Climate Pollution Reduction Grants – Implementation Grants
Technical Appendix

1. Documentation of Greenhouse gas (GHG) Reduction Assumptions

This appendix explains the method and assumptions used for developing the estimated GHG and co-pollutant emissions reduced by the various priority measures included in the Implementation Grant Application for the state of Texas. Assumptions used to quantify emission reductions also include implementation schedules. The emission reductions for the priority measures were estimated using the Energy Policy Simulator (EPS) v. 3.4.3, an open-source computer model created by Energy Innovation and the Rocky Mountain Institute (RMI). The EPS is a system dynamics computer model simulated by a tool called Vensim. Vensim was developed by Ventana Systems for the creation and simulation of System Dynamics models. Current emissions were calibrated to the U.S. Environmental Protection Agency's (EPA's) inventory and current policy progress was assessed using information in Climate Xchange's State Climate Policy tracker and supplemental desk research (EPS Documentation and RMI State scorecard, 2024).

a. Emissions Reduction Estimate Method

Data used to estimate the emissions reductions for the priority measures were obtained primarily from national data sets and data sets that are open source. This data includes energy consumption per sector from the Energy Information Administration (EIA), EPA-developed GHG emissions inventory for Texas, and data on technology stock and cost of technologies from the National Renewable Energy Lab (NREL). GHG emissions were quantified in million metric tons (MMT) carbon dioxide equivalents (CO_2e) but converted to metric tons (MT) CO_2e for the purpose of this grant application and include the following GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gasses (F-gasses). The co-pollutants quantified include nitrogen oxide (NO_X), fine particulate matter ($PM_{2.5}$), coarse particulate matter (PM_{10}), black carbon (BC), organic carbon (OC), volatile organic compounds (VOC), sulfur oxide (SO_X), and carbon monoxide (CO). Table 1 shows the data sources summary used for the model.

Table 1: Data Source Summary used for the TCEQ Emissions Reduction Model

Sector	Subsectors	Sources
Electricity	In-state capacity and generation	EIA's Form 923 and EIA's Form 860 EIA's State Electricity Profiles
Industrial Energy Use	All fuel use for industrial sector	EIA's Annual Energy Outlook tables on Industrial Energy Use & EIA's State Energy Data Systems from 2020
Industrial Process Emissions	Industrial Process Emissions	U.S. State-level Non-CO2 GHG Mitigation Report

Sector	Subsectors	Sources
Transportation	All energy use, vehicle miles	EIA's State Energy Data Systems from 2020, EIA's Annual Energy Outlook tables on Industrial Energy Use & NREL Electrification Futures Study - Reference Scenario

The methodology for the Business-as-Usual (BAU) policies varies by sector. For the industry energy and process emissions, the annual energy outlook reference case was used to project growth rates. For the electric power BAU, the state's renewable portfolio standards were used. Also, federal tax credits (prior to the Inflation Reduction Act) were included. For the transportation sector, vehicle sales were estimated using forecasted vehicle prices, resulting in some economic adoption of electric vehicles. Subsidies on zero-emission vehicles were also included in the BAU modeling. Fuel economy assumptions accounted for the most recent EPA/National Highway Traffic Safety Administration tailpipe CO_2 and fuel economy standards.

Some of the projected emissions for the proposed measures in the implementation grant application were estimated using the Nationally Determined Contributions (NDC) (EPS Documentation 2024). The policy assumptions for the U.S. NDC Scenario is shown in Table 2 below.

Table 2: NDC Policy Assumptions used for the TCEQ Emissions Reduction Model

Sector	U.S. NDC Scenario
Electricity	• Clean electricity standard of 80% by 2030, and 100% by 2035 • Accelerated deployment of storage, transmission, and demand response • Electricity sector carbon capture and sequestration applied to remaining gas plants run for occasional balancing and reliability by 2050
Industry	• 14% improvement in industrial energy intensity/efficiency by 2050 • 100% shift from fossil fuels to a mix of electricity and hydrogen, varying by industrial potential for each fuel type, by 2050 • 100% achievement of potential emissions reductions from methane capture and destruction in natural gas and oil, coal mining, water, and waste sectors by 2030 • 100% of hydrogen is produced via electrolysis by 2050 • Industrial CO2 emissions captured and sequestered by 2050 for refining, chemicals, cement, iron and steel, and energy processing sectors
Transportation	• 100% electric new light-duty vehicle, motorbike, and bus sales by 2035 • 100% electric new medium- and heavy-duty truck sales by 2045 • 60% improvement in fuel economy standards for internal combustion engine light-duty vehicles by 2035, as well as a 50% improvement for buses, a 50% improvement for medium- and heavy-duty freight vehicles, a 60% improvement for aircraft, and a 25% improvement for rail and ships • 10% light-duty vehicle miles traveled reduced or shifted from BAU by 2050 • 3% reduction in truck freight transport by 2050

The methodology for TCEQ measures proposed in this grant application is explained further below.

Petrochemical and Refinery Innovation: The petrochemical and refinery innovation measures will include projects that focus on industrial decarbonization, electrification and hydrogen efficiency, and carbon capture. To estimate the emissions reductions for this measure, the EPS policy lever on electrification and hydrogen was used. This policy reduces GHG emissions by switching the fuel used by facilities for medium and high temperature operations to electricity and hydrogen. Since it is easier to electrify low temperature operations while hydrogen can meet needs of any temperature, this was considered in the model.

A 100% fuel shift to electricity was estimated for oil and gas extraction. Meanwhile, for chemicals and refined petroleum and coke, a 19% shift to hydrogen and 81% shift to electricity was estimated because there is more high temperature equipment in these sectors that can utilize hydrogen.

The measure on promoting industrial processes that would ease improved carbon capture was modeled using the industry carbon capture and sequestration (CCS) policy. This policy specifies the fraction of CO_2 emissions from industry that is captured and stored, above the amount predicted in the business-as-usual scenario. Although very few CCS-equipped industrial facilities exist today, CCS settings as high as 100% is workable under scenarios in which industry mostly or entirely transitions to clean energy due to other policies such as industrial fuel switching and industrial energy efficiency. Thus, industries considered in this measure include, refined petroleum and coke, and chemicals. CO_2 emissions in both energy-related emissions and process emissions were considered. GHG emissions reductions from methane capture was also calculated. This will include innovations to stop leaks from wellheads and pipes, increasing the methane capture from these industries that is currently being released into the atmosphere. The percentage of potential achieved was projected at 50%. For all measures, it was assumed that the implementation schedules will reach 100% by 2030 in accordance with the timeframe for the CPRG implementation grant. A forecast of the emissions reductions till 2050 with this implementation schedule is shown.

Figure 1 below shows the emission effects for the petrochemical and refinery innovation measure from 2020 to 2050, comparing the BAU with the TCEQ petrochemical and refinery model. The graph shows that industrial electrification and hydrogen use will have the most impact on emissions reductions compared to carbon and methane capture (EPS 2024, Industrial sector).

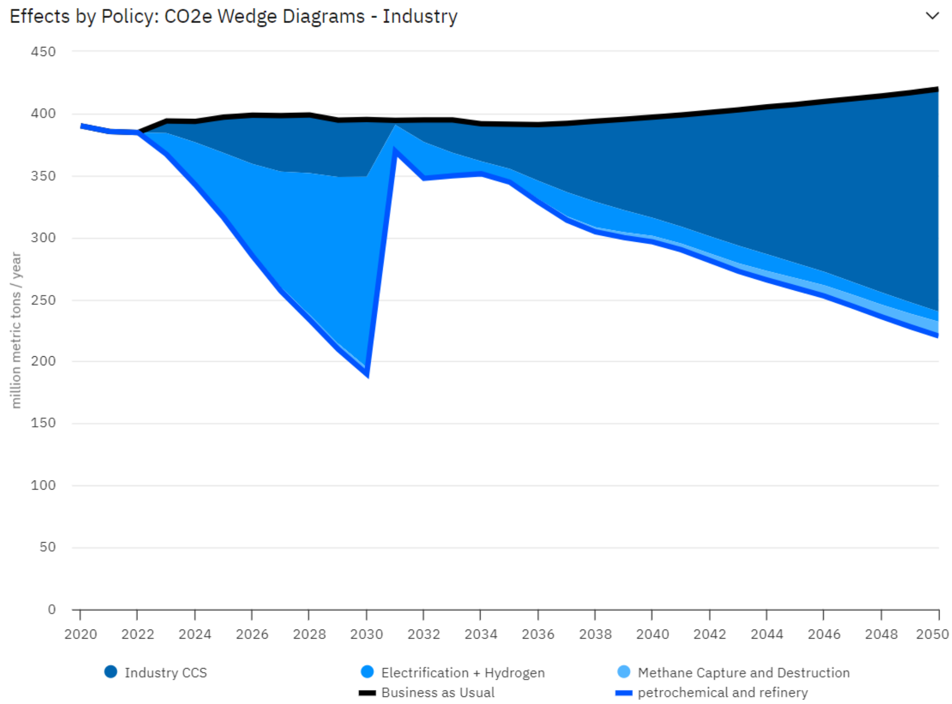

Figure 1: Emission Effect for the Petrochemical and Refinery Innovation Measures from 2020 through 2050

<u>New Oil and Gas Technology:</u> The Oil and Gas New Technology measure, like the refinery and petrochemical measure, also considered electrification of equipment as a means of reducing GHG emissions. It used the electrification and hydrogen policy lever to model the electrification model. The industry category considered includes oil and gas extraction, machinery, appliances, and electrical equipment as well as energy pipelines and gas processing. A 100% fuel shift to electricity was used for this model. It should be noted that only fuel consumed for energy, not fuel used as a chemical feedstock was modelled. The improved system design and industry energy efficiency standards policy levers were used to model the proposed measures on developing more efficient equipment and monitoring new technology projects (i.e., reporting, notification, record keeping and permit conditions). For all oil and gas new technology measures, the model assumed an implementation schedule of 50% achieved by 2030 and 100% by 2050. Figure 2 shows the emission effects for the oil and gas new technology measure from 2020 to 2050, comparing the BAU with the TCEQ Oil and Gas model. The graph shows that industrial electrification and hydrogen use will have the most impact on emissions reductions compared to carbon and methane capture (EPS 2024, Industrial sector).

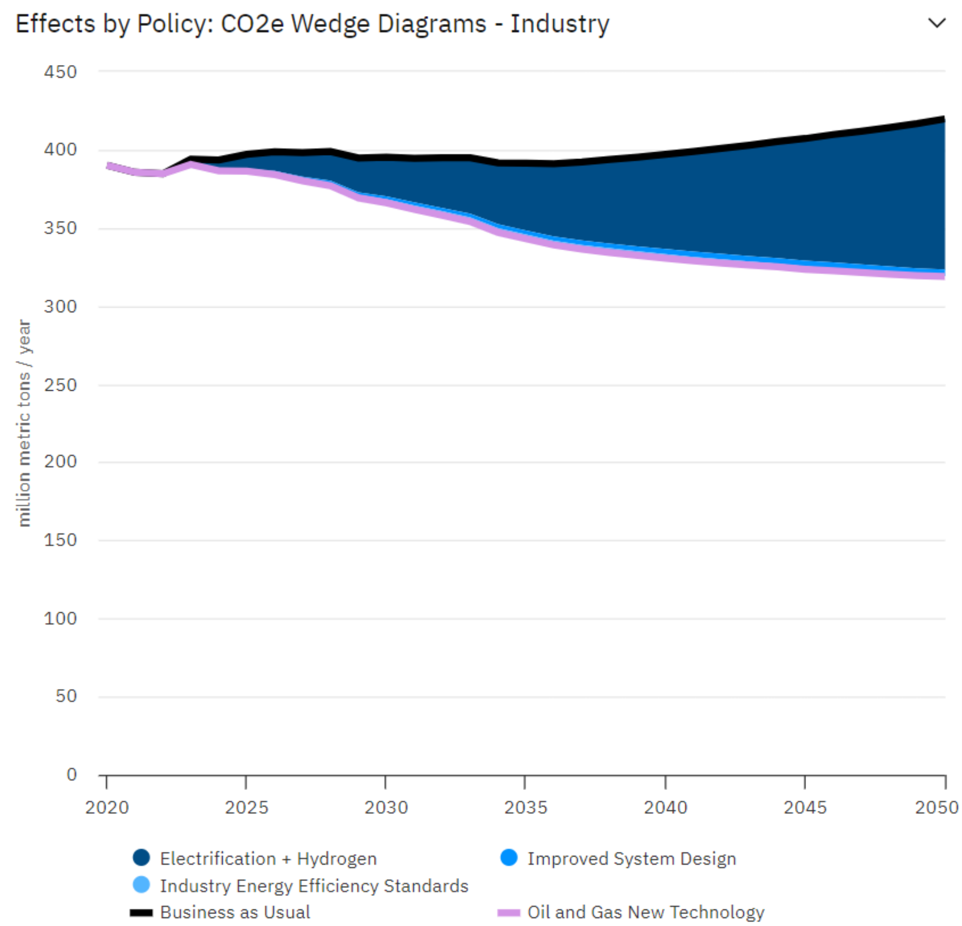

Figure 2: Emission Effect for the Oil and Gas New Technology Measures from 2020 through 2050

Electric Power Innovation: To model the Electric Power Innovation measures, several policies from the Electricity Supply section of the EPS were used. The Carbon Capture and Sequestration lever was used to model emissions reductions for carbon capture. Electricity sources considered here include petroleum and natural gas peaker. A 100% CO_2 capture was estimated. To model load shifting projects, the demand response policy in the EPS was used. This policy represents regulations that cause more demand response (DR) capacity to be added to the electric grid. Demand response provides flexibility that allows for the integration of more wind and solar PV, if the electricity system is flexibility constrained. This could lead to a 52% increase in the demand capacity in 2050 compared to the Business-as-usual (BAU) scenario. Grid-Scale Electricity Storage and Increase Transmission policies were used to estimate the reductions for transmission upgrades and renewable storage projects. This will involve building additional transmission capacity. Transmission increases the flexibility of the grid, allowing for the integration of more wind and solar PV, if the electricity system is flexibility constrained. The electricity storage measure would involve innovations for developing chemical batteries for increased storage capacity. A 100% potential achieved was used to model both transmission and grid storage. For projects that would involve developing modular nuclear or molten salt reactors, the lever on subsidy for capacity construction was used to model this. A 30% construction cost for nuclear reactor projects and 1% construction cost for geothermal projects was used for this model although, this can vary based on the implementation agency's discretion. For all measures, it was assumed that the implementation schedules will reach 100% by 2030 in accordance with the timeframe for the CPRG implementation grant. A forecast of the emissions reductions till 2050 with this implementation schedule is shown. Further emissions reductions can be achieved beyond 2030 to 2050 with other funding sources that can enable the implementation of new clean energy technologies. Figure 3 below shows the emission effects of the different policy measures on the electric power industry sector from 2020 to 2050, comparing the BAU with the TCEQ model. The graph shows that carbon capture and sequestration will have the most impact on emissions reductions compared to other policy measures (EPS 2024, Electricity sector).

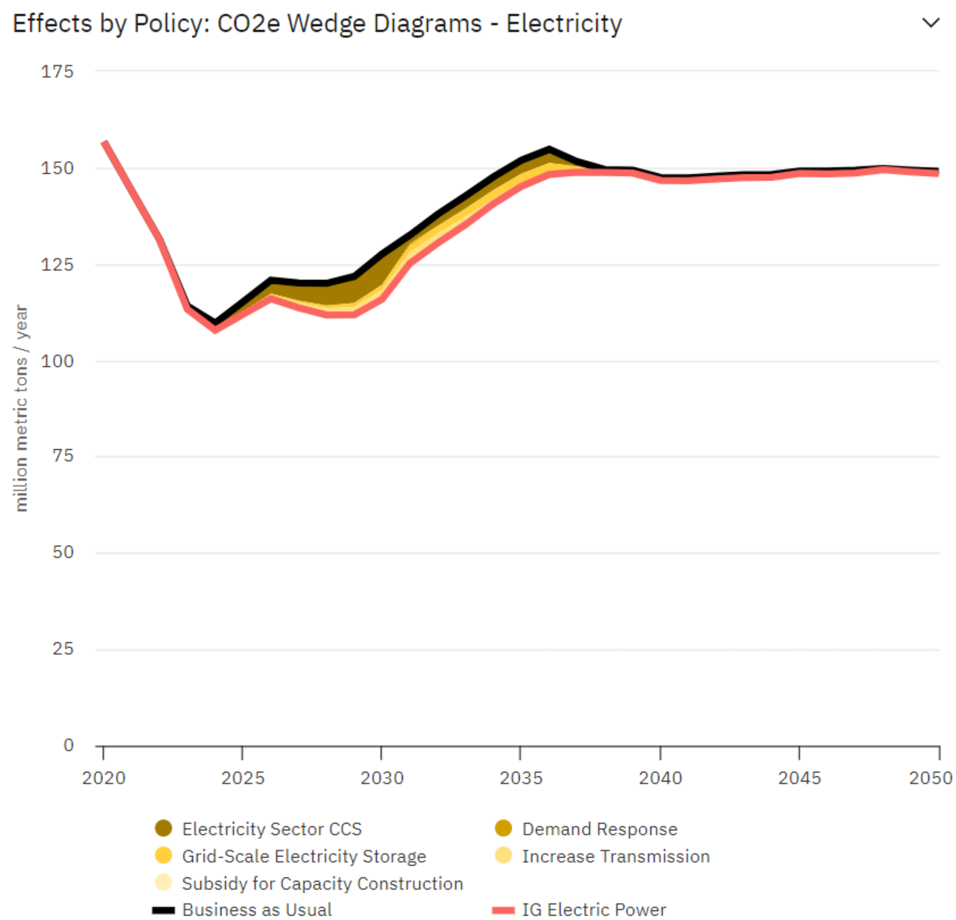

Figure 3: Emission Effect for the Electric Power Industry Measures from 2020 through 2050

<u>Rural Vehicle Replacement:</u> To model the Rural Vehicle Replacement measure, the electric vehicle subsidy in the transportation section was used. It was estimated that 18% of the vehicle cost would be rebated and this was used for the model although this can vary based on the implementing agency's discretion. Figure 4 shows the emission effects for the rural vehicle replacement measure from 2020 to 2050, comparing this to the business as usual (BAU) scenario. The graph shows that replacing rural vehicles with vehicle electrification technologies will continue to lead to a decrease in GHG emissions within the transportation sector (EPS 2024, Transportation sector).

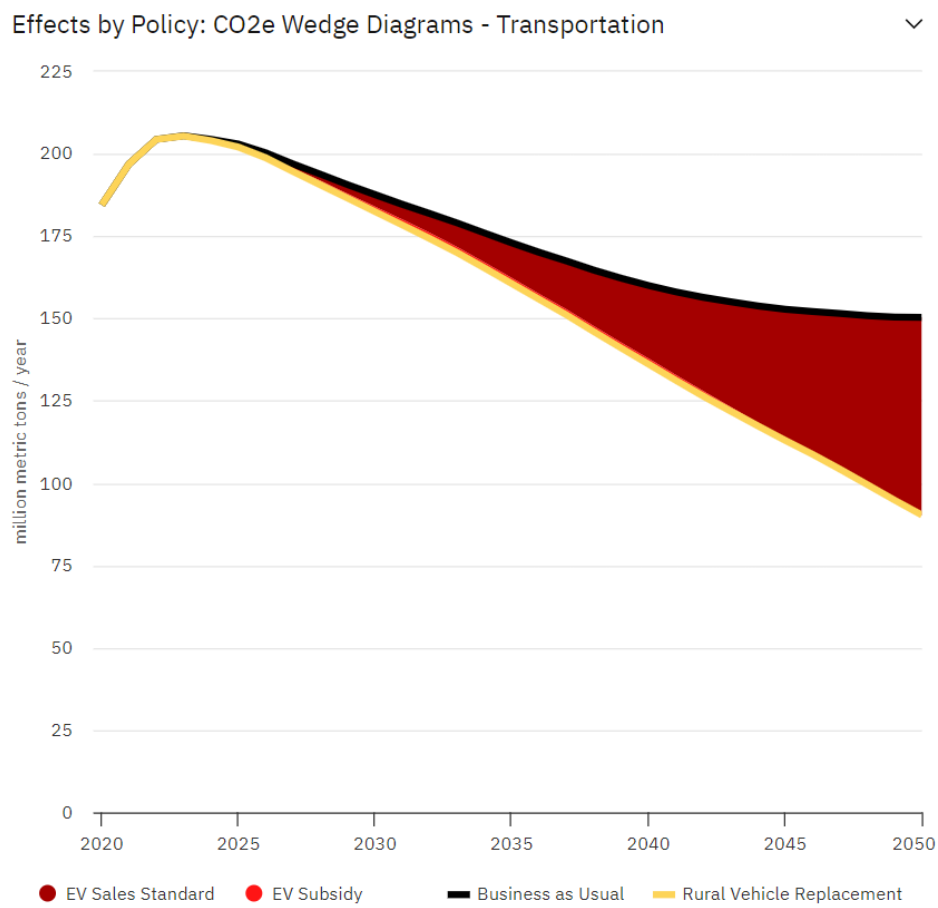

Figure 4: Emission Effect for the Rural Vehicle Replacement Measure from 2020 through 2050

b. Cost Effectiveness Estimate Method

To calculate the cost effectiveness of each measure based on the requested funding for the projects, the policy package cost in the Energy Policy Simulator was used. The proportion of emissions reductions based on the capital equipment cost for each measure was used to estimate how much reductions would be achieved with the requested funding. Assumptions were made for the cost sharing capacity that the implementing agency would utilize as shown in Table 3 below. For the petrochemical and refinery innovation, a 30% cost sharing was assumed. The oil and gas new technology measure used a 50% cost sharing while the rural vehicle replacement assumed a 75% cost sharing. For the electric power, it was assumed that 100% of the cost would come from the CPRG funding. These cost-sharing assumptions may change as the details of each grant program are developed with a third-party administrator.

Table 3: Cost Effectiveness of the Proposed Measures for the Implementation Grant

Proposed Measures	GHG Emission Reductions (MT CO_2e) by 2030	Cost	Cost Sharing Percentage Used
Rural Vehicle Replacement	187,247	$62,194,996	75%

Proposed Measures	GHG Emission Reductions (MT CO_2e) by 2030	Cost	Cost Sharing Percentage Used
Electric Power	1,811,763	$194,646,247	100%
Oil and Gas New Technology	2,352,838	$186,350,000	50%
Petrochemical and Refinery Innovation	2,743,437	$482,145,820	30%

c. Measure Implementation Assumptions

The following key assumptions about measure implementation were used for the emissions reduction quantification:

- Geographic scope: The state of Texas was used as the geographical scope for the model in EPS.
- Measure lifetime: Based on the CPRG implementation grant, the measure implementation is expected to span five years from 2024 to 2029.
- Capital cost assumptions: This was estimated based on the policy package cost from EPS. The cost of operations and maintenance was not included.
- The Assessment Report 5 Global Warming Potential (AR5 GWP) values were used.
- The simulator tried to incorporate the latest state policy, but some sectorial policies may be missing, especially if they principally affect energy demand.

d. Emissions Reduction Estimate Assumptions

Several assumptions exist in the EPS simulator for modelling the emissions reduction. The goal of the model's design was to forecast the results of combinations of policy measures, not necessarily to find the "optimal" set of activities to accomplish a particular goal in Vensim. Policies that include establishing goals that must be reached by unidentified means are typically excluded from the EPS's collection of policy control levers. There are, however, some outliers, where the EPS has decision-making logic built in and technical and economic factors are the primary considerations. The model determines the kinds of new power plants that utilities will construct, for instance, taking into consideration different costs and the need for system flexibility. A policy known as the Renewable Portfolio Standard / Clean Energy Standard is included in the EPS and sets a target for the percentage of clean electricity that must be produced. Since this operates within a narrow domain supported by an EPS decision-making framework, it is possible to include a policy that specifies a target and lets the EPS build power plants to meet it, rather than specifying which plant types to build.

e. Reference Case Scenario

To understand how the GHG emissions reductions were calculated, we consider a reference case scenario e.g., Industrial Decarbonization by Electrification and Hydrogen Use. The BAU input data for the process emissions were obtained from industrial production, imports, and exports. The amount of desired fuel shifting for the petrochemical, refinery and oil and gas applications was specified using the policy levers. The industrial fuel shifting strategy was divided into two levers, one for low temperature industrial heat and the other for medium and high temperature industrial heat. This is because distinct industrial processes want heat at different temperatures, meaning that distinct technological solutions will be needed. Industrial heat pumps are the most economical and efficient solution for low temperature heating needs. Induction or electric resistance heating, as well as the burning of an emission-free fuel such as green hydrogen, may be necessary for operations requiring higher temperatures. Using the input data, the percentage of fuel used for energy purposes was determined by temperature range. All heat demand below 200 degrees Celsius was classified as low temperature industrial heat in the United States, and all demand beyond that temperature was classified as medium and high temperature industrial heat.

The fuel shifting was applied to all fuels labeled as eligible in the input data variable, 'Industrial Fuels Subject to Fuel Shifting'. To reflect the use of industrial heat pumps, all fuel consumption for low temperature industrial heat was switched to electricity.

Since the conversion is based on the fuel's energy content, an efficiency adjustment was made when using electricity as a recipient fuel type to consider its higher efficiency when compared to thermal fuels. Since temperature range is a subscript in efficiency modification, moving "Low Temperature Industrial Heat" was done according to industrial heat pumps' coefficient of performance. The target fuel type was subscripted into the policy lever for medium and high temperature industrial heat. Electricity can supply a significant amount of this heat requirement, and switching to electricity requires an efficiency adjustment as well. To achieve the maximum temperature requirements that are not feasible to electrify, some fuel use was also shifted to hydrogen.

To find "Industrial Fuel Use for Energy Purposes before CCS and Methane Capture," the variable "Fuel Use for Energy Purposes before Fuel Shifting" was multiplied by the change in fuel consumption from fuel shifting (EPS Documentation 2024).

f. Co-pollutant Emissions Reduced

The EPS tool also provided quantified emission changes for NO_X, $PM_{2.5}$, PM_{10}, BC, OC, VOC, SO_X, and CO for the proposed measures. Each co-pollutant shows an overall decrease and there is an overall decrease in total co-pollutants. Implementation of the priority measures for the different measures is predicted to reduce a total of 0.37 MMT of co-pollutants from 2025 through 2030 and 1.05 MMT from 2025 through 2050. Table 4 shows the cumulative change in co-pollutants emissions for the proposed measures. NO_X and CO have the most emissions for all measures. Comparing the business-as-usual scenario with the projected model shows implementation of the priority measures will decrease all co-pollutant emissions up to 2050.

Table 4: Cumulative Chane in Co-Pollutant Emissions for the Four Proposed Measures

Co-Pollutant	2025 – 2023 BAU	2025 – 2030 Projected	2025 – 2030 Change	2025 – 2050 BAU	2025 – 2050 Projected	2525 – 2050 Change
PM_{10}	0.1703	0.1669	0.0035	0.19297	0.16542	0.02754
$PM_{2.5}$	0.109617	0.100779	0.008838	0.1249897	0.0776858	0.0473039
BC	0.014934	0.014473	0.000461	0.015514	0.011749	0.003765
OC	0.03035	0.02944	0.00091	0.0338	0.031	0.0028
NO_x	1.5430264	1.4320077	0.1110187	1.619602	1.348412	0.271191
VOC	2.73907	2.60422	0.13485	3.20403	3.13748	0.06655
SO_X	0.295416	0.292236	0.00318	0.35275713	0.31963698	0.03312015
CO	3.0256762	2.9145149	0.1111613	2.85941	2.2618	0.59761

Co-Pollutant	2025 – 2023 BAU	2025 – 2030 Projected	2025 – 2030 Change	2025 – 2050 BAU	2025 – 2050 Projected	2525 – 2050 Change
Total	7.928400984	7.554518618	0.373882366	8.403098	7.353195	1.049903

g. References

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