle Natural Gas Turbine F-Frame (NREL ATB 2022 Technology) |
| NG\_F-FRAME\_CT\_NEW | Natural Gas Combustion Turbine F-Frame - Simple Cycle (NREL ATB 2022 Technology) |
| NG\_H-FRAME\_CC\_95CC\_NEW | Combined Cycle Natural Gas Turbine H-Frame With 95 % of Carbon Capture (NREL ATB 2022 Technology) |
| NG\_H-FRAME\_CC\_97CC\_NEW | Combined Cycle Natural Gas Turbine H-Frame With 97 % of Carbon Capture (NREL ATB 2022 Technology) |
| NG\_H-FRAME\_CC\_NEW | Combined Cycle Natural Gas Turbine H-Frame (NREL ATB 2022 Technology) |
| NUCLEAR-AP1000\_NEW | Nuclear Generation Using AP1000 PWR (NREL ATB 2022 Technology) |
| NUCLEAR-SMR\_NEW | Small Modular Nuclear Reactor (NREL ATB 2022 Technology) |
| PV-COMMERCIAL\_NEW | Commercial Solar PV (NREL ATB 2022 Technology) |
| PV-RESIDENTIAL\_NEW | Residential Solar PV (NREL ATB 2022 Technology) |
| PV-UTILITY\_NEW | Utility Solar PV (NREL ATB 2022 Technology) |
| WAT\_HY\_NEW | Conventional Hydroelectric (NREL ATB 2022 Technology) |
| WAT\_PS\_NEW | Hydroelectric Pumped Storage (NREL ATB 2022 Technology) |
| WIND-LAND-C8\_NEW | Onshore Wind Turbine Class 8 From NREL ATB 2022 (NREL ATB 2023 Technology) |
| WIND-OFFSHORE-C6\_NEW | Offshore Wind Turbine Class 6 From NREL ATB 2022 (NREL ATB 2023 Technology) |

**Table 2.3:** Non-Generation Technologies Represented in The Model

|  |  |
| --- | --- |
| **Technology Code** | **Description** |
| CO2\_STORAGE | CO2 Storage |
| DISTRIBUTION | Energy Distribution |
| FT\_BIOMASS | Fuel for Generation Technologies That Use Biomass |
| FT\_COAL | Fuel for Generation Technologies That Use Coal |
| FT\_NG | Fuel for Generation Technologies That Use Natural Gas |
| FT\_NUCLEAR | Fuel for Nuclear Generation Technologies |
| FT\_PETROLEUM | Fuel for Generation Technologies That Use Petroleum |
| TRANSMISSION\_INTERREGIONAL | Transmission Between Different Regions |
| TRANSMISSION\_REGIONAL | Transmission In the Same Region |

* 1. **Existing Capacity**

Data from existing generation capacity comes from the EIA-860M reports [1]. Figure 2.1 shows the vintage (operational year) of each existing technology on the NC system and its corresponding capacity. On the left legend, the total existing capacity is shown in parathesis.

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**Figure 2.1:** Total Existing Capacity on the NC Power System by Different Operational Years (Vintage)

* 1. **Lifetime Tech and Loan**

The default lifetimes and loan periods of the technologies considered in our models are detailed in Tables 2.4, 2.5, and 2.6 with their corresponding references.

**Table 2.4:** Default Technologies Lifetime For Existing Generation Technologies

|  |  |  |
| --- | --- | --- |
| **Technology Code** | **Lifetime Tech** | |
| **Years** | **Reference** |
| AB\_ST\_EXISTING | 27 | Average of Past Retirements on US [1] |
| BIT\_ST\_EXISTING | 56 | Average from DEC/DEP in IRPs [3, 4] |
| BLQ\_ST\_EXISTING | 55 | Average of Past Retirements on NC [1] |
| DFO\_CC\_EXISTING | 58 | Average of Past Retirements on NC [1] |
| DFO\_GT\_EXISTING | 69 | Average from DEC/DEP in IRPs [3, 4] |
| DFO\_IC\_EXISTING | 36 | Average of Past Retirements on East Coast [1] |
| LFG\_GT\_EXISTING | 20 | Average Retirement on East Coast [1] |
| LFG\_IC\_EXISTING | 16 | Average Retirement on East Coast [1] |
| MWH\_BA1H\_EXISTING | 15 | From NREL ReEDS [2] |
| MWH\_BA2H\_EXISTING | 15 | From NREL ReEDS [2] |
| NG\_CC\_EXISTING | 37 | Average from DEC/DEP in IRPs [3, 4]  For NG CA and CT |
| NG\_GT\_EXISTING | 42 | Average from DEC/DEP in IRPs [3, 4] |
| NG\_ST\_EXISTING | 53 | Average Retirement on East Coast [1] |
| NUC\_ST\_EXISTING | 59 | Average from DEC/DEP in IRPs [3, 4] |
| OBG\_IC\_EXISTING | 15 | Average of Past Retirements on US [1] |
| SUN\_PV\_EXISTING | 30 | From NREL ReEDS [2] |
| WAT\_HY\_EXISTING | 109 | Average from DEC/DEP in IRPs [3, 4] for WAT\_HY |
| WAT\_PS\_EXISTING | 109 |
| WDS\_ST\_EXISTING | 34 | Average of Past Retirements on NC [1] |
| WH\_ST\_EXISTING | 33 | Average of Past Retirements on US [1] |
| WND\_WT\_EXISTING | 30 | From NREL ReEDS [2] |

**If 100< NC>East>US**

**Table 2.5:** Default Technologies Lifetime and Loan Periods Times For New Generation Technologies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Technology Code** | **Lifetime Tech** | | **Loan Period (Recovery Period)** | |
| **Years** | **Reference** | **Years** | **Reference** |
| BATT\_2H\_NEW | 15 | From NREL ReEDS [2] | 15 | From NREL ReEDS [2] |
| BATT\_4H\_NEW | 15 | From NREL ReEDS [2] | 15 | From NREL ReEDS [2] |
| BATT\_6H\_NEW | 15 | From NREL ReEDS [2] | 15 | From NREL ReEDS [2] |
| BATT\_8H\_NEW | 15 | From NREL ReEDS [2] | 15 | From NREL ReEDS [2] |
| BIOMASS\_CC90\_NEW | 50 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| BIOMASS\_NEW | 50 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| COAL\_95CC\_NEW | 65 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| COAL\_99CC\_NEW | 65 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| COAL\_NEW | 65 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NG\_F-FRAME\_CC\_95CC\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NG\_F-FRAME\_CC\_97CC\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NG\_F-FRAME\_CC\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NG\_F-FRAME\_CT\_NEW | 50 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NG\_H-FRAME\_CC\_95CC\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NG\_H-FRAME\_CC\_97CC\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NG\_H-FRAME\_CC\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NUCLEAR-AP1000\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| NUCLEAR-SMR\_NEW | 60 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| PV-COMMERCIAL\_NEW | 30 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| PV-RESIDENTIAL\_NEW | 30 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| PV-UTILITY\_NEW | 30 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| WAT\_HY\_NEW | 109 | Average from DEC/DEP in IRPs [3, 4] for WAT\_HY | 20 | From NREL ReEDS [2] |
| WAT\_PS\_NEW | 109 | 20 | From NREL ReEDS [2] |
| WIND-LAND-C8\_NEW | 30 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |
| WIND-OFFSHORE-C6\_NEW | 30 | From NREL ReEDS [2] | 20 | From NREL ReEDS [2] |

**Table 2.6:** Default Technologies Lifetime and Loan Periods For Non-Generation Technologies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Technology Code** | **Lifetime Tech** | | **Loan Period (Recovery Period)** | |
| **Years** | **Reference** | **Years** | **Reference** |
| DISTRIBUTION | 60 |  | 20 |  |
| TRANSMISSION\_INTERREGIONAL | 60 |  | 20 |  |
| TRANSMISSION\_REGIONAL | 60 |  | 20 |  |
| CO2\_STORAGE\* | NA\* | | | |
| FT\_BIOMASS\* | NA\* | | | |
| FT\_COAL\* | NA\* | | | |
| FT\_NG\* | NA\* | | | |
| FT\_NUCLEAR\* | NA\* | | | |
| FT\_PETROLEUM\* | NA\* | | | |

\*We do not consider investment costs for this technology (all costs for it are variable or fixed); as such, the lifetime of the tech and its loan period can be ignored.

Some specific generation units (123 units – 24.5 GW – 63% of the NC existing capacity) managed by Duke Energy in North Carolina have estimated retirement dates available at [3, 4]. Because of those generation units, modifications to the available capacity were made at each vintage to ensure proper capacity retirement of each technology type. However, for generators without estimated retirement dates from Duke Energy [3, 4], it was assumed the lifetimes reported in Tables 2.4, 2.5, and 2.6.

It is important to mention that due to limitations on data availability and model approximations, an existing generator reported at the EIA-860M [1] and not available at [3, 4] may be retired prior to the first year of simulation (year 2023) as we consider an average retirement date for all generators not referenced on [3, 4]. In this case, this capacity is eliminated from the pool of existing capacity; however, it is important to mention that these correspond to less than 0.32GW (less than 0.8% of the existing capacity).

Figure 2.2 shows the retirement dates and capacity for existing technologies retired after 2023, and Figure 2.3 shows the retirement dates and capacity for existing technologies retired before or at 2023 (a modeling effect of the values on Tables 2.4, 2.5, and 2.6).

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\*A technology retired at year X does not contribute to the generation at year X.

**Figure 2.2:** Retirement Year and Capacity for Existing Technologies Retired After 2023.

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\*A technology retired at year X does not contribute to the generation at year X.

**Figure 2.3:** Retirement Year and Capacity for “Existing Technologies Retired Before 2023”. This Happens Because of the Average Lifetime Approximations Considered and Limitations on Data Availability. This Corresponds To Less Than 0.8% of the Existing Capacity.

* 1. **Costs**

In this work, we assume that new capacity can only be added using the technologies described in Table 2.7, which also contains the investment costs in millions of dollars per new GW installed at each future period in the capacity expansion model. Table 2.7 also contains the discount rate (weighted average cost of capital) for each technology investment.

**Table 2.7:** Investment Cost For New Technologies and Discount Rates

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology Code** | **Investment Cost [M$/GW]** | | | | | | | **Discount**  **Rate** | **Reference** |
| **2023** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| BATT\_2H\_NEW | 809 | 762 | 682 | 682 | 682 | 682 | 682 | 0.065 | [5] |
| BATT\_4H\_NEW | 1394 | 1312 | 1174 | 1174 | 1174 | 1174 | 1174 | 0.065 | [5] |
| BATT\_6H\_NEW | 1978 | 1862 | 1666 | 1666 | 1666 | 1666 | 1666 | 0.065 | [5] |
| BATT\_8H\_NEW | 2563 | 2413 | 2158 | 2158 | 2158 | 2158 | 2158 | 0.065 | [5] |
| BIOMASS\_CC90\_NEW | 5529 | 5495 | 5410 | 5333 | 5255 | 5178 | 5100 | 0.058 | [2, 5] |
| BIOMASS\_NEW | 4332 | 4276 | 4186 | 4046 | 3906 | 3766 | 3626 | 0.058 | [5] |
| CO2\_STORAGE | Assuming no Investment Costs and Only Variable Costs as in The NREL ReEDS Model [5] | | | | | | | | |
| COAL\_95CC\_NEW | 4750 | 4677 | 4495 | 4313 | 4131 | 3949 | 3766 | 0.065 | [5] |
| COAL\_99CC\_NEW | 4860 | 4786 | 4599 | 4414 | 4227 | 4040 | 3853 | 0.065 | [5] |
| COAL\_NEW | 3047 | 3027 | 2962 | 2861 | 2761 | 2664 | 2567 | 0.065 | [5] |
| DISTRIBUTION | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.050 |  |
| NG\_F-FRAME\_CC\_95CC\_NEW | 2117 | 2066 | 1974 | 1892 | 1812 | 1732 | 1658 | 0.065 | [5] |
| NG\_F-FRAME\_CC\_97CC\_NEW | 2150 | 2099 | 2004 | 1922 | 1841 | 1760 | 1683 | 0.065 | [5] |
| NG\_F-FRAME\_CC\_NEW | 1026 | 1010 | 989 | 967 | 946 | 925 | 905 | 0.065 | [5] |
| NG\_F-FRAME\_CT\_NEW | 900 | 872 | 838 | 815 | 793 | 772 | 750 | 0.065 | [5] |
| NG\_H-FRAME\_CC\_95CC\_NEW | 1997 | 1948 | 1862 | 1785 | 1709 | 1635 | 1564 | 0.065 | [5] |
| NG\_H-FRAME\_CC\_97CC\_NEW | 2027 | 1978 | 1889 | 1811 | 1736 | 1659 | 1587 | 0.065 | [5] |
| NG\_H-FRAME\_CC\_NEW | 981 | 958 | 929 | 909 | 889 | 869 | 854 | 0.065 | [5] |
| NUCLEAR-AP1000\_NEW | 7302 | 7040 | 6966 | 6731 | 6496 | 6261 | 6026 | 0.058 | [5] |
| NUCLEAR-SMR\_NEW | 7839 | 7739 | 7661 | 7405 | 7150 | 6894 | 6639 | 0.058 | [5] |
| PV-COMMERCIAL\_NEW | 1574 | 1549 | 1494 | 1352 | 1210 | 1069 | 927 | 0.056 | [5] |
| PV-RESIDENTIAL\_NEW | 2569 | 2488 | 2285 | 1968 | 1651 | 1334 | 1016 | 0.057 | [5] |
| PV-UTILITY\_NEW | 1161 | 1157 | 1150 | 1051 | 952 | 853 | 754 | 0.053 | [5] |
| TRANSMISSION\_INTERREGIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.050 |  |
| TRANSMISSION\_REGIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.050 |  |
| WAT\_HY\_NEW | 2574 | 2574 | 2590 | 2590 | 2590 | 2590 | 2590 | 0.054 | [5] |
| WAT\_PS\_NEW | 1999 | 1999 | 2011 | 2011 | 2011 | 2011 | 2011 | 0.054 | [5] |
| WIND-LAND-C8\_NEW | 1323 | 1231 | 1006 | 981 | 956 | 931 | 906 | 0.071 | [5] |
| WIND-OFFSHORE-C6\_NEW | 3855 | 3726 | 3570 | 3450 | 3362 | 3294 | 3238 | 0.066 | [5] |

Tables 2.8, 2.9, and 2.10 contain the fixed costs of the technology represented in the capacity expansion model. Technologies with zero fixed cost are not shown for simplicity.

**Table 2.8:** Fixed Costs for Existing Generation

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology Code** | **Fixed Cost [M$/GWyear]** | | | | | | | **Reference** |
| **2023** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| AB\_ST\_EXISTING | 151 | 151 | 151 | 151 | 151 | 151 | 151 | [5] |
| BIT\_ST\_EXISTING | 141 | 141 | 141 | 141 | 141 | 141 | 141 | [5] |
| BLQ\_ST\_EXISTING | 151 | 151 | 151 | 151 | 151 | 151 | 151 | [5] |
| DFO\_CC\_EXISTING | 21 | 21 | 21 | 21 | 21 | 21 | 21 | [5] |
| DFO\_GT\_EXISTING | 21 | 21 | 21 | 21 | 21 | 21 | 21 | [5] |
| DFO\_IC\_EXISTING | 21 | 21 | 21 | 21 | 21 | 21 | 21 | [5] |
| LFG\_GT\_EXISTING | 151 | 151 | 151 | 151 | 151 | 151 | 151 | [5] |
| LFG\_IC\_EXISTING | 151 | 151 | 151 | 151 | 151 | 151 | 151 | [5] |
| MWH\_BA1H\_EXISTING | 28 | 26 | 23 | 23 | 23 | 23 | 23 | [5] |
| MWH\_BA2H\_EXISTING | 20 | 19 | 17 | 17 | 17 | 17 | 17 | [5] |
| NG\_CC\_EXISTING | 21 | 21 | 21 | 21 | 21 | 21 | 21 | [5] |
| NG\_GT\_EXISTING | 21 | 21 | 21 | 21 | 21 | 21 | 21 | [5] |
| NG\_ST\_EXISTING | 27 | 27 | 27 | 27 | 27 | 27 | 27 | [5] |
| NUC\_ST\_EXISTING | 146 | 146 | 146 | 146 | 146 | 146 | 146 | [5] |
| OBG\_IC\_EXISTING | 151 | 151 | 151 | 151 | 151 | 151 | 151 | [5] |
| SUN\_PV\_EXISTING | 20 | 20 | 20 | 19 | 18 | 16 | 15 | [5] |
| WAT\_HY\_EXISTING | 64 | 64 | 64 | 64 | 64 | 64 | 64 | [5] |
| WAT\_PS\_EXISTING | 18 | 18 | 18 | 18 | 18 | 18 | 18 | [5] |
| WDS\_ST\_EXISTING | 151 | 151 | 151 | 151 | 151 | 151 | 151 | [5] |
| WH\_ST\_EXISTING | 27 | 27 | 27 | 27 | 27 | 27 | 27 | [5] |
| WND\_WT\_EXISTING | 43 | 43 | 43 | 43 | 43 | 43 | 43 | [5] |

**Table 2.9:** Fixed Costs for New Generation

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology Code** | **Fixed Cost [M$/GWyear]** | | | | | | | **Reference** |
| **2023** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| BATT\_2H\_NEW | 20 | 19 | 17 | 17 | 17 | 17 | 17 | [5] |
| BATT\_4H\_NEW | 35 | 33 | 29 | 29 | 29 | 29 | 29 | [5] |
| BATT\_6H\_NEW | 49 | 47 | 42 | 42 | 42 | 42 | 42 | [5] |
| BATT\_8H\_NEW | 64 | 60 | 54 | 54 | 54 | 54 | 54 | [5] |
| BIOMASS\_CC90\_NEW | 162 | 162 | 162 | 162 | 162 | 162 | 162 | [2] |
| BIOMASS\_NEW | 151 | 151 | 151 | 151 | 151 | 151 | 151 | [5] |
| COAL\_95CC\_NEW | 115 | 115 | 115 | 115 | 115 | 115 | 115 | [5] |
| COAL\_99CC\_NEW | 117 | 117 | 117 | 117 | 117 | 117 | 117 | [5] |
| COAL\_NEW | 74 | 74 | 74 | 74 | 74 | 74 | 74 | [5] |
| NG\_F-FRAME\_CC\_95CC\_NEW | 58 | 58 | 58 | 58 | 58 | 58 | 58 | [5] |
| NG\_F-FRAME\_CC\_97CC\_NEW | 59 | 59 | 59 | 59 | 59 | 59 | 59 | [5] |
| NG\_F-FRAME\_CC\_NEW | 28 | 28 | 28 | 28 | 28 | 28 | 28 | [5] |
| NG\_F-FRAME\_CT\_NEW | 21 | 21 | 21 | 21 | 21 | 21 | 21 | [5] |
| NG\_H-FRAME\_CC\_95CC\_NEW | 53 | 53 | 53 | 53 | 53 | 53 | 53 | [5] |
| NG\_H-FRAME\_CC\_97CC\_NEW | 54 | 54 | 54 | 54 | 54 | 54 | 54 | [5] |
| NG\_H-FRAME\_CC\_NEW | 27 | 27 | 27 | 27 | 27 | 27 | 27 | [5] |
| NUCLEAR-AP1000\_NEW | 146 | 146 | 146 | 146 | 146 | 146 | 146 | [5] |
| NUCLEAR-SMR\_NEW | 114 | 114 | 114 | 114 | 114 | 114 | 114 | [5] |
| PV-COMMERCIAL\_NEW | 18 | 17 | 17 | 16 | 14 | 13 | 12 | [5] |
| PV-RESIDENTIAL\_NEW | 28 | 27 | 25 | 22 | 19 | 16 | 13 | [5] |
| PV-UTILITY\_NEW | 20 | 20 | 20 | 19 | 18 | 16 | 15 | [5] |
| WAT\_HY\_NEW | 64 | 64 | 64 | 64 | 64 | 64 | 64 | [5] |
| WAT\_PS\_NEW | 18 | 18 | 18 | 18 | 18 | 18 | 18 | [5] |
| WIND-LAND-C8\_NEW | 43 | 43 | 43 | 43 | 42 | 42 | 41 | [5] |
| WIND-OFFSHORE-C6\_NEW | 115 | 112 | 106 | 102 | 99 | 97 | 95 | [5] |

**Table 2.10:** Fixed Costs For Non-Generating Units

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology Code** | **Fixed Cost [M$/GWyear]** | | | | | | | **Reference** |
| **2023** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| DISTRIBUTION | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| TRANSMISSION\_INTERREGIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| TRANSMISSION\_REGIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |

Tables 2.11, 2.12, and 2.13 contain the variable costs of the technology represented in the capacity expansion model. Technologies with zero variable cost are not shown for simplicity.

**Table 2.11:** Variable Costs for Existing Generation

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology Code** | **Variable Cost [M$/GWh]** | | | | | | | **Reference** |
| **2023** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| AB\_ST\_EXISTING | 600 | 600 | 600 | 600 | 600 | 600 | 600 | [5] |
| BIT\_ST\_EXISTING | 1400 | 1400 | 1400 | 1400 | 1400 | 1400 | 1400 | [5] |
| BLQ\_ST\_EXISTING | 600 | 600 | 600 | 600 | 600 | 600 | 600 | [5] |
| DFO\_CC\_EXISTING | 1575 | 1575 | 1575 | 1575 | 1575 | 1575 | 1575 | [5] |
| DFO\_GT\_EXISTING | 1575 | 1575 | 1575 | 1575 | 1575 | 1575 | 1575 | [5] |
| DFO\_IC\_EXISTING | 1575 | 1575 | 1575 | 1575 | 1575 | 1575 | 1575 | [5] |
| LFG\_GT\_EXISTING | 600 | 600 | 600 | 600 | 600 | 600 | 600 | [5] |
| LFG\_IC\_EXISTING | 600 | 600 | 600 | 600 | 600 | 600 | 600 | [5] |
| NG\_CC\_EXISTING | 500 | 500 | 500 | 500 | 500 | 500 | 500 | [5] |
| NG\_GT\_EXISTING | 500 | 500 | 500 | 500 | 500 | 500 | 500 | [5] |
| NG\_ST\_EXISTING | 200 | 200 | 200 | 200 | 200 | 200 | 200 | [5] |
| NUC\_ST\_EXISTING | 284 | 284 | 284 | 284 | 284 | 284 | 284 | [5] |
| OBG\_IC\_EXISTING | 600 | 600 | 600 | 600 | 600 | 600 | 600 | [5] |
| WAT\_PS\_EXISTING | 51 | 51 | 51 | 51 | 51 | 51 | 51 | [5] |
| WDS\_ST\_EXISTING | 600 | 600 | 600 | 600 | 600 | 600 | 600 | [5] |
| WH\_ST\_EXISTING | 200 | 200 | 200 | 200 | 200 | 200 | 200 | [5] |

**Table 2.12:** Variable Costs for New Generation

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology Code** | **Variable Cost [M$/GWh]** | | | | | | | **Reference** |
| **2023** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| BIOMASS\_CC90\_NEW | 1660 | 1660 | 1660 | 1660 | 1660 | 1660 | 1660 | [5] |
| BIOMASS\_NEW | 252 | 252 | 252 | 252 | 252 | 252 | 252 | [5] |
| COAL\_95CC\_NEW | 1400 | 1400 | 1400 | 1400 | 1400 | 1400 | 1400 | [5] |
| COAL\_99CC\_NEW | 1400 | 1400 | 1400 | 1400 | 1400 | 1400 | 1400 | [5] |
| COAL\_NEW | 800 | 800 | 800 | 800 | 800 | 800 | 800 | [5] |
| NG\_F-FRAME\_CC\_95CC\_NEW | 400 | 400 | 400 | 400 | 400 | 400 | 400 | [5] |
| NG\_F-FRAME\_CC\_97CC\_NEW | 400 | 400 | 400 | 400 | 400 | 400 | 400 | [5] |
| NG\_F-FRAME\_CC\_NEW | 200 | 200 | 200 | 200 | 200 | 200 | 200 | [5] |
| NG\_F-FRAME\_CT\_NEW | 500 | 500 | 500 | 500 | 500 | 500 | 500 | [5] |
| NG\_H-FRAME\_CC\_95CC\_NEW | 400 | 400 | 400 | 400 | 400 | 400 | 400 | [5] |
| NG\_H-FRAME\_CC\_97CC\_NEW | 400 | 400 | 400 | 400 | 400 | 400 | 400 | [5] |
| NG\_H-FRAME\_CC\_NEW | 200 | 200 | 200 | 200 | 200 | 200 | 200 | [5] |
| NUCLEAR-AP1000\_NEW | 284 | 284 | 284 | 284 | 284 | 284 | 284 | [5] |
| NUCLEAR-SMR\_NEW | 360 | 360 | 360 | 360 | 360 | 360 | 360 | [5] |
| WAT\_PS\_NEW | 51 | 51 | 51 | 51 | 51 | 51 | 51 | [5] |

**Table 2.13:** Variable Costs For Non-Generating Units

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology Code** | **Variable Cost** | | | | | | | **Reference** |
| **2023** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| CO2\_STORAGE [M$/Metric Ton CO2] | 11 | 11 | 11 | 11 | 11 | 11 | 11 | [2] |
| DISTRIBUTION | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| FT\_BIOMASS [$/MMBTU] | 5 | 5 | 5 | 5 | 5 | 5 | 5 | [5] |
| FT\_COAL [$/MMBTU] | 2.52 | 2.41 | 2.33 | 2.35 | 2.34 | 2.33 | 2.32 | [2, 6] |
| FT\_NG [$/MMBTU] | 4.26 | 3.77 | 4.09 | 4.16 | 4.24 | 4.17 | 4.17 | [2, 6] |
| FT\_NUCLEAR [$/MMBTU] | 0.72 | 0.72 | 0.73 | 0.74 | 0.75 | 0.76 | 0.77 | [2, 6] |
| FT\_PETROLEUM [$/MMBTU] | 10.95 | 11.44 | 11.86 | 12.33 | 12.81 | 13.87 | 14.00 | [2, 6] |
| TRANSMISSION\_INTERREGIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |
| TRANSMISSION\_REGIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |  |

* 1. **Efficiency**
  2. **Emission Activity and Limits**

**>emission per activity**

**>Limits of emission**

* 1. **Capacity Factors**
  2. **Capacity Credit and Planning Reserve Margin**
  3. **Maximum Capacity**

**>Hydro and pumped**

* 1. **Maximum Activity**

**>Biomass**

**>Wind (Discuss)**

**>Solar (Discuss)**

* 1. **Minimum Activity**

**>Solar Residential**

**>Solar Commercial**

* 1. **Regionalization**

**>**Differentiate existing and future tech

**>**Plot with their Location

* 1. **Fragility Curves and Damage Statistics**

>Define fragilities considered

>Table with damages at each hurricane speed and per scenario

# **References**

|  |  |
| --- | --- |
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