ACES Model Version 2.0 Technical Documentation

Contents

1. Introduction

This document provides detailed technical information on the Atlantic Canada Energy System (ACES) Model Version 2.0 and functional decisions that were made. Here, you will find information on the Wind and Solar Site Selection and Capacity Factors, Representative Day Selection, and the SQLite Databases. Please note that to avoid repetition, several other sources are linked in this document to point documentation from original sources that were used to create the ACES model. For more general explanation on The ACES Model Framework, Model Databases, and Running ACES, please refer to the ACES Model User Guide.

2. Wind Site Selection and Capacity Factors

2.1 Existing Onshore Wind

In each region, the existing wind fleet is represented as a single generation technology, "E_WIND-ON_EX". The process by which their capacity factors are derived is outlined below:

1. Using publicly available data, a list documenting the names, capacities and locations of each wind farm is compiled. Table 2.1 provides this data for Prince Edward Island as an example.

Table 2.1: A list of existing wind farms in Prince Edward Island.

Name	Capacity [MW]	Location
North Cape	10.6	47.04284906467128, -64.00031673028577
Aeolus	3	47.04284906467128, -64.00031673028577
Engie Norway	9	47.00761030321843, -64.0335692850232
Eastern Kings	30	46.437228364683385, -62.0857299653888
WEICan	10	47.05254074080945, -63.996914753373176
Hermanville-Clearsprings	30	46.463925254735386, -62.30468415938275
West Cape	99	46.72041534605856, -64.37684112996843
Summerside	12	46.432620802242006, -63.813843308491165

2. The hourly generation from each of these wind farms is generated using the renewables.ninja[1] tool. For each wind farm, the following inputs are used:

    a. **Lat:** The wind farm's latitude.

    b. **Lon:** The wind farms' longitude

    c. **Dataset:** MERRA-2 (global)

[1] This is a commonly used tool in energy systems modelling. A webpage with its documentation and a list of selected publications using the tool available here.

d. **Year:** 2018
e. **Capacity:** The wind farm's capacity.
f. **Hub height:** 80m
g. **Turbine model:** Vestas V90 3000

3. The hourly generation from each wind farm is then summed and divided by the total capacity to achieve the existing wind fleet's hourly capacity factors. The resulting average annual capacity factors are summarized in Table 2.2.

Table 1.2: Average annual capacity factors for the existing wind fleet in each region.

Nova Scotia	New Brunswick	Prince Edward Island	Newfoundland
36.76%	25.92%	35.95%	40.45%

Note: The above process is not used for Nova Scotia. Historical data provided by Nova Scotia Power is used instead.

2.2 New Onshore Wind

Due to the relatively strong wind resource in Atlantic Canada, the model includes up to four land-based wind technologies in each region. Including multiple technologies allows the model to better represent the spatial variability of the resource within each province.

The wind resource sites for each region are selected using data from the Pan-Canadian Wind Integration Study (PCWIS). The study evaluated 4,984 potential wind sites across the country and analyzed four wind penetration scenarios. The ACES model includes every wind site that was selected in at least one of the PCWIS scenarios. This includes 13 sites in Nova Scotia, 11 sites in New Brunswick, 6 sites in Prince Edward Island and 8 sites in Newfoundland. Sites within close proximity to one another are grouped as single technology in the ACES model. The specific locations and the groupings of the wind sites are pictured in Figure 2.1 for NS, NB and PEI and Figure 2.2 for Newfoundland. Note, the PCIWS did not include any viable sites in Labrador.

The hourly capacity factors for each grouping are calculated as the average of the hourly capacity factors for each individual site. The hourly capacity factors for each individual site are calculated using the renewables.ninja tool, which uses as input the precise locations (as provided in the PCWIS) in addition to the following wind turbine assumptions:

- Hub height: 120 m
- Turbine model: GE 5.5 158

These parameters are selected because they best match the representative onshore wind technology used in the 2022 NREL Annual Technology Baseline (moderate case), which is what the ACES model uses for the wind technology technoeconomic data. Specifically, the NREL ATB's representative wind technology has a hub height of 120 m, a rotor diameter of 175 m and a turbine rating of 5.5 MW. The GE 5.5 158 turbine has a rotor diameter of 158 m and a rating of 5.5 MW. As a final step, a 7.85% loss to the capacity factors output by the renewables.ninja tool is applied. This follows the approach in the PCWIS and is intended to account for maintenance and electrical losses that occur onsite prior to transmission and distribution.

The resulting annual capacity factors for each wind technology within each region are summarized in Table 2.3.

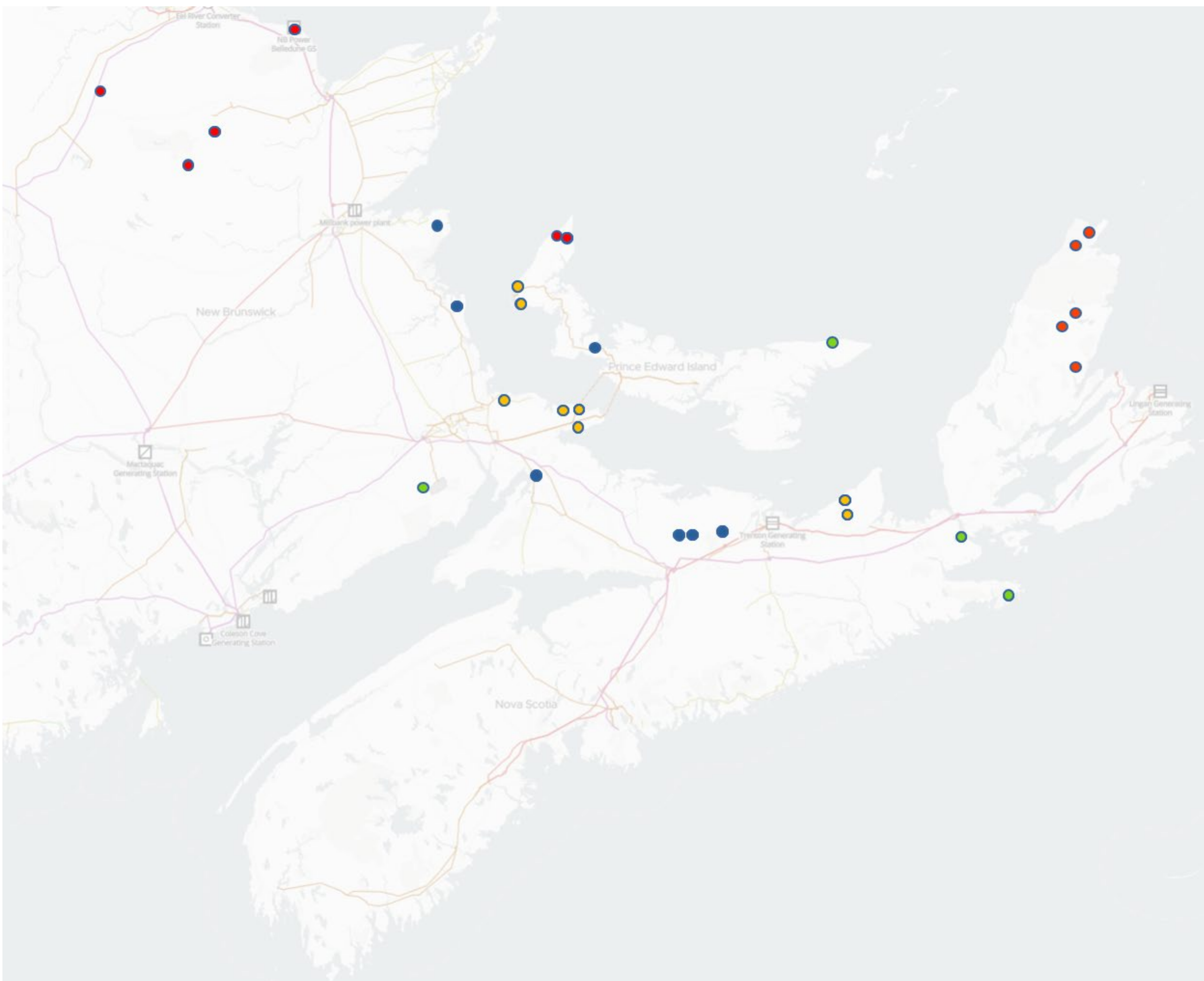

Figure 2.1: Map of the Maritimes indicating the locations and groupings of potential wind locations. The groupings are as follows: Red = E_WIND-ON-1, Green = E_WIND-ON-2, Blue = E_WIND-ON-3, Orange = E_WIND-ON-4

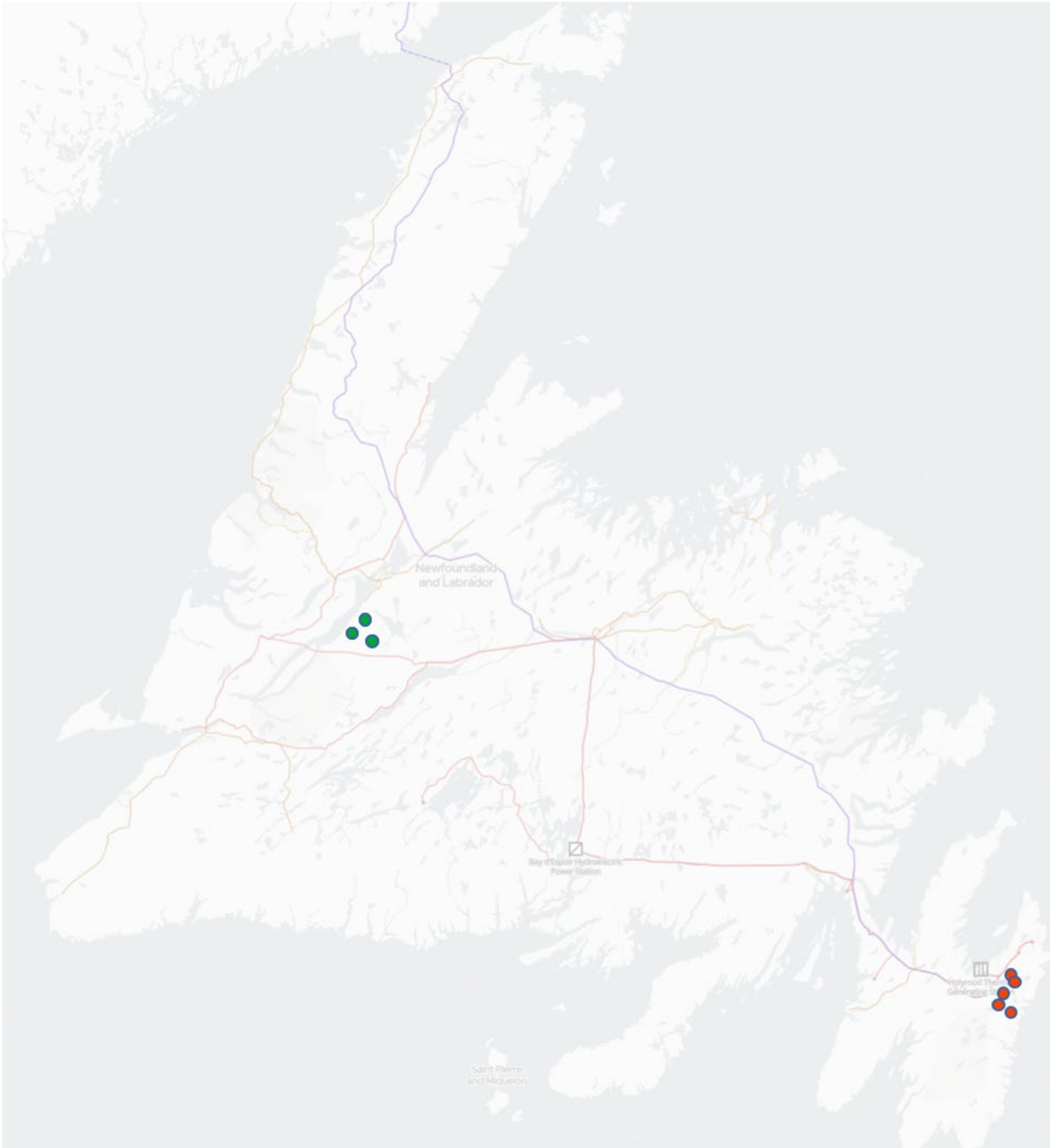

Figure 2.2: Map of the Newfoundland indicating the locations and groupings of potential wind locations. The groupings are as follows: Red = E_WIND-ON-1, Green = E_WIND-ON-2.

Table 2.3: Summary of the annual capacity factors for each onshore wind technology across all regions.

Region	E_WIND-ON-1	E_WIND-ON-2	E_WIND-ON-3	E_WIND-ON-4
Nova Scotia	57.6%	49.3%	42.2%	44.23%
New Brunswick	42.8%	41.3%	46.2%	43.3%
Prince Edward Island	54.9%	55.0%	50.1%	50.1%

Newfoundland	51.8%	47.1%	--	--

2.3 New Offshore Wind

The locations and resource availabilities for the fixed-bottom offshore wind technologies are based off a Geological Survey of Canada analysis. The specific locations are:

- Nova Scotia: Sable Island Bank (precise location shown in Figure 8 in linked report)
- New Brunswick: Baie des Chaleurs (precise location shown in Figure 6 in linked report)
- Prince Edward Island: Northumberland Straight (precise location shown in Figure 7 in linked report)
- Newfoundland: St. George's Bay (precise location shown in Figure 9 in linked report)

Similar to above the approach with onshore wind, the renewables.ninja tool is used to determine the hourly capacity factors for the offshore wind technologies at these sites. The turbine assumptions used are:

- Hub height: 150 m
- Turbine model: Vestas V162 9500

These parameters are selected because they best match the representative fixed-bottom offshore wind technology used in the 2022 NREL Annual Technology Baseline (moderate case), which is what the ACES model uses for the wind technology technoeconomic data. Calculated annual capacity factors are shown in Table 4.

3. Solar Site Selection and Capacity Factors

3.1 New Utility-Scale Solar

The utility-scale solar resource location within each province is determined by selecting the location with the highest solar radiation potential, as determined by a Natural Resources Canada database. These are:

- Centreville, Nova Scotia
- Belledune, New Brunswick
- Cape Egmont, Prince Edward Island
- South Brook, Newfoundland

The NREL PVWatts Calculator is used to derive the hourly capacity factors using the following technical assumptions:

- Module type: Standard

- Array type: 1-axis tracking
- System Losses: 14%
- Tilt (deg): equal to the latitude.
- Azimuth (deg): 180
- DC to AC size ratio: 1.34
- Inverter efficiency: 96%

These parameters are selected to match those of the representative utility-scale solar technology in the 2022 NREL Annual Technology Baseline, which is what the ACES model uses for technoeconomic assumptions. Calculated annual capacity factors are shown in Table 3.1.

3.3 New Residential Solar

The residential solar resource location for each region is assumed to be its most populated city:

- Halifax, Nova Scotia
- Moncton, New Brunswick
- Charlottetown, Prince Edward Island
- St. John's, Newfoundland

The NREL PVWatts Calculator is used to derive the hourly capacity factors using the following technical assumptions:

- Module type: Standard
- Array type: Fixed (roof mount)
- System Losses: 14%
- Tilt (deg): 45
- Azimuth (deg): 180
- DC to AC size ratio: 1.2
- Inverter efficiency: 96%

Calculated annual capacity factors are shown in Table 3.1.

Table 3.1: Summary of annual capacity factors for offshore wind, utility scale solar and residential scale solar for each region.

Region	Offshore Wind	Utility Scale Solar	Residential Solar
Nova Scotia	58.8%	16.4%	13.9%
New Brunswick	41.1%	18.0%	13.8%
Prince Edward Island	54.4%	17.8%	13.6%
Newfoundland	50.5%	14.3%	12.7%

4. Representative Day Selection

Representative days are selected with an optimization approach based on the work outlined in Poncelet et al. (2016)[2]. The idea is that a given year can be effectively represented by a subset of its days that are weighted in terms of their relative frequency.

To determine which days are selected and their respective weights, the following approach is taken:

1. First, a metric by which we determine the "representativeness" of a set of days must be defined. The most common approach found in literature is to use the comparison between the annual "duration curves" of a set of loads and/or technologies with those of the weighted representative days. For instance, we may be interested in how well the representative days can approximate the load duration curve and the production duration curves of the wind and solar resources.

   We select the approximation error of the following curves to serve as the metric:

   1. Normalized load duration curve
   2. Normalized existing wind production duration curve
   3. Normalized new wind availability (i.e., capacity factor)

2. Each day of the year is then encoded into a vector; that is, the hourly load, existing wind production and new wind availability is encoded into a vector with length 3x24=72.

3. The problem of selecting the optimal set of representative days with their respective weights is then encoded into a combinatorial optimization problem. The problem is told to select K days (where K is a user input) with corresponding weights such that a) the weights sum to 365 and b) the root-mean-square error between the approximated duration curves and the annual duration

[2] Poncelet, Kris, et al. "Selecting representative days for capturing the implications of integrating intermittent renewables in generation expansion planning problems." IEEE Transactions on Power Systems 32.3 (2016): 1936-1948.

curves is minimized.

The approach also enables the user to select a set of days that are forced to be included. For instance, the model user may wish to force the representative day selection algorithm to select as one of the representative days the day with the peak annual load. Alternatively, the user may wish to select three consecutive days with relatively high loads and low wind resource availability.

As an example, here is the annual (in black) and approximated (in red) duration curves for K=8 in Figures 4.1, 4.2, and 4.3.

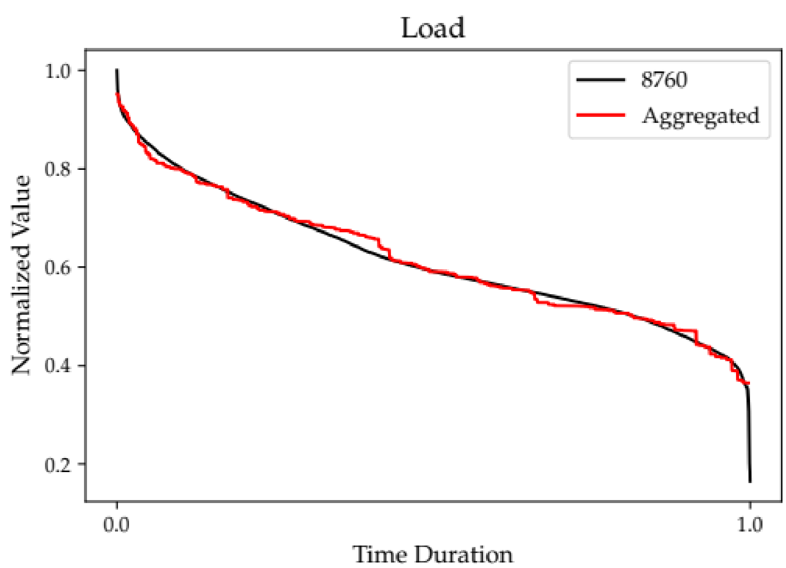

Figure 4.1: Measured and aggregated load duration curves.

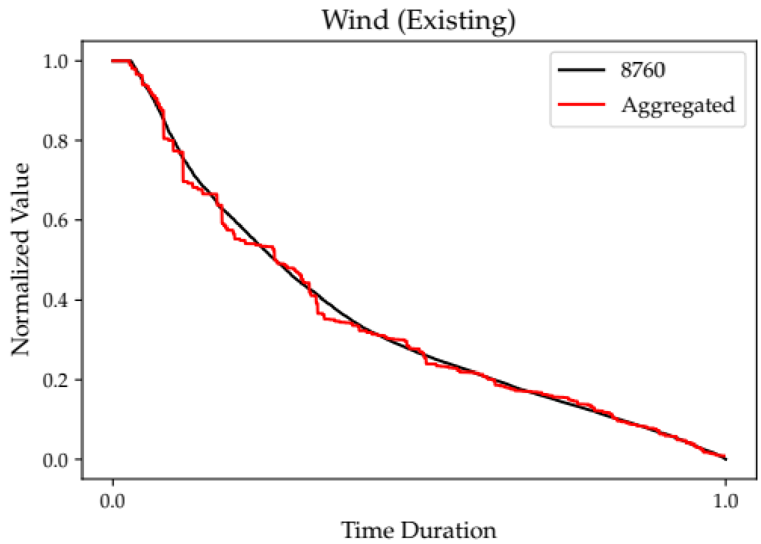

Figure 3.2: Measured and aggregated existing wind production duration curves.

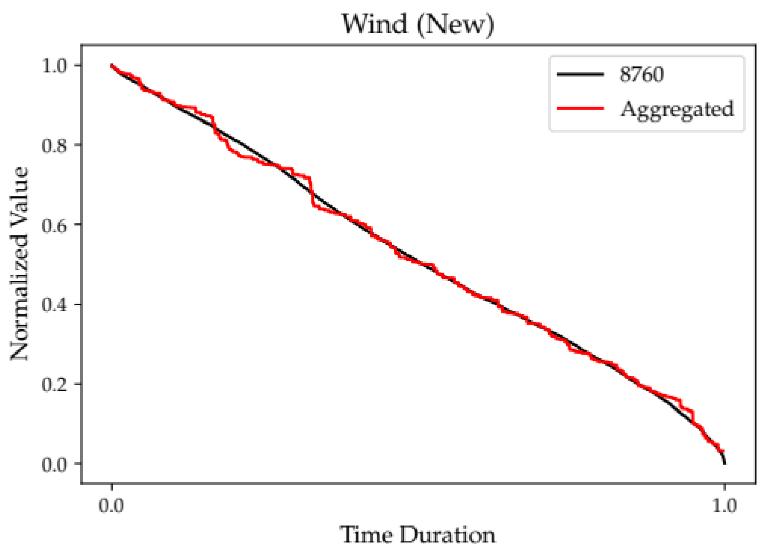

Figure 4.3: Measured and aggregated new wind production duration curves.

5. Implementation of Renewable Portfolio Standards

A renewable portfolio standard (RPS)[3] is a regulatory mandate that sets a minimum share of renewable (or clean) electricity generation or procurement. The ACES model is designed to easily facilitate the inclusion of renewable portfolio standards. This is done by including an accounting technology, "*E_RPS_Counter* ", that tracks the amount of electricity that does and does not qualify as renewable.

This has been implemented in a procurement-based framework as opposed to a generation-based framework. This means that in a given region, only electricity that is procured (or consumed) in that region is included in the RPS calculation, meaning imported clean electricity can qualify under the RPS.

A simplified schematic of the RPS implementation is provided in Figure 5.1. Table 5.1 lists the assumptions of which imports qualify as renewable.

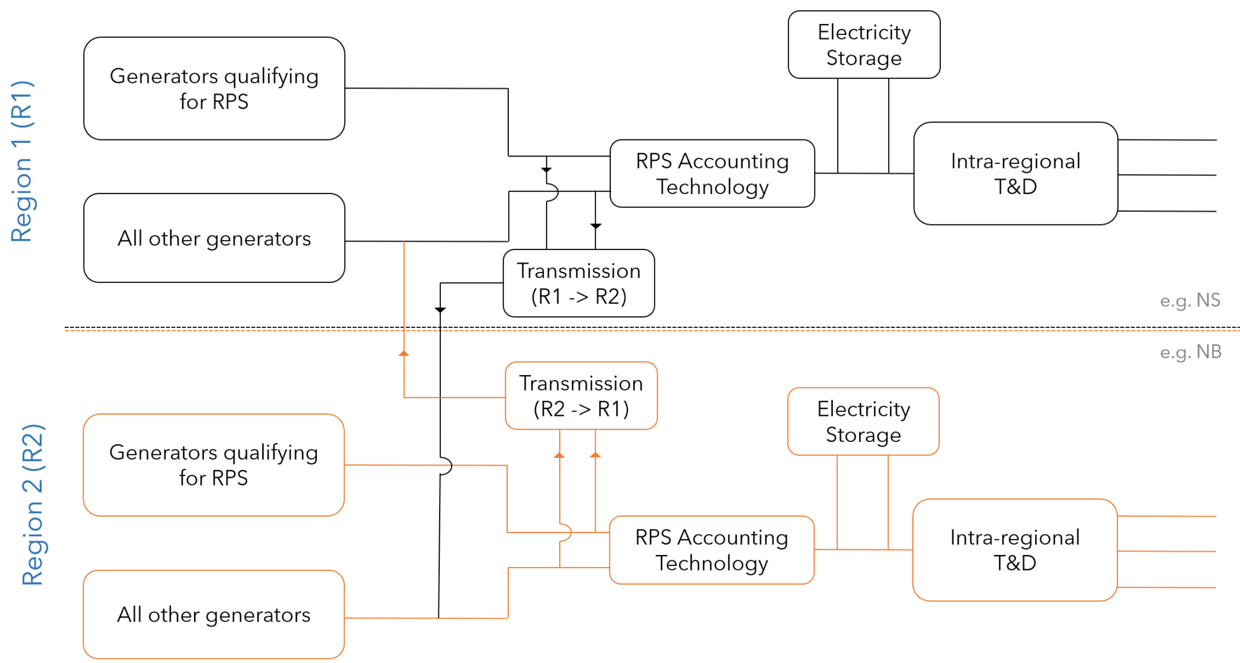

Figure 5.1: A schematic of the implementation of the renewable portfolio standard in the ACES mode. The RPS Accounting Technology tracks the amount of electricity that does and does not qualify as renewable in each region

Table 5.1: Assumptions of which imports qualify as renewable in each of the five modelled regions.

[3] Renewable portfolio standards are sometimes called renewable electricity standards or clean electricity standards.

Region	Source of Imports	Qualify as Renewable?
New Brunswick	Quebec	Yes
	Maine	Yes
	Prince Edward Island	No
	Nova Scotia	No
Nova Scotia	New Brunswick	No
	Newfoundland	Yes
Prince Edward Island	New Brunswick	No
Newfoundland	Nova Scotia	No
	Labrador	Yes
Labrador	Quebec	Yes
	Newfoundland	Yes

To set a renewable portfolio standard in the model, use the *TechInputSplitAverage* parameter for the region in question using the "*ELCG-RPS-Tx*" commodity as the input commodity. Figure 5.2 shows a snapshot of how the Nova Scotia RPS appears in the SQLite file. The "*ti_split*" value is the minimum fraction of procured electricity in the region that must qualify as renewable.

The ACES model includes specific renewable portfolio standards for Nova Scotia and New Brunswick, reflecting their existing policies. Nova Scotia requires 40% of its electricity sales be renewable from 2020 – 2030 and 80% thereafter while New Brunswick has a 40% requirement for the entire modelling period.

regions	periods	input_comm	tech	ti_split	ti_split_notes
Filter	Filter	Filter	Filter	Filter	Filter
NS	2020	ELCG-RPS-Tx	E_RPS-COUNTER	0.4	Nova Scotia Renewable Electricity Standard
NS	2025	ELCG-RPS-Tx	E_RPS-COUNTER	0.4	Nova Scotia Renewable Electricity Standard
NS	2030	ELCG-RPS-Tx	E_RPS-COUNTER	0.8	Nova Scotia Renewable Electricity Standard
NS	2035	ELCG-RPS-Tx	E_RPS-COUNTER	0.8	Nova Scotia Renewable Electricity Standard
NS	2040	ELCG-RPS-Tx	E_RPS-COUNTER	0.8	Nova Scotia Renewable Electricity Standard
NS	2045	ELCG-RPS-Tx	E_RPS-COUNTER	0.8	Nova Scotia Renewable Electricity Standard
NS	2050	ELCG-RPS-Tx	E_RPS-COUNTER	0.8	Nova Scotia Renewable Electricity Standard

Figure 5.2: A screenshot of the "TechInputSplitAverage" table in the ACES SQlite database showing how Nova Scotia's RPS is implemented in the SQLite input files.

6. Temperature-dependent efficiencies (EfficiencyVariable Table)

The *Efficiency* table is used to define technology efficiencies for converting specific input commodities to specific output commodities. These efficiencies are reported as annual averages, which is sufficient for many technologies. However, certain technologies have large variations in their intra-annual efficiency. The *EfficiencyVariable* table allows you to vary technology efficiencies at the timestep level. The default value for *EfficiencyVariable* is 1.0, so only technologies whose intra-annual efficiencies you wish to vary need to be included in the table.

Currently, the ACES model includes intra-annual variations for the efficiency of the following technologies:

- Heat pumps
- Electric vehicles (light duty cars; light duty trucks; medium duty trucks; heavy duty trucks; and buses)
- Plug-in hybrid vehicles (light duty cars and light duty trucks)

For heat pumps, temperature-dependent efficiencies are taken from this peer-reviewed journal article by Vaishnav and Fatimah. The authors use data provided by the Northeast Energy Efficiency Partnership (NEEP) to derive a relationship between outdoor air temperature and heat pump coefficient of performance. This relationship is used along with historical hourly temperatures from each province's largest city to derive the *EfficiencyVariable* parameter.

For electric vehicles, we use temperature-dependent driving efficiency data for the 2019 Tesla Model 3 Standard Range Plus in conjunction with regional temperatures to make adjustments to the annual average efficiencies reported by vehicle manufacturers. This approach was advised by staff at Natural Resources Canada.

7. Electricity and natural gas import prices

Price forecasts for natural gas and electricity imports consist of two components: 1) a long-term price forecast and 2) intra-annual variations to the average annual price. This section outlines how we use the *CostVariable* and *CostVariableVariable* parameter to implement these price forecasts.

For electricity imports, we use historical price data as well as data from the Energy Information Agency's (EIA) 2022 Annual Energy Outlook (AEO) to define the long-term price forecast. Specifically, the 2020 price is defined as the average wholesale price reported by ISO-NE for the Maine market over the years 2017, 2018 and 2019. For 2021 onwards, we apply the year-over-year change in price forecasts from the EAI 2022 AEO[4] to the 2020 price.

We then define the intra-annual price variation using ISO-NE data. The monthly wholesale load cost report is used to determine average monthly electricity prices for on- and off-peak periods (Figure 7.1). This data is then input into the *CostVariableVariable* table to define hourly price variations from the average annual price defined in the *CostVariable* table.

- Finally, we make assumptions around the emission intensity of imported electricity, which can affect its price if there is an explicit price on emissions. Imports from Quebec are assumed to be carbon free and therefore have an emission intensity of zero. Imports from New England are assumed to have an emission intensity of 49.17 kt CO2e per PJ, which is equal to the average emission intensity of electricity generated in New England in the year 2020[5]. The following notes are important to keep in mind:The emission intensity of imports is fixed and cannot change over time.
- The emission intensity of imports is strictly used for pricing purposes – not for emissions accounting purposes. This is because Temoa is not currently configured to account for emissions from inter-regional trade. As a result, the region importing the electricity is not responsible for its associated emissions but pays a premium in proportion to the applicable carbon tax.
- The associated prince increase of imported electricity is the product of its emission intensity (in units of kt/PJ; found in the "EmissionActivity" table) and the carbon tax (in units of M$/PJ; found in the "CostEmissions" table).

[4] Table 3: Energy Prices by Sector and Source for the New England region.
[5] U.S. Energy Information Administration. Annual Energy Outlook 2022. Table 54: Electric Power Projections by Electricity Market Module Region. Case: Reference Case. Region: New England.

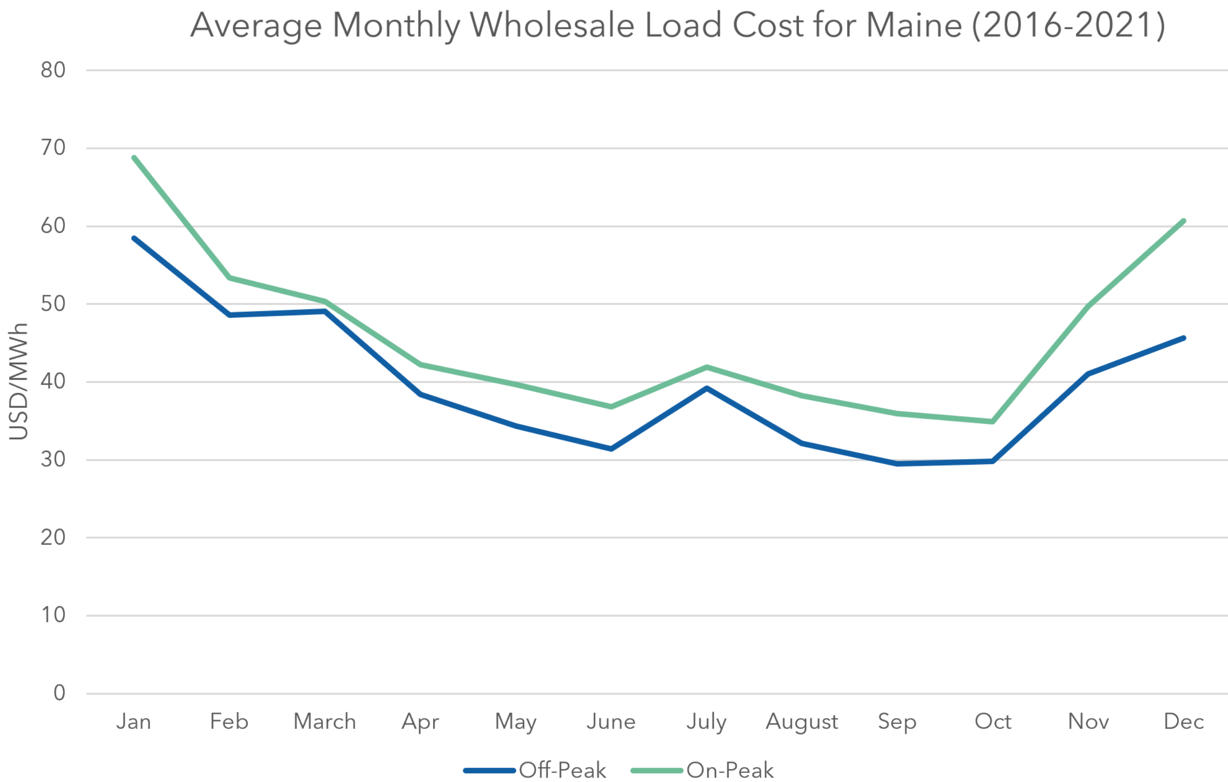

Figure 7.1: Average monthly wholesale electricity prices in Maine. The ACES model uses this data to determine the intra-annual price variation for electricity imports.

For natural gas imports, the price forecast is taken from the EIA 2022 AEO[6] and a $2/MMBtu cost is added for transportation to the Atlantic Canadian market. Historical data of average monthly natural gas prices at Algonquin Citygates is then used to determine the intra-annual variation to those average annual costs (Figure 7.2). This data is then input to the *CostVariableVariable* table to define hourly price variations from the average annual price defined in the *CostVariable* table.

[6] Table 3: Energy Prices by Sector and Source for the New England (electric power sector).

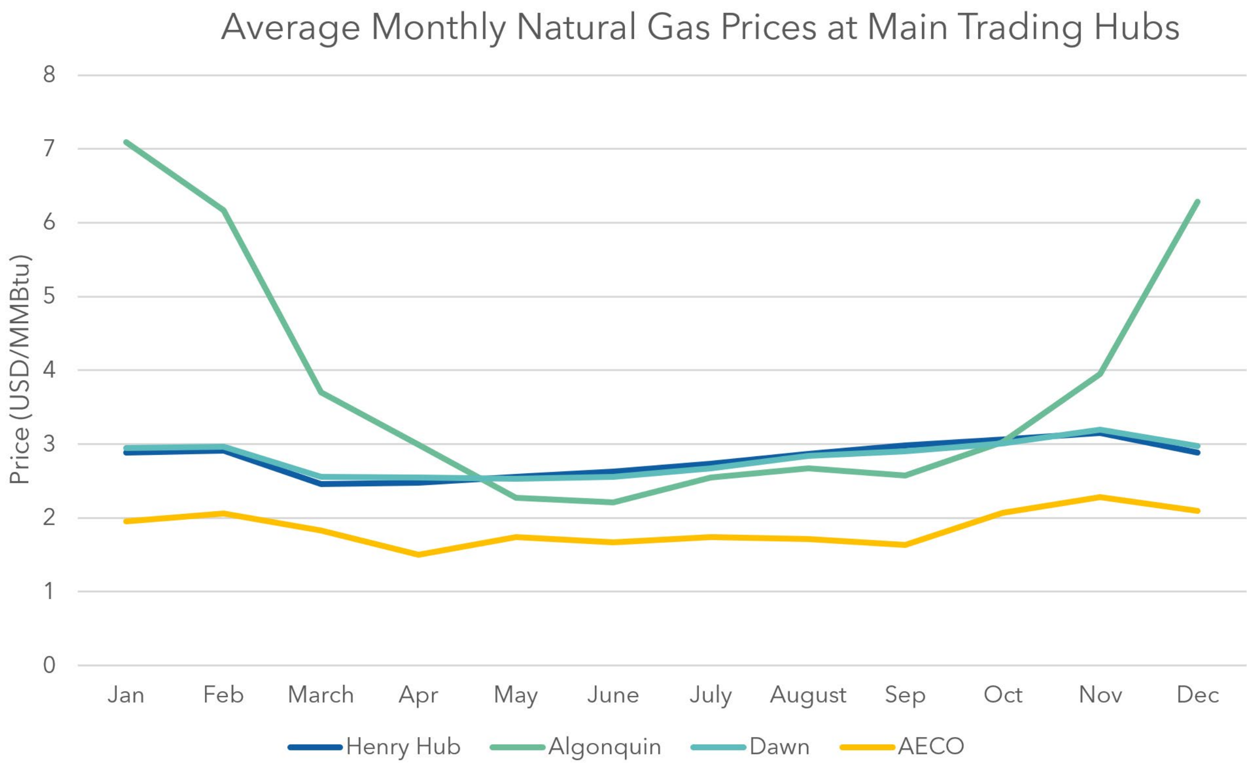

Figure 7.2: Average monthly wholesale natural gas prices at several trading hubs. The ACES model uses the Algonquin Citygates data to determine intra-annual variations to the price of natural gas.

8. Carbon capture processes

In general, CO_2 emissions are introduced to the model at the same time fossil fuels are. For instance, when one PJ of natural gas is imported into the model for future use, the associated 49.61 kt of CO_2 are immediately accounted for via the emission activity of the importing technology. This means that conversion technologies, such as natural gas power plants, do not directly emit CO_2. This is because the emissions related to the natural gas combusted by the power plant have already been accounted for when the fuel itself was imported into the model.

To account for facilities with carbon capture, the following is done. A negative emissions activity is set for the facility in question. This activity is equal to 90% of the CO_2 content of the fuel combusted to generate one unit of output (90% is the assumed capture rate). For instance, natural gas used in the electric power sector is assumed to have a CO_2 emission intensity of 49.61 kt/PJ. The natural gas power plant with carbon capture and sequestration (CCS) has an efficiency of 47.65% (i.e., one PJ of natural gas is converted to 0.4765 PJ of electricity). Therefore, to generate 1 PJ of electricity, 1/0.4765=2.0986 PJ of natural gas is imported, resulting in 104.113 kt of CO_2 emissions. The power plant in question then has a CO_2 emission intensity of -0.9 x 104.13 kt/PJ = -93.69 kt/PJ. This negative activity offsets the 104.113 kt of CO_2 that the model associates with the import of natural gas, resulting in 10.42 kt of net CO_2 emissions per PJ of electricity.

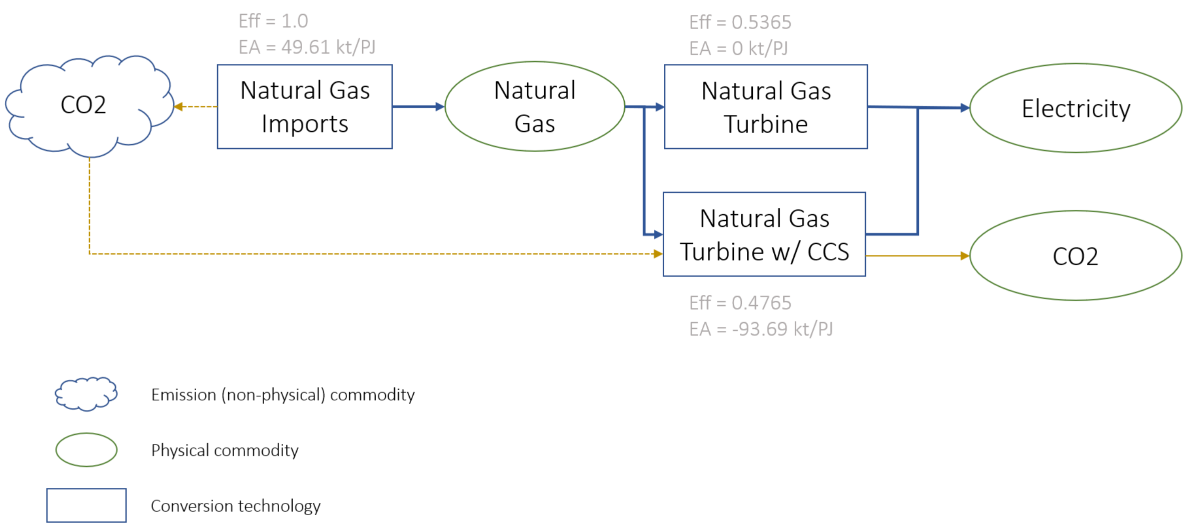

Figure 8.1: A schematic detailing the accounting procedure for CCS technologies.

9. Overview of SQLite Tables

This section provides an overview of the input SQLite database tables. Detailed information for most of these tables is found via Temoa's official documentation. Tables marked with an asterisk (*) are unique to the ACES model and are described in greater detail.

In general, tables that start with a capital letter (e.g., CostInvest, EmissionLimit) are technology-specific parameters. Tables that start with a lowercase letter represent the sets across which the parameters are indexed (e.g., technologies, regions, years). Tables that start with "Output_" (e.g., Output_Costs) are where Temoa prints model outputs, which are model variables that Temoa solves for. It is important to note that model users do not complete the output tables; once the model solves, these tables are automatically updated.

CapacityCredit

See Temoa's official documentation.

CapacityFactorProcess

See Temoa's official documentation.

CapacityFactorTech

See Temoa's official documentation.

CapacityToActivity
See Temoa's official documentation.

CostEmissions*
This parameter enables emissions pricing and is indexed over the following sets: regions, periods, and emission commodities. The units of this parameter should be in [cost units]/[emission units]. In the ACES model, our base dataset uses the units of M$/kt. This table is where a carbon tax would be implemented.

CostFixed
See Temoa's official documentation.

CostInvest
See Temoa's official documentation.

CostVariable
See Temoa's official documentation.

CostVariableVariable*
This parameter is used to set variable costs at the timestep level. Temporally, the *CostVariable* parameter is indexed by years – meaning it sets the annual average variable cost. The *CostVariableVariable* parameter is indexed by timesteps – meaning it sets the intra-annual variation of variable costs. For a given timestep and period, the effective variable cost is the product of *CostVariable* for that period and *CostVariableVariable* for that timestep. Note: the default value for *CostVariableVariable* is 1.0, so only costs that you wish to vary intra-annually need to be explicitly defined.

Demand
See Temoa's official documentation.

DemandSpecificDistribution
See Temoa's official documentation.

Note: We have added a period index to this parameter. Users can now vary the *DemandSpecificDistribution* for a given demand commodity across distinct model years.

DiscountRate
See Temoa's official documentation.

Efficiency
See Temoa's official documentation.

EfficiencyVariable*
This parameter is used to set technology efficiencies at the timestep level. Temporally, the *Efficiency* parameter is indexed by years – meaning it sets the annual average annual efficiency. By contrast, the

EfficiencyVariable parameter is indexed by timesteps – meaning it sets the intra-annual variation of technology efficiency. For a given timestep and period, the effective efficiency is the product of Efficiency for that period and *EfficiencyVariable* for that timestep. Note: the default value for *EfficiencyVariable* is 1.0, so only efficiencies that you wish to vary intra-annually need to be explicitly defined.

EmissionActivity
See Temoa's official documentation.

EmissionLimit
See Temoa's official documentation.

Note: This constraint has been slightly modified to additionally be indexed over sectors. The valid entries for the sectors index are:

1) Any sector defined in the *sector_labels* table, e.g. "electricity".
2) Any combinations of sectors from the *sector_labels* table. To do so, separate the sectors with a dash, e.g., "electricity-transportation".
3) The keyword "all", meaning across all sectors.

EmploymentPerCapacity*
This parameter indicates the number of jobs per unit of capacity of a technology in all of the periods throughout its technical lifetime. Period and vintage information are included because technologies require varying amount and type of labour over their lifetime: from construction to annual maintenance to retirement.

ExistingCapacity
See Temoa's official documentation.

GlobalDiscountRate
See Temoa's official documentation.

GrowthRateMax
See Temoa's official documentation.

GrowthRateSeed
See Temoa's official documentation.

LifetimeLoanTech
See Temoa's official documentation.

LifetimeTech
See Temoa's official documentation.

LinkedTechs

See Temoa's official documentation.

MaxActivity

See Temoa's official documentation and information on constraints (equation 27).

MaxActivityGroup*

This parameter is used to set a maximum activity across a given technology group in a given region in a given period (i.e., the aggregate activity across all technologies belonging to that group). The technologies belonging to a particular technology group are defined in the *tech_groups* table.

MaxActivityShare*

This parameter is used to set a maximum share of activity a given technology from a given technology group can account for in a given region and in a given period. The technologies belonging to particular technology group are defined in the *tech_groups* table. This value must be in the unit interval [0, 1].

MaxAnnualCapacityFactor*

This parameter is used to set a maximum annual capacity factor for a given technology in a given region in a given period. This value must be in the unit interval [0, 1].

Note: a technology's capacity factor is the ratio of actual activity over maximum possible activity. In Temoa, the maximum possible activity is defined as the product of the technology's capacity and *CapacityToActivity* parameter.

MaxAsynchronousShare*

This parameter sets the maximum share that asynchronous generators (listed in the *tech_asynchronous* table) can provide in any timestep in a given region in a given period. Note: to calculate total generation, Temoa sums across all technologies in the *tech_reserve* table. The default is 1.

MaxCapacity

See Temoa's official documentation and information on constraints (equation 30).

MaxCapacityGroup*

This parameter is used to set a maximum aggregate capacity across a given technology group in a given region in a given period (i.e., the aggregate capacity across all technologies belonging to that group). The technologies belonging to particular technology group are defined in the *tech_groups* table.

MaxCapacityShare*

This parameter is used to set a maximum share of capacity a given technology from a given technology group can account for in a given region in a given period. The technologies belonging to particular technology group are defined in the *tech_groups* table. This value must be in the unit interval [0, 1].

MaxNewCapacity*

This parameter is used to set a maximum amount of new aggregate capacity across a given technology group in a given region in a given period (i.e., the new aggregate capacity across all technologies belonging to that group). The technologies belonging to particular technology group are defined in the *tech_groups* table.

MaxNewCapacityShare*

This parameter is used to set a maximum share of new capacity a given technology from a given technology group can account for in a given region in a given period. The technologies belonging to particular technology group are defined in the *tech_groups* table. This value must be in the unit interval [0, 1].

MaxSeasonalActivity*

This parameter is similar to the *MaxAcitivity* parameter, however it stipulates the maximum activity that can occur during a single "season". Note, the ACES model uses the notion of representative days, so a "season" here refers to a day.

This constraint, for instance, is used to limit the amount of natural gas that the Maritimes and Northeast pipeline can import to New Brunswick and Nova Scotia in any given day to 0.481 PJ (or 440 million cubic feet per day).

MinActivity

See Temoa's official documentation and information on constraints (equation 28).

MinActivityGroup*

This parameter is used to set a minimum activity across a given technology group in a given region in a given period (i.e., the aggregate activity across all technologies belonging to that group). The technologies belonging to particular technology group are defined in the *tech_groups* table.

MinActivityShare*

This parameter is used to set a minimum share of activity a given technology from a given technology group can account for in a given region and in a given period. The technologies belonging to particular technology group are defined in the *tech_groups* table. This value must be in the unit interval [0, 1].

MinAnnualCapacityFactor*

This parameter is used to set a minimum annual capacity factor for a given technology in a given region in a given period. This value must be in the unit interval [0, 1].

Note: a technology's capacity factor is the ratio of actual activity over maximum possible activity. In Temoa, the maximum possible activity is defined as the product of the technology's capacity and *CapacityToActivity* parameter.

MinCapacity

See Temoa's official documentation and information on constraints (equation 31).

MinCapacityGroup*

This parameter is used to set a minimum aggregate capacity across a given technology group in a given region in a given period (i.e., the aggregate capacity across all technologies belonging to that group). The technologies belonging to particular technology group are defined in the *tech_groups* table.

MinCapacityShare*

This parameter is used to set a minimum share of capacity a given technology from a given technology group can account for in a given region in a given period. The technologies belonging to particular technology group are defined in the *tech_groups* table. This value must be in the unit interval [0, 1].

MinNewCapacity*

This parameter is used to set a minimum amount of new aggregate capacity across a given technology group in a given region in a given period (i.e., the new aggregate capacity across all technologies belonging to that group). The technologies belonging to particular technology group are defined in the *tech_groups* table.

MinNewCapacityShare*

This parameter is used to set a minimum share of new capacity a given technology from a given technology group can account for in a given region in a given period. The technologies belonging to particular technology group are defined in the *tech_groups* table. This value must be in the unit interval [0, 1].

MinSeasonalActivity*

This parameter is similar to the MinActivity parameter, however it stipulates the minimum activity that can occur during a single "season". Note, the ACES model uses the notion of representative days, so a "season" here refers to a day.

This constraint, for instance, is used to impose minimum flow rates (via daily energy budgets) for certain hydroelectric facilities.

MyopicBaseyear

ACES model users can ignore this table.

Output_CapacityByPeriodAndTech
A calculated model output that lists the total capacity of each technology type in each model period.

Output_Costs
A model output listing all the costs incurred, both discounted and undiscounted. This includes investment costs, fixed costs, variable costs, and emissions costs.

Output_Curtailment
A model output equivalent to [Temoa's V_Curtailment variable.]

Output_Duals
A model output tabulating the value of all (non-zero) dual variables in the model, These outputs are typically reserved for advanced levels of analysis and require an understanding of mathematical optimization.

Output_Emissions
A model output tabulating the sources and quantity of all emissions.

Output_Employment*
A model output tabulating the number of jobs resulting from each technology type.

Output_ImplicitEmissionsPrice*
A model output that states the implicit emission price, or shadow price, of an associated *EmissionLimit.*

Output_Objective
The objective value of the model run, i.e., the total discounted system cost. This value is equal to all "discounted costs" printed in the *Output_Costs* table and accounts for investment costs, fixed costs, variable costs and emissions costs. Its precise formulation is available in Temoa's official documentation[7].

Output_VFlow_In
A model output tabulating the commodity flows into each technology in each model timestep.

Output_VFlow_Out
A model output tabulating the commodity flows into each technology in each model timestep.

Output_VStorageSOC*
A model output tabulating the state-of-charge of storage technologies in each model timestep.

[7] The ACES model has slightly edited this formulation to include emission costs (which follow the same approach as variable costs).

Output_V_Capacity

A model output tabulating the total capacity of each technology in each period by vintage. A summarized version of this table is presented in *Output_CapacityByPeriodAndTech*.

PlanningReserveMargin

See Temoa's official documentation and information on constraints (equation 20).

RampDown

The fraction of a technology's capacity that it can decrease its power output by in one hour.

RampUp

The fraction of a technology's capacity that it can increase its power output by in one hour.

SegFrac

See Temoa's official documentation.

StorageDuration

See Temoa's official documentation.

TechInputSplit

See Temoa's official documentation.

TechInputSplitAverage

See Temoa's official documentation.

TechOutputSplit

See Temoa's official documentation.

commodities

An exhaustive list of all commodities used in the model.

commodity_labels

Labels by which commodities are categorized. It is advisable not to edit this table.

groups

A list of groups to which technologies in *tech_groups* can belong.

regions

A list of all regions in the model.

sector_labels

A list of all sectors in the model.

subsector_labels*

A list of all subsectors in the model.

tech_annual

A list of all technologies that produce constant annual output.

tech_asynchronous*

A list of all technologies that are included in the *tech_asynchronous* constraint (see the description in the *tech_asnychronous* table).

tech_curtailment

A list of all technologies whose output can be curtailed at no cost.

tech_exchange

A list of all technologies that facilitate commodity flows between regions (e.g., electricity transmission).

tech_flex

A list of technologies that are permitted to produce excess commodity flows. See the Temoa documentation for a more detailed description.

tech_groups

A list of all technologies that belong to a group.

tech_mga

ACES model users can ignore this table.

tech_ramping

A list of all technologies that are characterized by ramp rates.

tech_reserve

A list of all technologies that are characterized by a *CapacityCredit*. **Important note:** To calculate the implicit electricity demand used in the reserve margin constraint, Temoa only considers technologies listed in the *tech_reserve* table. This means that all electricity generators and electricity transmission technologies should be included in the *tech_reserve* table.

tech_variable

A list of all technologies used in the *TechInputSplitAverage* table/constraint.

technologies

An exhaustive list of all technologies.

technology_labels

Labels by which technologies are categorized. It is advisable not to edit this table.

time_of_day

The set of time steps that together constitute a day.

time_period_labels
Labels by which time_periods are categorized. It is advisable not to edit this table.

time_periods
A list of all periods (i.e., years) in the model.

time_season
A list of all representative days in the model.