Assessing Value of Adding Flexibility to Washington State's Greenhouse Gas "Cap and Invest" Program

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OVERVIEW OF THE STUDY

As part of the Washington Climate Commitment Act, the State's Senate Bill SB 5126 would establish a greenhouse gas (GHG) cap and invest program to be implemented by the Washington State Department of Ecology. The bill was signed by Governor Jay Inslee on May 17, 2021. The Western States Petroleum Association (WSPA) retained NERA Economic Consulting to develop a model that represents the Washington state economy using its N_{ew}ERA modeling system and to use it to develop estimates of the economic impact benefits of adding provisions for greater flexibility into the bill. This document presents results for one specific form of such flexibility: allowing for linkage between Washington's and Western Climate Initiative's (WCI) climate program which comprises of California and Quebec.

This research study represents an analysis of the targets and some of the proposed measures in the bill. The measures accounted for in this analysis include the imposition of an emission cap with tradeable allowances, no-cost and direct allowance allocations, offsets credits, and allowances set aside in containment reserves. For the scenario where linkage is allowed between Washington's and WCI's climate program, two bounding cases were run – the first assumes a fully optimal forward looking rational behavior on the part of consumers and producers and the second assumes a myopic behavior on the part of consumers and producers to capture market expectations about the uncertainties surrounding California's GHG policy in the short run.[1] Some of the key research insights are presented below with the results for the two linked scenarios presented in Table 1 while the results for the unlinked scenario are presented in Table 2:

- The economic costs to Washington households in the linked program with access to "speed bumps" is projected to be lower in 2024 than in the scenario without "speed bumps." On average from 2024 to 2030, the economic costs to Washington households are projected to be on average about 1.3 times greater under the unlinked program than under the linked program both with and without "speed bumps". The average annual costs per household in Washington is projected to be about $930 both with and without "speed bumps" and about $1,170 without linkage over the 2024 to 2030 time period.[2]
- In an unlinked program, the allowance prices are projected to increase to about $185 and $250 in 2024 and 2030, respectively, to achieve the state's emissions goals. When the two programs are linked, Washington's allowance prices are projected to approach California's allowance ceiling prices of about $77 in 2024 and $103 in 2030. This result is due to the relative stringency of Washington's program and the additional demand for allowances from the WCI allowance market. If Washington links to the WCI program, it is projected to be a net importer of permits within the linked program. In the linked case with "speed bumps", Washington's allowance prices are projected to be about $49 in 2024 while they are projected to approach California's allowance ceiling prices by 2030. The lower allowance price in 2024 is a consequence of an adequate amount of allowances being available such that the allowance price would remain at the "speed bump" price in 2024.

[1] "Speed Bumps" refer to price containment points between the price floor and the price ceiling at which a certain amount of allowances from the allowance price containment reserve (APCR) are made available.

[2] All values are denominated in 2021 dollars.

- The average cost of compliance for motor gasoline and diesel with linkage to the WCI program is projected to be about $0.67 and $0.77 per gallon respectively over the 2024 to 2030 time period while they are projected to be about $0.60 and $0.69 per gallon respectively in the linked case with "speed bumps" over the same period. The average cost of compliance for motor gasoline and diesel respectively without linkage is projected to be about $1.61 and $1.83 per gallon over the 2024 to 2030 time period.

Table 1: Summary of Key Results (With WCI Linkage)

	With WCI Linkage (and "Speed Bumps")				With WCI Linkage			
	2024	2027	2030	Average Annual (2024-2030)	2024	2027	2030	Average Annual (2024-2030)
Loss in Annual Consumption per Household (2021$/HH)[3]	$810	$970	$1,020	$930	$870	$920	$1,000	$930
Cost of Compliance of Motor Gasoline (2021$/gal)	$0.37	$0.67	$0.77	$0.60	$0.58	$0.67	$0.77	$0.67
Cost of Compliance of Diesel (2021$/gal)	$0.42	$0.76	$0.88	$0.69	$0.66	$0.77	$0.88	$0.77
Loss in Output of Energy-Intensive Sectors (%)[4]	-3%	-4%	-5%	-4%	-3%	-4%	-5%	-4%
Allowance Price (2021$/MT CO_2)	$49	$90	$103		$77	$90	$103	
Allowance Floor Price (2021$/MT CO_2)*	$21	$24	$28		$21	$24	$28	

*Fiscal Note Summary (12 May 2021)

Table 2: Summary of Key Results (Without WCI Linkage)

	Without WCI Linkage			
	2024	2027	2030	Average Annual (2024-2030)
Loss in Annual Consumption per Household (2021$/HH)[5]	$1,110	$1,130	$1,260	$1,170
Cost of Compliance of Motor Gasoline (2021$/gal)	$1.38	$1.60	$1.84	$1.61
Cost of Compliance of Diesel (2021$/gal)	$1.58	$1.83	$2.10	$1.83
Loss in Output of Energy-Intensive Sectors (%)[6]	-4%	-6%	-7%	-6%
Allowance Price (2021$/MT CO_2)	$184	$214	$246	
Allowance Floor Price (2021$/MT CO_2)*	$21	$24	$28	

*Fiscal Note Summary (12 May 2021)

Two other sensitivity runs were carried out in which the Washington and WCI programs are unlinked but Washington was assumed to adopt its own price ceiling on cap-and-trade allowance prices.[7] Some of the key research insights for these sensitivity cases are presented below with the results presented in Table 3.

[3] This metric measures the impacts to an average Washington household's annual personal consumption expenditure (in terms of current spending).

[4] This metric measures the change in quantity of production of the aggregate energy-intensive sector (which comprises pulp and paper, chemicals, glass, cement, iron and steel, alumina and aluminum and mining).

[5] This metric measures the impacts to an average Washington household's annual personal consumption expenditure (in terms of current spending).

[6] This metric measures the change in quantity of production of the aggregate energy-intensive sector (which comprises pulp and paper, chemicals, glass, cement, iron and steel, alumina and aluminum and mining).

[7] In the first case, it was assumed that Washington would adopt California's ceiling price trajectory (i.e., $65/metric ton of CO_2 starting in 2021 rising at 5% per year (and adjusted for inflation) in the first year of its cap-and-invest program (2023). In the second case, it was assumed that Washington would adopt a ceiling price trajectory that starts at $40/metric ton of CO_2 in 2023 rising at 5% per year (and adjusted for inflation). Similar to California, it was assumed that the Washington State Department

- The economic costs to Washington households are projected to be lower under the unlinked program where Washington adopts its own ceiling price program than under the linked program.
- The average annual costs per household in Washington is projected to be about $720 in the scenario with Washington adopting California's ceiling price trajectory and $520 in the scenario with a lower ceiling price trajectory over the 2024 to 2030 time period.[8] The lower cost is a result of Washington retaining the value of ceiling price permits within its economy, which would not have been available to Washington under the linked program where it is a net importer of permits.
- The average cost of compliance for motor gasoline and diesel in the unliked program where Washington adopts a ceiling price trajectory that is the same as California's is projected to be the same as that in the linked program (i.e., $0.67 and $0.77 per gallon for gasoline and diesel respectively) while in the case with the lower ceiling price trajectory, the average cost of compliance for motor gasoline and diesel is projected to be about $0.36 and $0.41 over the 2024 to 2030 time period.[9]

Table 3: Summary of Key Results (Sensitivity Cases)

	Without WCI Linkage (California Ceiling Price)				Without WCI Linkage ($40 Ceiling Price)			
	2024	2027	2030	Average Annual (2024-2030)	2024	2027	2030	Average Annual (2024-2030)
Loss in Annual Consumption per Household (2021$/HH)[10]	$660	$710	$790	$720	$460	$520	$570	$520
Cost of Compliance of Motor Gasoline (2021$/gal)	$0.58	$0.67	$0.77	$0.67	$0.31	$0.36	$0.41	$0.36
Cost of Compliance of Diesel (2021$/gal)	$0.66	$0.77	$0.88	$0.77	$0.35	$0.41	$0.47	$0.41
Loss in Output of Energy-Intensive Sectors (%)[11]	-3%	-4%	-5%	-4%	-2%	-4%	-4%	-3%
Allowance Price (2021$/MT CO_2)	$76	$90	$103		$41	$48	$55	
Allowance Floor Price (2021$/MT CO_2)*	$21	$24	$28		$21	$24	$28	

*Fiscal Note Summary (12 May 2021)

of Ecology would issue the requisite amount of ceiling price permits to ensure that the allowance permit price stays at or below the adopted ceiling price trajectory.

[8] All values are denominated in 2021 dollars.

[9] The lower ceiling price trajectory consists of the ceiling price starting at $40 per metric ton of CO_2 in 2023 rising at 5% per year (and adjusted for inflation).

[10] This metric measures the impacts to an average Washington household's annual personal consumption expenditure (in terms of current spending).

[11] This metric measures the change in quantity of production of the aggregate energy-intensive sector (which comprises pulp and paper, chemicals, glass, cement, iron and steel, alumina and aluminum and mining).

OVERVIEW OF STUDY METHODOLOGY

The N$_{ew}$ERA model is a U.S. economy-wide integrated energy and economic modeling framework with regional disaggregation that integrates a capacity and dispatch model of the U.S. electricity sector with a dynamic computable general equilibrium model of the U.S. economy that accounts for production, consumption, and investment decisions across regions and economic sectors. The model includes household decisions that affect overall energy use and related emissions from combustion of fossil fuels and industrial process emissions.

The N$_{ew}$ERA modeling system includes 14 types of existing electric generating technologies. New technology types that the model can build, in addition to existing types, include advanced coal with carbon capture and storage (CCS), natural gas combined cycle with CCS, offshore wind, onshore wind with storage, and photovoltaic solar with storage. The model includes two different types of vehicles - internal combustion engine vehicles (ICEs) and battery-operated Electric vehicles (BEVs) as well as biofuel representation for the gasoline and the diesel markets. The modeling framework assesses the economic impacts from policies by accounting for important sectoral and regional interactions that take place in the economy in addition to the direct costs or other effects of the policy.

The N$_{ew}$ERA model used for this study represents Washington and California as separate regions. This disaggregation allows the model to simulate region specific policies, especially when modeling the WCI program. Quebec's program is represented by a marginal abatement cost curve in the model. The model includes five energy (coal, natural gas, crude oil, petroleum products, and electric) sectors and seven non-energy (agriculture, energy-intensive sectors, services, motor vehicle manufacturing, other manufacturing, commercial trucking, and commercial transportation) sectors.[12] The analysis baseline was calibrated to the projections published by the Energy Information Administration (EIA) as defined in its Annual Energy Outlook 2021 Reference Case.

For this study, four scenarios were simulated - a scenario that links Washington's program with the WCI program, a scenario in which there is no linkage (with the cap-and-invest program's default assumptions) and two additional sensitivity scenarios where the programs are unlinked but where Washington was assumed to adopt its own ceiling price trajectory. Since the N$_{ew}$ERA model only represents CO_2 emissions, Washington's CO_2 emission cap was developed using the total greenhouse gas (GHG) allowance budget level specified in the Fiscal Note Summary and a GHG to CO_2 emissions ratio for 2019.[13] Offset credit allowances and containment reserve allowance set-asides were also developed based on the information specified in the Fiscal Note Summary. No-cost allowance allocations are made to the energy intensive trade exposed (EITE) sectors, electric utilities and natural gas utilities.[14] Similar to the

[12] The model treats biomass as a carbon-neutral fuel source. It additionally does not include net-zero emission technologies which if deployed would likely reduce the projected impacts.

[13] Pg. 121, Fiscal Note Summary (available at https://fnspublic.ofm.wa.gov/FNSPublicSearch/GetPDF?packageID=63362).

[14] As specified in Pg. 120 of the Fiscal Note Summary, electric utilities are not required to consign any of their allocated no-cost allowances in the first compliance period. Thus, the study assumes none of the revenues from the no-cost allowances allocated to electric utilities are applied to reducing electricity rates in the first compliance period. In the absence of current rules relating to no-cost allowance allocations from the second compliance period onwards, it was assumed that from the second compliance period and going forward, 100% of the revenues from the no-cost allowances allocated to electric utilities are applied towards reducing electricity rates. For natural gas utilities, 65% of the allowances in 2023 would be consigned increasing to 5%/yr to

development of Washington's CO_2 emissions cap, the no-cost GHG allowances are also scaled down to represent CO_2 allowance allocations using the 2019 GHG to CO_2 emissions ratios for these entities. Allowances are assumed to be purchased at the model's projected allowance price rather than at the estimated average purchase price specified in the Fiscal Note.[15]

The auction revenues that are deposited into the Climate Commitment Account (which equal 75% of the total revenues from the Climate Investment Account) as well as the revenues deposited into the Air Quality and Health Disparities Improvement Account are assumed to be returned in a lumpsum manner to the Washington households in this study. The auction revenues deposited into the Natural Climate Solutions Account (which equal 25% of the revenues from the Climate Investment Account) are used to subsidize the output of the water and sewage utilities sector and the fishing and the forestry sector in the N_{ew}ERA model. The auction revenues deposited into the Carbon Emissions Reduction Account are used to subsidize electric vehicles and commercial transportation in the N_{ew}ERA model.

For California and Quebec, the joint emissions cap modeled follows the trajectories specified in the AB 398 and SB 32 bills with lumpsum revenue recycling to households. Under the linked scenario, permit trading is allowed among California, Quebec, and Washington; whereas in the unlinked scenarios, trading is prohibited between the WCI jurisdictions and Washington. The model assumes transfer of permit revenues between regions. In all of the scenarios, California's program also includes the current Low Carbon Fuels Standard, Renewable Portfolio Standard, energy efficiency programs as well as existing electric vehicle mandates.

100% consignment by 2030 (as specified in the Fiscal Note Summary) with the revenues applied towards reducing natural gas prices for the benefit of ratepayers. For EITEs, 100% of the revenues from the no-cost allowances are applied towards subsidizing the output from these entities (as specified in the Fiscal Note Summary).

[15] Per Pg. 121 of the Fiscal Note Summary, allowances are assumed to be purchased at an estimated average purchase price which is calculated as the floor price adjusted by the percentage change in the annual allowance budget for auctions caused by the removal of offset usage and compliance curve adjustments for EITE allowances. We have assumed in our modeling that allowances would be purchased at the model's projected allowance price instead.

OVERVIEW OF NEWERA MODELING FRAMEWORK AND MODELING ASSUMPTIONS

A. General Features of the NewERA Framework

NERA's NewERA model is an energy-economy modeling framework that integrates a bottom-up representation of the U.S. electricity sector with a top-down representation of the production, consumption, and investment decisions across the rest of the U.S, economy, including household decisions that affect overall energy use and related GHG emissions. The modeling framework assesses the economic impacts from policies by accounting for important sectoral and regional interactions that take place in the economy in addition to the direct costs or other effects of the policy.

The top-down portion of NewERA is a forward-looking dynamic computable general equilibrium (CGE) model of the U.S. economy. It simulates all key economic interactions in the U.S. economy, including those among industries, households, and the government. Industries and households maximize profits and utility, respectively, with foresight about future economic conditions. The theoretical construct behind the model is based on the circular flow of goods, services, and payments in the economy—every economic transaction has a buyer and a seller whereby goods and services go from a seller to a buyer and payments for the goods and services goes from the buyer to the seller.

The CGE model is centered around the decisions of a representative household that characterizes the economic behavior of an average consumer. Households provide labor and capital to businesses, taxes to the government, and savings to the financial markets, while also consuming goods and services and receiving government subsidies. One of the decisions that households make with respect to services is how to meet personal transportation needs. In addition to deciding on the quantity of personal vehicle miles traveled (VMT), households in NewERA choose between two different types of vehicles - internal combustion engine vehicles (ICEs) and battery-operated electric vehicles (BEVs). The household's vehicle choice depends upon the relative vehicle life-cycle cost differences and consumers' preferences for different vehicles.

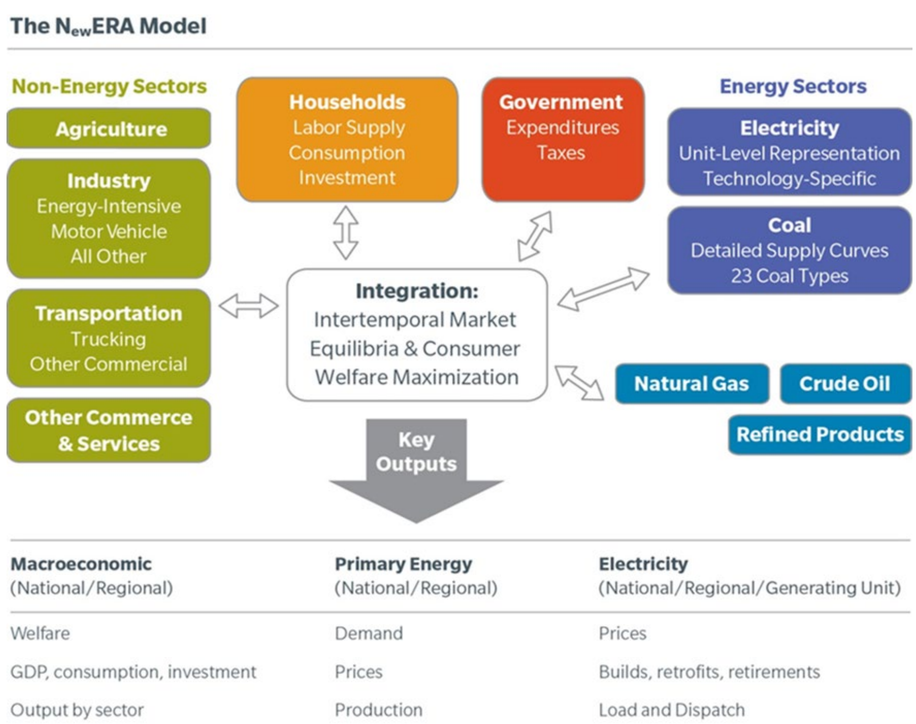
The economic sectors in the model, in aggregate, account for all of the production and commercial activities of the economy. Each economic sector uses labor, capital, energy resources, other sector's outputs, and imported inputs to produce their own specific category of goods or services. Economic sectors pay their share of Federal Insurance Contributions Act (FICA) tax and health insurance, and corporate taxes to the government. Industries are both consumers and producers of capital for investment in the rest of the economy.

One of the sectors in NewERA is the electricity sector. This sector is modeled in a bottom-up (i.e., technology-specific) manner that is fully integrated with the rest of the economy (which is simulated in the CGE framework described above). The model includes all existing electric generating units, while future capacity investment and economic retirement decisions are represented simultaneously with dispatch decisions. The model dispatches electricity to load duration curves. Long-term investment and retirement decisions and short-term unit dispatch decisions are projected by solving a dynamic, non-linear program with an objective function that minimizes the present value of total system costs, while complying with all system constraints, such as meeting demand, renewable portfolio standards, reserve margin requirements, emissions limits, transmission limits, clean energy standards, and other environmental and electric specific policy mandates.

The CGE portion of the N$_{ew}$ERA model also incorporates the government. In the model, the government collects revenues from taxes imposed on labor and capital. Revenues are used to pay for government services, which are held constant in every scenario. The model also holds overall government debt the same in all scenarios by either returning excess revenues to the consumers, or by increasing taxes. The rebates or revenue-raising actions may be performed on a lump-sum basis (e.g., by changing the standard deduction) or by altering tax rates. Unless otherwise stated, the model uses the lump-sum transfer assumption.

Within the circular flow of the above described macroeconomy, an equilibrium is found whereby demand for goods and services equals their supply, and investments are optimized for the long term. Thus, supply equals demand in all markets for all time periods. The model produces integrated projections of the energy sector and other economic activities for future years and estimates the energy market and macroeconomic impacts of a potential policy by comparing projections of the future with and without the policy's requirements included in the model's input assumptions. Figure 1 provides a simplified representation of the key elements of the N$_{ew}$ERA modeling system.

Figure 1: N$_{ew}$ERA Modeling System Representation



B. Electric Sector Model

The N$_{ew}$ERA modeling system's electric sector model is a detailed bottom-up model of the electric and coal sectors. The model is fully dynamic and includes perfect foresight (under the assumption that future conditions are known). Thus, all decisions within the model are based on minimizing the present value of costs over the entire time horizon of the model while meeting all specified constraints, regarding demand, peak demand, emissions limits, transmission limits, RPS regulations, CES regulations, fuel availability and costs, new build limits and CCS retrofit build or retire requirements for coal units. The model set-up is intended to mimic decisions made by electric sector investors and system operators. In determining the least-cost method of satisfying specified constraints, the model determines the following:

- Investment decisions (*e.g.*, addition of retrofits, build new capacity, repower unit, add fuel switching capacity, or retire units)
- Unit operations decisions (*e.g.*, unit dispatch by fuel and technology and optimal power generation mix)

In the model, we represent over 17,000 electricity generating units in the United States. Larger coal units (greater than 200 MW) are individually represented in the model and smaller units are aggregated based on region, size, and existing controls for ease of computation. All other types of units are included in different regional aggregates based on their operating characteristics. Table 4 shows the existing generating technologies in the electric sector model.

Table 4: Existing Generating Technologies in the Electric Sector Model

Coal	Pumped Storage Hydroelectric
Natural Gas Combined Cycle	Biomass
Natural Gas Combustion Turbine	Geothermal
Gas/Oil Steam	Landfill Gas
Oil Combustion Turbine	Municipal Solid Waste
Onshore Wind	Solar Photovoltaic
Hydroelectric (Run-of-River)	Concentrated Solar Thermal

New technology types that the model can build, in addition to existing types, include advanced coal with carbon capture and storage (CCS), natural gas combined cycle with CCS, offshore wind, onshore wind with storage, and photovoltaic solar with storage. Annual build limits can be specified to reflect real world constraints. The model can also accommodate joint build limits that apply to multiple new technology types.

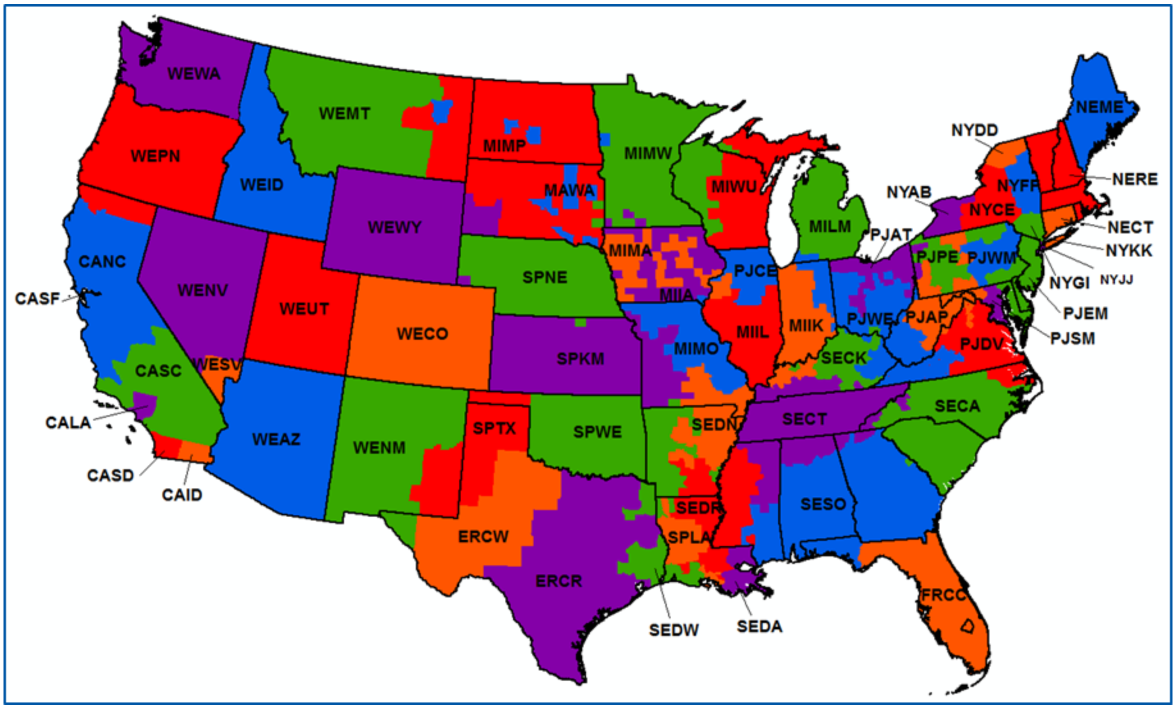
Each unit in the model has certain number of actions it can take. For example, all units can retire, and most can undergo retrofits. Any publicly-announced actions, such as planned retirements, planned retrofits (for existing units), or new units under construction can be specified. In the model, generating units are responsive to environmental limits specified in the model. Such limits include emission caps (for SO_2, NO_X, Hg, and CO_2) that can be applied at the national, regional, state or unit level. The user can also specify allowance prices for emissions, emission rates (especially for toxics such as Hg), and heat rate levels that must be met by assets.

Similar to investment decisions, the operation of each unit in a given year depends on the policies in place (e.g., unit-level standards), electricity demand, and operating costs – especially energy prices. The model accounts for these conditions in determining dispatch decisions of each unit. On top of unit-level regulations, the model also considers system-wide operational issues such as environmental regulations, limits on the share of generation from intermittent resources, transmission limits, and operational reserve margin requirements in addition to annual reserve margin constraints.

To meet increasing electricity demand and reserve margin requirements over time, the electric sector must build new generating capacity. Future environmental regulations and forecasted energy prices influence decisions on technology type and location of asset. Policies will also likely affect retirement decisions – an asset will be retired if the model deems it uneconomic to keep that asset operating given future regulatory, technological, and economic constraints. All model decisions hence optimize over all current and future assumptions that may impact resource planning. For this analysis, Washington state was modeled as a separate region in the electricity sector model. The version of the electricity sector model employed for this analysis contains 64 U.S. electricity regions (and 11 Canadian electricity regions) as shown in Figure 2 with Washington state's electric system represented by the "WEWA" power pool in the model. [16]

[16] The NewERA electric sector model regions are based on the model regions in EPA's Integrated Planning Model (IPM) and are designed to be approximately consistent with the configuration of the NERC assessment regions in the NERC Long-Term Reliability Assessments. (https://www.epa.gov/airmarkets/clean-air-markets-power-sector-modeling). The adjoining 11 Canadian electricity regions are not shown in the figure.

Figure 2: N$_{ew}$ERA Electric Sector Model – U.S. Regions



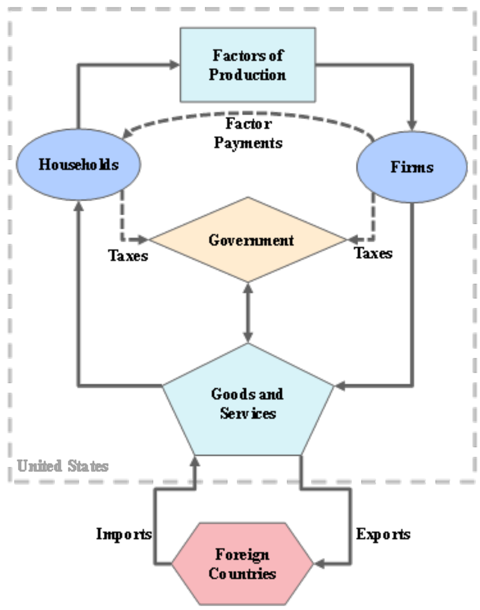
C. Macroeconomic Model

The N$_{ew}$ERA macroeconomic model is a forward-looking, dynamic, computable general equilibrium (CGE) model of the United States. The model simulates all economic interactions in the U.S. economy, including those among industry, households, and the government.

The N$_{ew}$ERA CGE framework uses a standard theoretical macroeconomic structure to capture the flow of goods and factors of production within the economy. A simplified version of these interdependent macroeconomic flows is shown in Figure 3. The model solution assumes an Arrow-Debreu general equilibrium. This general equilibrium is characterized by three principles: i) zero-profit, which states any economic activity must earn zero profit as the value of inputs equal the value of outputs; ii) market clearance, which states supply must equal demand for all positively priced goods; and iii) income balance, which states all agents' income must equal its factor endowments plus any net transfers received.

Accordingly, in the model, households supply factors of production, including labor and capital, to firms. Firms provide households with payments for the factors of production in return. Firm output is produced from a combination of production factors and intermediate inputs of goods and services supplied by other sectors of the economy (both domestic and foreign). Similarly, each firm's final output is either consumed within the United States or exported abroad. In addition to consuming goods and services, households can accumulate savings, which they provide to firms for investments in new production capacity. The government agent receives taxes from both households and firms, contributes to the production of goods and services, and purchases goods and services. Although the model assumes equilibrium, there exist capital flow within regions as they run deficits or surpluses. In aggregate, the value of firm output must equal the sum of its production inputs (zero-profit), the sum of regional commodities and factors of production must equal their demands (market clearance), and household income must equal its factor endowments plus any tax revenue received (income balance). In the model framework, the cost of fuels such as gasoline and diesel account for the costs associated with the manufacturing and transportation of the fuels. The price to the consumer is dependent on the dynamics of the fuel markets, including but not limited to supply and demand conditions, plus any applicable taxes and fees.

Figure 3: Interdependent Economic Flows in N$_{ew}$ERA's Macroeconomic Model



D. Modeling Assumptions

Baseline Conditions

The N$_{ew}$ERA baseline for this analysis was calibrated to the projections published by the Energy Information Administration (EIA) as defined in its Annual Energy Outlook 2021 (AEO 2021) Reference Case.[17] This baseline includes the effects of continuing implementation of energy and environmental regulations that have already been promulgated (e.g., the Regional Greenhouse Gas Initiative (RGGI), the California GHG cap-and-trade program, federal vehicle fuel economy standards, federal appliance energy efficiency standards, and state renewable portfolio standards). The current renewable portfolio standards (RPS) of each state are also represented in N$_{ew}$ERA's electricity sector baseline. The RPS policy

[17] U.S. Energy Information Administration, Annual Energy Outlook 2021, January 2021 (available at https://www.eia.gov/outlooks/aeo/).

specifications are based on the Lawrence Berkeley National Laboratory's RPS Annual Status Update publication.[18]

Key assumptions drawn from the AEO 2021 Reference case include natural gas and crude oil prices, regional electricity demand, and total stock projections for different light-duty vehicle classes. Assumptions relating to the non-electric sector CO_2 emissions for Washington state were drawn from the Carbon Tax Assessment Model (CTAM)[19] developed by the Washington State Department of Commerce supplemented by data from the AEO 2021 Reference case.[20] Assumptions relating to the non-electric CO_2 emissions for California were drawn from the 2020 edition of the California GHG Inventory[21] supplemented by data from the AEO 2021 Reference case. Assumptions relating to non-electric sector CO_2 emissions for the rest of the U.S. are also drawn from the AEO 2021 Reference case. The technology cost assumptions for new fossil-fuel, nuclear and renewable electric generators are based on the EIA's AEO 2021 cost and performance characteristics estimates.[22] Assumptions relating to the attributes of electric vehicles such as fuel economy and on the cost markups of electric vehicles relative to conventional vehicles were also drawn from the AEO 2021 Reference case. Assumptions relating to the cost characteristics, carbon intensity, conversion efficiencies, supply of biofuels as well as blend wall and blend limit specifications for biofuels were drawn from the California Air Resources Board's (CARB) Biofuel Supply Module and ARB's May 2015 Proposed 15 Day Changes LCFS Pathways Scenario.[23]

Model Details Specific to This Study

The version of the macroeconomic model used in the analysis is produced by calibrating the N_{ew}ERA computations framework to reflect a specific set of baseline projections (trends) over the policy impact time period of concern. This analysis estimates economic impacts for the period from 2021 through 2042 with estimates for every third year in that time period.

The N_{ew}ERA model used for this study represents Washington, California, and Rest of the U.S. as three separate regions. The model also includes sectoral disaggregation tailored to match policy implementation and impact considerations. The version of the N_{ew}ERA model used in this analysis includes 12 economic sectors. Five of these are energy sectors, which include coal mining (COL), natural gas extraction and gathering (GAS), crude oil (CRU), petroleum refining (OIL), and the electricity sector (ELE). (The labels

[18] Lawrence Berkeley National Laboratory, U.S. Renewable Portfolio Standards: 2021 Annual Status Update, Electricity Markets and Policy Group, 2021 (available at https://emp.lbl.gov/publications/us-renewables-portfolio-standards-3).

[19] Washington State Department of Commerce, Carbon Tax Assessment Model, January 2021 (available at https://www.commerce.wa.gov/growing-the-economy/energy/washington-state-energy-office/carbon-tax/).

[20] This includes CO_2 emissions from fossil fuel combustion and process CO_2 emissions from the industrial sector (which relate to emissions from the chemical transformation of raw materials).

[21] California Greenhouse Gas 2000-2018 Emissions Trends and Indicators Report (available at https://ww2.arb.ca.gov/ghg-inventory-data).

[22] "Cost and Performance Characteristics of New Generating Technologies," in Annual Energy Outlook, 2021 (available at https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf).

[23] ARB's Biofuel Supply Module Technical Documentation available as part of the materials from the September 14, 2016 CARB Public Workshop on the Transportation Sector to Inform Development of the 2030 Target Scoping Plan Update (available at https://www.arb.ca.gov/cc/scopingplan/meetings/meetings.htm; ARB's May 2015 Proposed 15-Day Changes Scenario).

used to identify each sector in the model are indicated in parentheses.) The seven non-energy sectors[24] represented in this analysis are as follows:

- Agriculture (AGR)
- Commercial transportation other than trucking (TRN)
- Commercial trucking (TRK)
- Energy-intensive sectors (EIS)[25]
- Motor vehicle manufacturing (M_V)
- All other sectors (MAN)[26]
- Services (SRV)

In the transportation sector, household chose between two different types of vehicles – internal combustion engine vehicles (ICEs) and battery-operated electric vehicles (BEVs) based on the relative vehicle life cycle cost differences and consumers' preferences for different vehicles. The model also includes biofuels that can be substituted for gasoline and diesel. Biofuels that can be substituted for gasoline includes imported sugar ethanol, corn ethanol, cellulosic ethanol, and biomass-to-liquid fuel (BTL), compressed natural gas (CNG). Likewise, for the diesel market we include bio-diesel from waste grease and corn, CNG, and BTL diesel.

This study has been conducted to produce Washington, California and rest of the U.S. average energy and macroeconomic outcomes for four policy scenarios through 2042. The first of these scenarios reflects one that links Washington's program with the Western Climate Initiative (WCI) program. In this scenario, all three regions (Washington, California, and Quebec) form a single allowance permit market and are able to sell and buy permits across regions while in the other three scenarios, no linkage between the two programs is assumed. In these scenarios, Washington cannot use permits to offset its emissions and has to rely on its own allowances. The differences in the economic impact of the four scenarios are characterized by comparing their projected changes for several model outputs that are commonly considered to be relevant measures of economic and energy market impact:

- Allowance permit prices
- Consumer welfare,
- U.S. gross domestic product,
- Household consumption,
- Economy-wide fuel consumption,
- Economy-wide electricity generation mix, and
- Wholesale and retail fuel and electricity prices.

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[24] The non-energy manufacturing sub-sectors are aggregated to 3-digit NAICS code and are consistent with U.S. Energy Information Administration's (EIA) Manufacturing Energy Consumption Survey (MECS) sectors.

[25] This comprises pulp and paper, chemicals, glass, cement, iron and steel, alumina and aluminum and mining.

[26] This comprises construction, food, beverage, and tobacco products, fabricated metal products, machinery, computer and electronic products, transportation equipment, electrical equipment, appliances, and components, wood and furniture, plastics and other manufacturing sectors.

The model has the capability to report variety of other modeling outputs of interest that are associated with the above economic impacts for each policy scenario. These include the mix of personal vehicles on the road (internal combustion vs. electric), and CO_2 emissions over time.

The following is a summary of the specific cap-and-trade elements for the different jurisdictions that were modeled for all of the scenarios.

Washington Specific Assumptions[27]

For Washington, the GHG allowance budget available to covered entities that is specified in the Fiscal Note Summary equals 65.6 $MMTCO_2e$ in 2023 declining to about 20.4 $MMTCO_2e$ in 2040. Since the N_{ew}ERA model only represents CO_2 emissions, a CO_2-only emissions cap was developed by scaling the GHG allowance budget downward using the ratio of GHG emissions to CO_2 emissions for 2019. This ratio was developed using data from the Washington Department of Ecology's facility-level greenhouse has reports.[28] The CO_2 emissions cap modeled equals 54.6 $MMTCO_2$ in 2023 declining to about 17.0 $MMTCO_2$ in 2040. The program specifies two compliance periods – a first compliance period from 2023 to 2026 and a second compliance period from 2027 to 2030. A total of 4% of the annual CO_2 emissions cap set were aside in the containment reserve with 30% of the prior's year reserve to be sold at the prior year's auction floor price, leaving unsold allowances in the reserve. The no-cost allowance allocations to EITEs, electric utilities and natural gas utilities are also scaled down to represent CO_2 allowance allocations using the 2019 GHG to CO_2 emission ratios for these entities using data from the Washington Department of Ecology's facility-level greenhouse has reports.[29]

- About 19% of the CO_2 allowance allocations on average in the first compliance period and about 24% in the second compliance period are allocated as an output subsidy to entities classified as emissions-intensive and trade exposed (EITE) entities.[30]

- About 29% of the CO_2 allowance allocations on average in the first compliance period and about 25% in the second compliance period are distributed to electric utilities in order to mitigate the cost of burden of the program on electricity customers.[31]

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[27] The elements of Washington state's cap-and-invest program that were modeled by NERA are consistent with the provisions of the program per the Final Bill Report and the Fiscal Note Summary (available at https://lawfilesext.leg.wa.gov/biennium/2021-22/Pdf/Bill%20Reports/Senate/5126-S2.E%20SBR%20FBR%2021.pdf?q=20211115065505; https://fnspublic.ofm.wa.gov/FNSPublicSearch/GetPDF?packageID=63362).

[28] Greenhouse gas emissions data, Facility greenhouse gas report, Department of Ecology, State of Washington (available at https://ecology.wa.gov/Air-Climate/Climate-change/Tracking-greenhouse-gases/Greenhouse-gas-reporting/Facility-greenhouse-gas-reports). The GHG to CO_2 emissions ratio for 2019 was calculated to be 83.17%.

[29] The 2019 GHG to CO_2 emission shares for EITEs, electric utilities and natural gas utilities were calculated to be 95%, 99% and 0.3% respectively.

[30] These include metals manufacturing, paper manufacturing, aerospace product and parts manufacturing, wood products manufacturing, nonmetallic mineral manufacturing, chemical manufacturing, computer and electronic product manufacturing, food manufacturing, cement manufacturing, and petroleum refining.

[31] As specified in Pg. 120 of the Fiscal Note Summary, electric utilities are not required to consign any of their allocated no-cost allowances in the first compliance period. Thus, the study assumes none of the revenues from the no-cost allowances allocated to electric utilities are applied to reducing electricity rates in the first compliance period. In the absence of current rules relating to no-cost allowance allocations from the second compliance period onwards, it was assumed that from the second compliance

- About 0.1% of the CO_2 allowance allocations on average in the first compliance period and about 0.05% in the second compliance period are allocated to natural gas utilities for the benefit of ratepayers.

Offset credits that could be used to satisfy compliance obligations are specified as fixed percentages of the CO_2 auction allowance budget, calculated by subtracting the allowance set asides in the containment reserve and the no-cost allowances from the CO_2 emissions cap.[32] It was assumed that offsets would be available at a 20% discount to the estimated average auction purchase price outlined in the state's fiscal note.

An estimate of the total CO_2 allowances available to be purchased at auction is obtained by subtracting the offset credits, the allowance set-asides in the containment reserve and the no-cost CO_2 allowance allocations from the CO_2 emissions cap. This estimate is then multiplied by the shares of the fiscal revenue deposited into each of the state investment accounts to calculate the CO_2 allowances that relate to each of the accounts (Climate Investment Account, Carbon Emissions Reduction Account, and the Air Quality and Health Disparities Improvement Account). The revenue from the auctioned CO_2 allowances that relate to each of these accounts is modeled as follows.

- The auction revenues that are deposited into the Climate Commitment Account (which equal 75% of the total revenues from the Climate Investment Account) as well as the revenues deposited into the Air Quality and Health Disparities Improvement Account are assumed to be returned in a lumpsum manner to the Washington households in this study.

- The auction revenues deposited into the Natural Climate Solutions Account (which equal 25% of the revenues from the Climate Investment Account) are used to subsidize the output of the water and sewage utilities sector and the fishing and the forestry sector.

- The auction revenues deposited into the Carbon Emissions Reduction Account are used to subsidize electric vehicles and commercial transportation.

The emissions from the following categories were exempted from coverage across the entire duration of the program.

- Aviation fuel combustion and watercraft fuels[33]
- Coal-fired electric generation[34]

period and going forward, 100% of the revenues from the no-cost allowances allocated to electric utilities are applied towards reducing electricity rates.

[32] 8% during the first compliance period (2023-2026) and 6% thereafter.

[33] The emissions from these two categories to calculated to be about 86% of the total emissions from all the categories that constitute the N_{ew}ERA model's commercial transportation sector using data from Washington's state 1990-2018 GHG inventory (available at https://ecology.wa.gov/Air-Climate/Climate-change/Tracking-greenhouse-gases/Greenhouse-gas-reporting/Inventories).

[34] We exempt emissions from the two coal-fired units in Washington state (Centralia Units 1 and 2).

- Biofuels that have 40 percent lower GHG emissions based on a full-life cycle analysis compared to petroleum fuels[35]
- Motor vehicle and special fuel used for agricultural purposes by a farm fuel user[36]
- National security facilities[37]
- Entities with GHG emissions lesser than 25,000 $MTCO_2e$[38]

Table 5 shows the baseline CO_2, non-CO_2 and GHG emission projections.

Table 5: Baseline Total CO_2, Non-CO_2 and GHG Emission Projections

$MMTCO_{2e}$	**2024**	**2027**	**2030**	**2033**	**2036**	**2039**	**2042**
Residential CO_2	6.5	6.8	6.7	6.5	6.5	6.5	6.6
Commercial CO_2	4.0	4.1	4.1	3.9	3.9	3.9	4.0
Industrial CO_2	15.5	16.0	16.7	16.9	17.2	17.8	17.7
Transportation CO_2	44.0	45.1	46.5	46.5	46.2	47.7	47.0
Electric CO_2	7.5	3.6	3.3	3.3	4.6	4.6	4.6
Total CO_2	77.6	75.6	77.3	77.2	78.4	80.6	80.1
Covered CO_2	56.4	56.7	57.4	56.9	57.5	59.3	58.4
Non-Covered CO_2	21.2	18.9	19.9	20.3	20.9	21.3	21.6
Non-CO_2[39]	15.7	15.3	15.6	15.6	15.8	16.3	16.2
Total GHG[40]	93.2	90.9	92.9	92.8	94.3	96.9	96.2

Table 6 shows the GHG emissions allowance budget specified in the Fiscal Note Summary, the CO_2 emissions allowance budget (CO_2 emissions cap) developed and the no-cost CO_2 allowance allocations to EITEs, electric utilities and natural gas utilities.

[35] We exempt emissions from Sugar Ethanol, Cellulosic Ethanol, BTL diesel, Bio-diesel, and CNG.

[36] We exempt about 53% of the petroleum emissions from the agriculture sector in Washington state.

[37] We exempt emissions from national security facilities in Washington state which is estimated to account for about 45% of the emissions from the government sector.

[38] To exempt emissions from these entities in our modeling, we rely on the 2018 Statistics of U.S. Businesses (SUSB) data tables for Washington state (available at https://www.census.gov/data/tables/2018/econ/susb/2018-susb-annual.html). Using this data, we calculate the percentage of firms in each of the four NewERA sectors in Washington state - AGR, EIS, MAN, that are reported to have <10 employees. This is employed as a proxy to represent entities with GHG emissions lesser than 25,000 $MTCO_2e$. These percentages are then applied to the baseline CO_2 emissions from each of the four sectors in the NewERA model to calculate the emission exemptions from these sectors. The exemption shares developed using this approach were obtained to be 83% for AGR, 52% for EIS, 78% for MAN, and 74% for the SRV sector.

[39] The Non-CO_2 emissions in the baseline are estimated using the total CO_2 emissions in the baseline and the GHG to CO_2 emissions ratio for 2019 of 83.17%.

[40] The total GHG emissions equal the sum of the total CO_2 and non-CO_2 emissions.

Table 6: GHG, CO_2 Emissions Allowance Budget and No-Cost CO_2 Allowance Allocations

MMTCO$_2$e	**2024**	**2027**	**2030**	**2033**	**2036**	**2039**	**2042**
GHG Emissions Allowance Budget	61.3	51.0	37.1	31.7	26.6	21.5	18.4
CO_2 Emissions Allowance Budget	51.0	42.4	30.9	26.4	22.1	17.9	15.3
CO_2 No-Cost Allocations (EITEs)	9.1	8.8	8.8	8.6	8.6	8.6	8.6
CO_2 No-Cost Allocations (ELE)	14.7	11.1	7.4	6.1	4.7	3.3	2.2
CO_2 No-Cost Allocations (GAS)	0.03	0.02	0.01	0.01	0.01	0.01	0.004

In the linked case with "speed bumps", Washington was assumed to adopt reserve tiers or otherwise have access to "speed bump" allowances from California with the "speed bump" prices set at one-half and three-fourths of the difference between the floor and ceiling prices. To represent myopic behavior, it was assumed that the obligated parties will use an adequate amount of allowances such that the allowance price would remain at the "speed bump" price in 2024. In the two additional sensitivity scenarios (without WCI linkage) that were run, Washington was assumed to adopt its own price ceiling on cap-and-trade allowance prices. In the first scenario, it was assumed that Washington would adopt California's ceiling price trajectory (i.e., \$65/metric ton of CO_2 starting in 2021 rising at 5% per year (and adjusted for inflation) in 2023, the first year of its cap-and-invest program. In the second scenario, it was assumed that Washington would adopt a ceiling price trajectory that starts at \$40/metric ton of CO_2 in 2023 rising at 5% per year (and adjusted for inflation).

California Specific Assumptions[41]

For California, the emissions cap modeled in N$_{ew}$ERA was based on a 2030 GHG target of 40% below 1990 levels with the emissions cap assumed to decline towards the 2050 target of 80% below 1990 levels. Offset credits that could be used to satisfy compliance obligations were specified as fixed percentages of the annual emissions cap.[42] A price ceiling on cap-and-trade allowance prices of \$65/metric ton of CO_2 in 2021 rising at 5% per year (and adjusted for inflation) was modeled along with two reserve tiers with the prices of allowances to be made available at these tiers set at one-half and three-fourths of the difference between the floor and ceiling prices. A certain portion of the allowances from the annual emissions cap was placed into an Allowance Containment Reserve (APCR).[43] Two-thirds of the remaining APCR allowances at the end of 2020 were spread evenly across the two reserve tiers and the remaining one-third plus unsold allowances that have been transferred into the APCR were made available for purchase at the

[41] Regulation for the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms (available at https://ww2.arb.ca.gov/resources/documents/cap-and-trade-regulation-unofficial-current-version); "USA – California Cap-and-Trade Program," ETS Detailed Information, International Carbon Action Partnership, Last Updated: 12 April 2021 (available at https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=45).

[42] 8% from 2018 to 2020, 4% from 2021 to 2025, and 6% post 2025.

[43] 1% from the 2013-2014 compliance period; 4% from the 2015-2017 compliance period; and 7% from the 2018-2020 compliance period.

ceiling price. Additional allowances were set aside for the two lower price reserve tiers from 2021-2030 per the specification in the cap-and-trade regulation (as shown in Table 7).[44]

Table 7: Number of California GHG Allowances Allocated to the APCR for Budget Years 2021 to 2030

Budget Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
APCR Allocations (MMT CO_2e)	12.77	11.57	10.37	9.27	8.07	6.97	5.77	4.57	3.47	2.27

A suite of the California specific complementary measures was also modeled for all of the scenarios which include a 50% renewable portfolio standard by 2030, a doubling of energy efficiency in commercial buildings by 2030, low carbon fuel standard (LCFS) targets which involve a 10% improvement in carbon intensity (vs. 2010 levels) by 2020 and an 18% improvement in carbon intensity by 2030 and a zero-emission vehicle requirement of 1.5 million vehicles by 2025 and 4.2 million vehicles by 2030.

Quebec Specific Assumptions[45]

For Quebec, the emissions cap modeled in N_{ew}ERA was based on a 2030 GHG target of 37.5% below 1990 levels with the emissions cap assumed to decline towards zero to attain carbon neutrality by 2050. Offset credits that could be used to satisfy compliance obligations were specified as fixed percentages of the annual emissions cap.[46]

A total of 4% of the annual emissions cap set were aside in an APCR. Since the N_{ew}ERA model does not explicitly include Quebec as a separate region, reductions that could be attained from the non-electric sector in Quebec were modeled through a marginal abatement cost curve (MAC) which specify different abatement quantities and associated carbon prices. The MAC curve for Quebec was developed by comparing its non-electric emissions intensity with those of U.S. states. The N_{ew}ERA model was then run for those U.S. states whose non-electric emissions intensity matched most closely with that in Quebec using different carbon prices imposed on the non-electric sectors to obtain the associated quantity of emissions abatement. No reductions were assumed to come from the electric sector.

[44] Regulation for the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms (available at https://ww2.arb.ca.gov/resources/documents/cap-and-trade-regulation-unofficial-current-version).

[45] "Technical Overview", Quebec cap-and-trade system for greenhouse gas emission allowances (C&T) (Available at https://www.environnement.gouv.qc.ca/changements/carbone/documents-spede/technical-overview.pdf) ; Canada – Quebec Cap-and-Trade Program," ETS Detailed Information, International Carbon Action Partnership, Last Updated: 12 April 2021 (Available at https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=73).

[46] Up to 8% of each entity's compliance obligation.

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