Canadian Engineering
Competition 2021
Compétition Canadienne
d'Ingénierie 2021

Programming Competition Case

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1. Background

In a world where numerous renewable energy methods are being implemented, it is also important to mitigate wasted power and costs of producing and transporting power. Trend data can be especially useful in these times, allowing for previous years' trends to give average guidelines for the expected demand in the coming year.

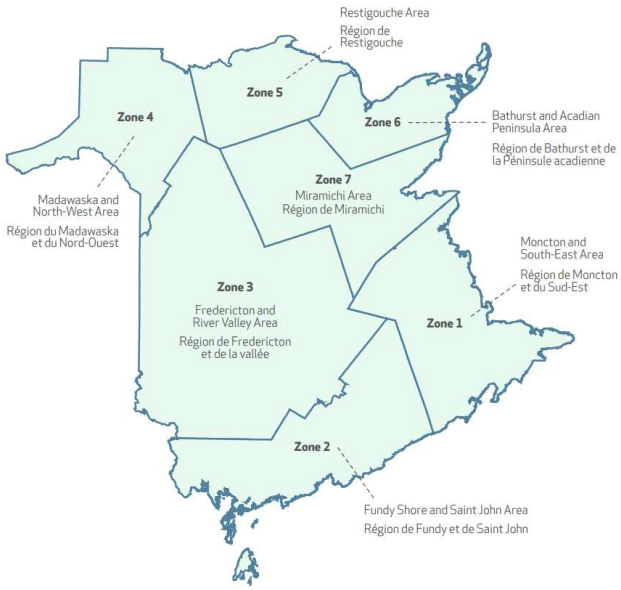

Figure 1: Map of zones in the province of New Brunswick.

The provincial power company wants to make sure that they are using their renewable energy sources to their best potential. They also want to minimize transportation of energy costs and how much electricity is sold out of province. There are different power generation stations around the province.

For the purposes of this problem, the province was sectioned into the zones as displayed in Figure 1. There are also 4 extra zones that are considered, Maine (ME), Nova Scotia (NS), Prince Edward Island (PEI), and Quebec (QC). Excess power can be sold to these 4 zones.

In the province of New Brunswick, there are 3 non-renewable and 2 renewable sources of energy. The non-renewables include thermal power, combustion turbine power, and nuclear power sources. The renewable sources include wind power and hydroelectrical power. For more information see the definitions section below.

For non-renewable sources such as thermal and combustion turbines, they can be operated for periods of time and deactivated when not needed, in order to save costs. The non-renewable nuclear power is a constant generation source. Nuclear power cannot be stopped, but if in surplus can be dissipated to ground, i.e. waste, or sold to other provinces or regions. The renewable source of hydroelectrical power, like the nuclear power source, will be considered as if it is a constant power supply, when in reality, it is more variable. For the purposes of this problem, wind power will also be a constant source of power. In reality, wind power changes depending on the weather conditions.

2. Competition Challenge

Develop a program that can read a previous years' set of data and predict a forecast of energy needs across a province. The forecasting includes making cost effective choices as to where the energy is sourced from, and where it should be sent to. The program should be easily adaptable as to allow for more energy sources to be added or removed when necessary. There are 2 levels to this problem, you must complete the levels in order.

Level 1: Using one of the methods below, along with the past years' data, predict the provinces power consumption for the coming year. Print the details in the appropriate file format, see Section 5 (Desired Output).

- Linear extrapolation
- Polynomial extrapolation

Level 2: Optimize the power between the zones of the province while trying to minimize cost. Use the optimizing equation seen In Section 3 (Given Information), and print the details below in the appropriate file format, see Section 5 (Desired Output).

- Monthly cost for the province ($)
- Total consumed power (GWh)
- Renewable power used (%)

3. Given Information

Use Equation 1 below as the cost function of all the resources being used. This cost will need to be calculated in each zone, using the respective vectors and values.

$$C_{zone,month}(h) = p_{zone} \cdot h_{zone} + e \times h_{emissive} - b \times h_{non-emissive} \quad \text{(Eq. 1)}$$

Where the variable $\mathbf{C_{zone,month}}$ is the cost associated to a particular month and zone, the zones go from 1 to 11, where zones 1 - 7 are in New Brunswick, zone 8 is Maine, zone 9 is Nova Scotia, zone 10 is Prince Edward Island, and zone 11 is Quebec. The value **h** is the vector of kilowatt hours (kWh) being sent from all zones to the zone of interest. The variable **p** is the vector of penalties associated with sending power to that zone of interest from all other zones. The variable **e** ($/kWh) is the carbon tax that will be added to any kWh's generated from emissive sources. The $\mathbf{h_{emissive}}$ variable is the total kWh's generated in the zone of interest from emissive sources. The variable **b** ($/kWh) is the incentive bonus for using non-emissive sources. The $\mathbf{h_{non\text{-}emissive}}$ variable is the total kWh's generated in the zone of interest from non-emissive sources.

An example is given below, Equation 2, where the cost equation is evaluated for the month of January in zone 1. The values of **p** are taken from the PenaltyValues.csv, see Table 3. The values of **h**, $\mathbf{h_{emissive}}$, and $\mathbf{h_{non\text{-}emissive}}$ are to scale, however, are fictional for the purposes of this

example. Finally, the values of **e** and **b** are taken from the IncentiveRates.csv, see Table 1.

$$C_{1,1}(h) = \begin{bmatrix} 0.12 \\ 0.38 \\ 0.45 \\ 0.59 \\ 0.62 \\ 0.43 \\ 0.37 \\ 0 \\ 0.18 \\ 0.24 \\ 0 \end{bmatrix} \cdot \begin{bmatrix} 50 \times 10^6 \\ 25 \times 10^6 \\ 75 \times 10^6 \\ 15 \times 10^6 \\ 13 \times 10^6 \\ \dots \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} + (0.015 \times 170 \times 10^6) - (0.009 \times 90.6 \times 10^6) \quad \text{(Eq. 2)}$$

It is important to note that the power values represented in **h**, $\mathbf{h}_{\text{emissive}}$, and $\mathbf{h}_{\text{non-emissive}}$ need to be in kWh, this is why in Equation 2 the values are multiplied by a factor of 10^6.

To calculate the overall costs in a given month for the entire province you must implement Equation 3, seen below.

$$T_{month} = \sum_{zone=1}^{11} C_{zone,month} \quad \text{(Eq. 3)}$$

In the above equation $\mathbf{T}_{\text{month}}$ ($) is the total monthly cost of operations throughout the entire province. **C** ($) is the cost of operation in a specific zone, in a given month.

4. Materials

You will be given the following files which contain data to be read in and applied to the code. Please pay careful attention to the units.

IncentiveRates.csv

This file contains the penalty factor and incentive factor.

See Appendix A, Table 1 for representation of the data.

Units: **$/kWh**

PlantProductionRates.csv

This file has the production values of the different plants.

See Appendix A, Table 2 for representation of the data.

Units: **MW**

PenaltyValues.csv

This file contains the penalty values for power.

See Appendix A, Table 3 for representation of the data.

Units: **$/kWh**

NBTrend20##.csv

This file contains the consumption data for the given year.

See Appendix A, Table 4 for representation of the data.

Units: **GWh**

For Level 1, you will be given data for the past 4 years of power consumption. This data will take on the same form as seen in Figure 5, in Appendix A. The files will be titled NBTrend2018, NBTrend2017, NBTrend2016, and NBTrend2015.

For Level 2, you will need to use the all the files mentioned above as well as your predicted power consumption values.

5. Desired Output

It is necessary for all levels that the outputs are sent to a CSV file that is easily readable, i.e. can be easily used to make graphs/tables in excel.

For Level 1:

Display the predicted power forecast for each zone in the province, for each month of the year.

- The output should be written to one CSV file, whose form matches the Input files. 7 columns (Zones) and 12 rows (months).
- All units should be In GWh
- Note In your presentation what method of extrapolation was used.

For Level 2:

Display the optimized allocation of power for the province, in order to minimize cost. Include what percentage of the overall power supplied was renewable.

- The output should be written to a CSV file, where the 3 values below are displayed for the whole province every month.
    - Cost ($)
    - Total Consumed Power (GWh)
    - Renewable Power Used (%)

6. Deliverables

There should be one file that acts as the driver for the submitted code, when it is executed, it runs through your simulations and produces the desired output files. This file should be named as seen below; python is used as an example however file type is up to the team's discretion.

codename_programmingDriver.py

You must also include the produced output files for all completed levels.

For the presentation it should also be included in the GitHub repository along with any additional material required. It is important to note that there is a format to naming the presentation that will be submitted.

codename_programming.ppt

If the files fail to be successfully submitted via GitHub, contact your director immediately alerting them of the problem.

7. Definitions

Non-Renewable: Uses a fuel type that is not renewable, i.e. using fossil fuels.

Renewable: Uses natural features and forces to move turbines that generate usable electricity.

Non-Emitting: Systems that do not release any harmful emissions.

Emitting: Systems that release certain emissions.

Thermal: By burning a fuel source to create heat, which is used to create steam, which in turn moves the steam turbine, this type of plant can generate usable electricity.

Class: Emitting and Non-Renewable.

Hydroelectric: This energy is collected from turbines that are housed in dams and other structures. Using these structures, we can convert potential energy into electricity.

Class: Non-Emitting and Renewable.

Nuclear: This energy is produced by controlled fission reactions. Controlled fission produces heat, which is then used to make steam. The steam then turns the turbine to move which generates usable electricity.

Class: Non-Emitting and Non-Renewable.

Combustion Turbine: Similar to Thermal, this form of energy is generated by burning a fuel source, and the hot gases produced are used to directly turn a gas turbine, generating usable electricity.

Class: Emitting and Non-Renewable.

Wind: Using high wind speeds to rotate wind turbine blades allows for electricity to be generated.

Class: Non-Emitting and Renewable.

8. Judging Metrics

Programming Judging Matrix		
Strategy/Algorithm	Simplicity	/10
	Ingenuity	/10
	Ability to Achieve Desired Outcome	/15
		/35
Code	Structure	/10
	Consistency	/5
	Readability	/10
	Efficiency	/10
		/35
Resource Management	Memory Usage Efficiency	/5
	Program's CPU Usage	/5
		/10
Presentation	Design Process and Justification	/7
	Design Critique	/4
	Voice, Articulation and Timing	/4
	Visual Aids	/2
	Response to Questions	/3
		/20
Deduction Total		
Total		**/100**

Point Penalties	
Plagiarism	Elimination
Insufficient Citation	-50
Documents Received After Deadline	-50
Absent Team Member	-25
Verbal Disclosure of School During Presentation	-10
Disclosure of School in Presentation Files/Documents	-10
Wearing School Apparel During Presentation	-50
Entering presentation room before allotted time (after first offense)	-10
Total	

9. Appendix A – File Layouts

To discuss the footprint of the different power generation systems, the values have been clearly laid out in Table 1. This information will be given to contestants as part of a CSV file as seen in Figure 2.

Table 1: Incentive Rates and Taxes for generation types.

	Emission Tax	Non-Emissive Incentive
Rate	0.015 $/kWh	0.009 $/kWh

Figure 2: Sample picture of the CSV file containing the Incentive Rates and Taxes.

The overall production rates in each zone of the province are displayed in Table 2. The numbers will be given as part of a CSV file, as seen in Figure 3.

Table 2: Locations of certain plant types, and their production rates, all values in MW.

	Thermal	Nuclear	Combustion Turbine	Hydro	Wind
Zone 1	-	-	-	-	150MW
Zone 2	972MW	660MW	407MW	18MW	-
Zone 3	-	-	-	809MW	-
Zone 4	39MW	-	-	75MW	-
Zone 5	467MW	-	-	99MW	-
Zone 6	-	-	99MW	11MW	45MW
Zone 7	-	-	397MW	-	-

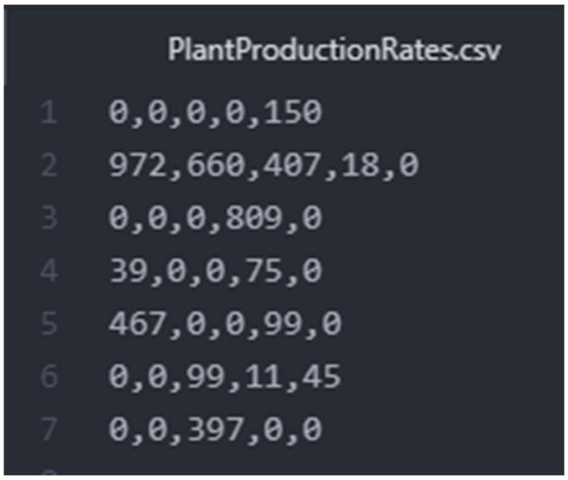

Figure 3: Sample file for the plant production rates the five numbers in each row correspond to the 5 columns of Table 2.

The cost associated to produce and transport power inside a zone and in-between zones is laid out in Table 3. Table 3 also describes the cost of moving energy into other provinces or regions. This information is given to contestants in the form of a CSV file, as seen in Figure 4.

Table 3: Penalties of creating and moving energy between zones (all numbers are costs in $/kWhr).

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9	Z10	Z11
Z1	0.12	0.38	0.45	0.59	0.62	0.43	0.37	0.36	0.18	0.24	0.29
Z2	0.38	0.25	0.30	0.45	0.59	0.47	0.61	0.16	0.42	0.28	0.27
Z3	0.45	0.30	0.09	0.18	0.21	0.36	0.25	0.19	0.25	0.26	0.21
Z4	0.59	0.45	0.18	0.05	0.25	0.35	0.27	0.23	0.16	0.26	0.12
Z5	0.62	0.59	0.21	0.25	0.10	0.30	0.11	0.32	0.28	0.21	0.15
Z6	0.43	0.47	0.36	0.35	0.30	0.14	0.15	0.27	0.31	0.29	0.26
Z7	0.37	0.61	0.25	0.27	0.11	0.15	0.05	0.20	0.25	0.26	0.28
Z8	0.36	0.16	0.19	0.23	0.32	0.27	0.20	0	0	0	0
Z9	0.18	0.42	0.25	0.16	0.28	0.31	0.25	0	0	0	0
Z10	0.24	0.28	0.26	0.26	0.21	0.29	0.26	0	0	0	0
Z11	0.29	0.27	0.21	0.12	0.15	0.26	0.28	0	0	0	0

PenaltyValues.csv

```
0.12,0.38,0.45,0.59,0.62,0.43,0.37,0.36,0.18,0.24,0.29
0.38,0.25,0.30,0.45,0.59,0.47,0.61,0.16,0.42,0.28,0.27
0.45,0.30,0.09,0.18,0.21,0.36,0.25,0.19,0.25,0.26,0.21
0.59,0.45,0.18,0.05,0.25,0.35,0.27,0.23,0.16,0.26,0.12
0.62,0.59,0.21,0.25,0.10,0.30,0.11,0.32,0.28,0.21,0.15
0.43,0.47,0.36,0.35,0.30,0.14,0.15,0,0,0,0
0.37,0.61,0.25,0.27,0.11,0.15,0.05,0,0,0,0
0.36,0.16,0.19,0.23,0.32,0.27,0.20,0,0,0,0
0.18,0.42,0.25,0.16,0.28,0.31,0.25,0,0,0,0
0.24,0.28,0.26,0.26,0.21,0.29,0.26,0,0,0,0
0.29,0.27,0.21,0.12,0.15,0.26,0.28,0,0,0,0
```

Figure 4: Sample picture of the CSV file containing the Penalty Values.

The past year's data will be given in CSV file, similar to the ones above, and provide monthly energy consumption for each of the 7 zones. All of the values are displayed in giga-Watt hours, GWh. An example of the tabulated data is seen below in Table 4, and the data would be given in a CSV format as seen in Figure 5 below.

Table 4: Sample data showing what the CSV file given to contestants will contain. All values are given in GWh.

	Z1	Z2	Z3	Z4	Z5	Z6	Z7
JAN	420.16	488.8	455.52	416.0	399.36	382.72	366.08
FEB	377.74	439.45	409.53	374.0	359.04	344.08	329.12
MAR	436.32	507.6	473.04	432.0	414.72	397.44	380.16
APR	410.06	477.05	444.57	406.0	389.76	373.52	357.28
MAY	359.56	418.3	389.82	356.0	341.76	327.52	313.28
JUN	337.34	392.45	365.73	334.0	320.64	307.28	293.92
JUL	319.16	371.3	346.02	316.0	303.36	290.72	278.08
AUG	337.34	392.45	365.73	334.0	320.64	307.28	293.92
SEP	349.46	406.55	378.87	346.0	332.16	318.32	304.48
OCT	381.78	444.15	413.91	378.0	362.88	347.76	332.64
NOV	410.06	477.05	444.57	406.0	389.76	373.52	357.28
DEC	432.28	502.9	468.66	428.0	410.88	393.76	376.64

NBTrend2018.csv

```
420.16,488.8,455.52,416,399.36,382.72,366.08
377.74,439.45,409.53,374,359.04,344.08,329.12
436.32,507.6,473.04,432,414.72,397.44,380.16
410.06,477.05,444.57,406,389.76,373.52,357.28
359.56,418.3,389.82,356,341.76,327.52,313.28
337.34,392.45,365.73,334,320.64,307.28,293.92
319.16,371.3,346.02,316,303.36,290.72,278.08
337.34,392.45,365.73,334,320.64,307.28,293.92
349.46,406.55,378.87,346,332.16,318.32,304.48
381.78,444.15,413.91,378,362.88,347.76,332.64
410.06,477.05,444.57,406,389.76,373.52,357.28
432.28,502.9,468.66,428,410.88,393.76,376.64
```

Figure 5: Example CSV file for a given year, showing energy consumption data for each zone, each month. All values are in GWh.