

Environmental Impacts of Capacity Expansion: Manipulating Carbon Penalties and Uncertainty Analysis to Reach Goal Resource Mix

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Final Project Interim Presentation

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Motivation

Gain a deeper understanding of the requirements for deep decarbonization in New York state that will align with the goals of the state. Is the current energy mix enough to do that?

70% Renewable Electricity by 2030

**Investment in Renewable Energy
Infrastructure**

(NYSERDA)

Goal

This project aims to evaluate the environmental impacts of different capacity expansion strategies in the NYISO system. The focus will be on incorporating **carbon penalties** for greenhouse gas (GHG) emitting generators and modeling the uncertainty in wind, solar, and demand forecasts. The interest lies in the **resulting generator mix** as a result of the uncertainty and added penalty. Moreover, the implementation of the **carbon penalty** can act as a proxy for **governmental intervention**. What rate of carbon penalties is necessary on an annual basis to enforce **70% renewables** in the mix?

Scope

Timeframe:

Model will cover a
1-year period

Provide annual
energy mix of New
York state

Key Activities:

Carbon Penalties

Forecasting
uncertainty

Scenario Analysis

Energy Sources:

Solar

Wind

Hydro

Existing Nuclear

Natural Gas

Batteries

Hypothesis (Carbon Tax Only)

- As carbon tax increases, the energy mix becomes more renewable.
- We will hit a point where the **raising of price** will become **non useful** (Carbon Price).
- Carbon tax alone may **not be enough** to **reach goals** in a reasonable manner.

First Steps

Formulating the base case model



Implement the Carbon Tax



Iterate through prices until
Emissions Goal Reached

Base Case With Carbon Tax

Two main ways to implement carbon tax

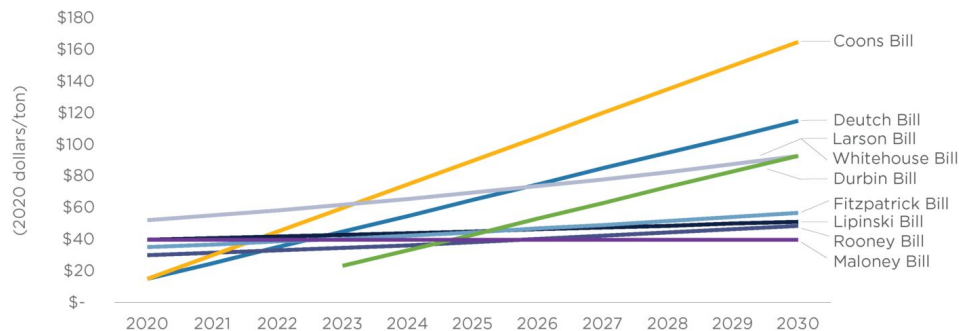
1. Additional price on capacity expansion
2. Price per GHG emitted (would require a conversion factor)
 - a. Could also be done as a cap and trade carbon tax

Base Case With Carbon Tax

Main Question: How do we decide what price to set?

1. Heavily influenced by political factors
 - a. Base case will be what we expect from the current administration (no carbon tax)
2. Federal tax proposals:
 - a. One proposal suggests to start at \$43 per metric ton and increase between 3 and 5% above inflation each year
3. We will need to test this against the desired 70% renewable resource mix

Figure 1: Carbon Tax Rates for Federal Carbon Tax Proposals (dollars/ton)



Source: CGEP Analysis

Base Case With Carbon Tax

In 2022, a total of 1,637 power plants used natural gas to generate at least 95% of their electricity (EPA 2024). These plants emitted 382,205.02 metric tons CO₂/power plant in 2022.

U.S. utility-scale net electricity generation and resulting CO₂ emissions by fuel in 2023

	Electricity generation	CO ₂ emissions		
	million kWh	million metric tons	million short tons	pounds per kWh
Coal	675,115	709	781	2.31
Natural gas	1,806,063	790	871	0.96
Petroleum	16,233	18	20	2.46
All other energy sources	4,183,271	1,532	1,688	0.81

Source: <https://www.eia.gov/tools/faqs/faq.php?id=74&t=11>

According to The U.S. Energy Information Administration (EIA) 0.96 pounds CO₂ per kWh

Converting to the units in our model we get:

(0.96 lb CO₂/ kWh) (1 metric ton / 2204.62 lb) (1000 kWh/ 1 MWh)

= 0.435449 metric tons / MWh

Base Case With Carbon Tax

Currently, the carbon tax looks like this in our model:

Addition to our Parameters: this is an initial guess for a tax which will be changed in our .run file by iterating

```
#add carbon tax amount  
param tax >= 0; # $/metric ton  
param conversion = 0.435449; #metric ton/MWh
```

Addition to our Objective Function:

```
+ sum {z in ZONES, t in TIMES} p_gt['GAS',z,t] * tax * conversion
```

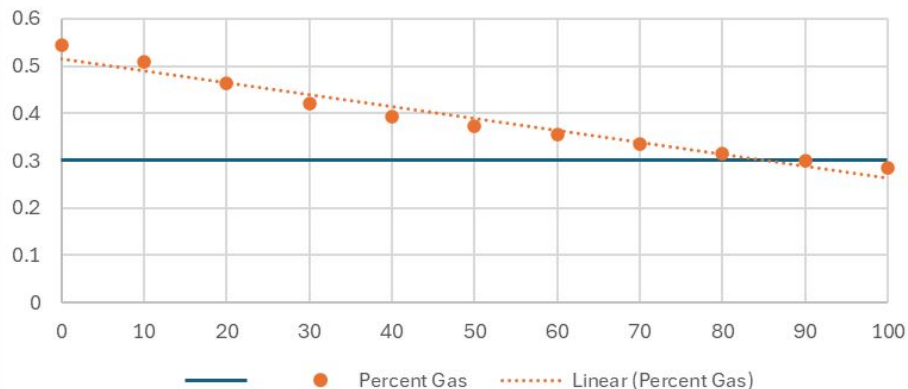
Base Case With Carbon Tax

Initial Results:

- Reached a 70% Renewable production at a carbon tax of \$90 / metric ton of CO₂
- This is in the upper range of values in the proposal chart

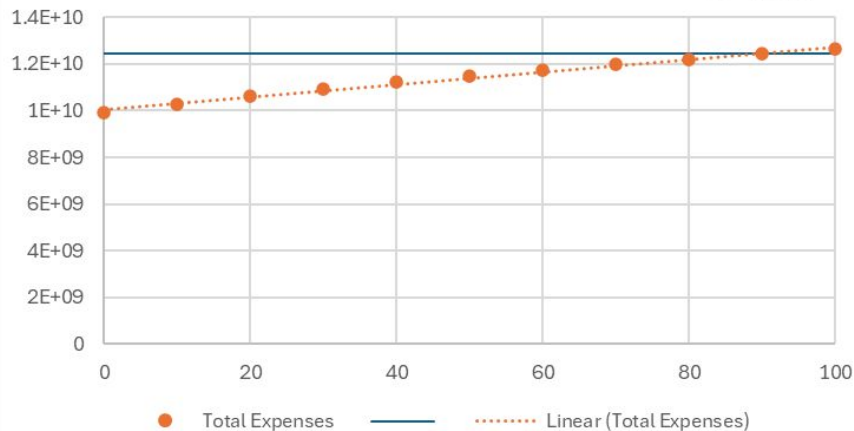
Percent Gas versus Carbon Tax

$R^2 = 0.9596$



Total Expenses versus Carbon Tax

$R^2 = 0.9919$



Next Steps

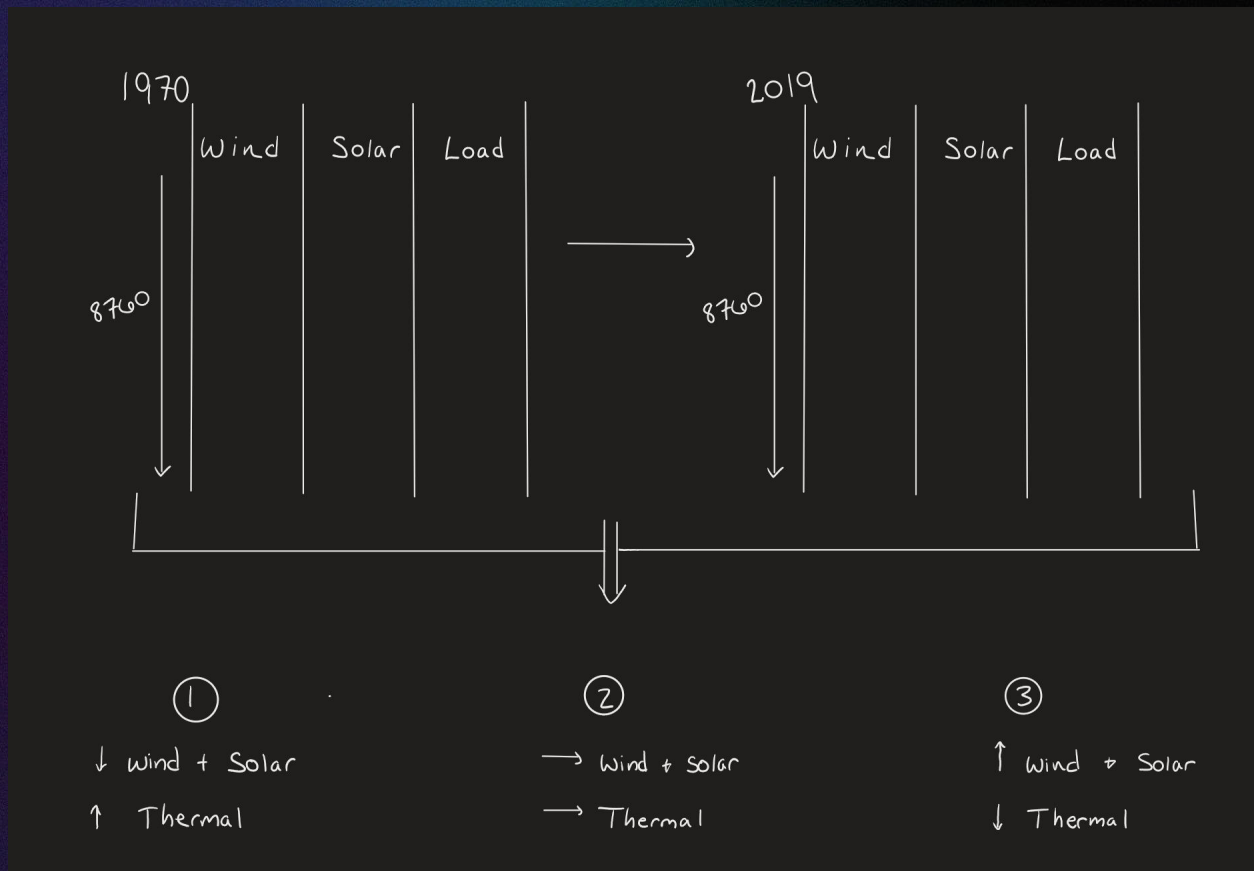
Environmental Impact Assessment:
Evaluate the GHG emissions using a **GHG emissions/MWH rate**

**Generate Scenarios to Model
Uncertainty**

Add any **additional data** we are
interested in

Scenario Analysis

- 3 Scenarios (**Low, Average, High**)
- Test Carbon Tax in all 3
- Serves as **proxy** for **uncertainty**
- Provides additional **reasoning** for carbon **price chosen**



Limitations

Carbon Price only **implemented** in a **single year**

No cap on expansion abilities in most zones

Does **not account** for **demand growth**

Does **not account** for any **growth in transmission**

Policy constraints

Useful Sources

- 1) <https://www.energypolicy.columbia.edu/publications/what-you-need-to-know-about-a-federal-carbon-tax-in-the-united-states/>
- 2) <https://www.eia.gov/tools/faqs/faq.php?id=74&t=11>
- 3) <https://www.nyserda.ny.gov/All-Programs/Clean-Energy-Standard>
- 4) <https://www.timesunion.com/business/article/closer-look-new-york-s-pending-emissions-cap-18568746.php>
- 5) <https://climate.ny.gov/Resources/-/media/project/climate/files/Cap-and-invest-vs-cap-and-trade-vs-carbon-tax.pdf>

Questions for the Class

Any suggestions for uncertainty implementation?

Limitations of scenario analysis as proxy for uncertainty?