An Impact Evaluation Proposal

Oregon's "Cap-and-Trade" Climate Protection Program

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Introduction

In its most recent report, the Intergovernmental Panel on Climate Change (IPCC) warned that without immediate and deep emission reductions, limiting the worst effects of global warming and preventing temperatures from rising above 1.5°C will not be possible.[1] After the report was published, IPCC Chair Hoesung Lee claimed that humanity is "at a crossroads," with the "tools and know-how required to limit warming" and "secure a livable future" despite misleading information from governments resistant to radical changes in the composition of energy markets and the global economy.[1]

One of the mechanisms increasingly supported by economists, policymakers, and industry leaders to achieve emission reductions is known as "cap-and-trade." A cap-and-trade program– also known as an emissions trading system (ETS)– seeks to reduce greenhouse gas (GHG) emissions, provide a market-friendly alternative to traditional command and control structures, and establish a high level of certainty about the level of future emissions.

On January 1st, 2022, the Climate Protection Program (CPP)– based on the cap-and-trade model– went into effect in the State of Oregon. As the newest cap-and-trade market in the United States, the impact of the program on Oregon GHG emissions are of massive importance. Indeed, the effectiveness of the program may determine whether cap-and-trade is a viable solution for decreasing emissions in U.S. in the face of command-and-control alternatives like emissions regulation.

This proposal is split into several parts. I begin by outlining the basic design of cap-and-trade systems and CPP-specific functions. I provide a causal logic model detailing the program. Then, I discuss prior studies and evaluations. I introduce my proposed impact evaluation design, data sources, measures, and methods of analysis for the first compliance period (2022-2024). I close with a description of challenges and recommendations relevant to the implementation of my proposed impact evaluation.

Policy Background

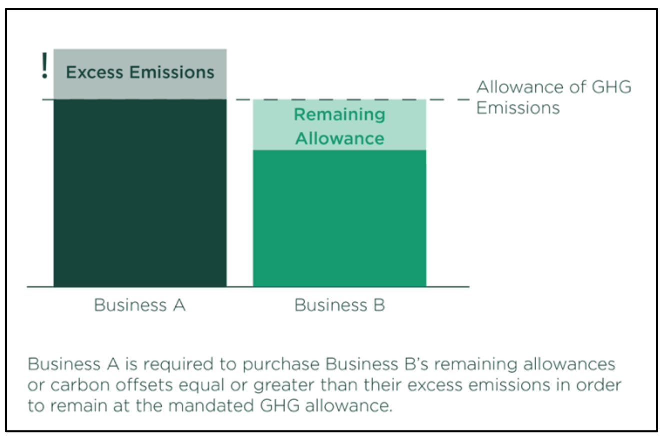
Basic Design

A cap-and-trade system has two main components. The government (or another facilitating administrator) sets an emissions cap and issues a quantity of emission allowances credits, also known as a "permit to pollute." Covered entities must hold allowances for GHG emissions they produce. Entities can then buy and sell these allowances, which establishes the market price of carbon.[2] Thus, companies are incentivized to lower emissions so they can sell their excess allowances to companies that are above the emissions cap. Figure 1 demonstrates the basic design of a cap-and-trade market. In this example, the allowance limit applies to Business A and Business B. Because Business A is out of compliance, it must purchase Business B's remaining allowance credits.

Table 1. Other Key Elements

Offsets	A reduction or removal of emissions made in order to compensate for emissions made elsewhere. (C2ES)
Target	The level of emission reduction required by when, based upon a specified baseline year. (C2ES)
Compliance Periods	The number of times an entity is able to surrender allowances. (C2ES)
Banking	The ability to submit permits issued in one year to account for emissions in later years. (C2ES)
Borrowing	The ability to use permits for future years in the current year. (C2ES)

Figure 1. Basic Design of Cap-and-Trade



Other key elements are highlighted in Table 1. These are not required– rather, they are key mechanisms present in some (but not all) cap-and-trade systems. In some markets, there are sectors (e.g., agriculture, forestry, landfills) not covered by the cap. If allowed, GHG emission reductions from these uncovered actors can be sold to covered entities in the form of a carbon offset credit. This provides an alternative to trading and selling allowances. Instead, entities with emissions beyond the cap can simply "offset" their emissions by purchasing offsets from unregulated sectors.[3] Critics claim that offsetting emissions are not a valid substitute for real emissions reductions, and rather allow companies to "pay to pollute."[4]

Climate Protection Program Design

According to the Oregon Department of Environmental Quality (DEQ), the purpose of the CPP is to reduce GHG emissions, achieve co-benefits from other air contaminant reductions, and enhance public welfare for Oregon communities– particularly environmental justice communities.[5] The program seeks to achieve these goals and regulate emissions through two approaches:

1. Using declining and enforceable limits on GHG emissions for covered fuel suppliers.
2. Utilizing the best emissions reduction approach for covered stationary sites (e.g., BAER assessments and orders).

Figure 2. Covered Fuel Suppliers

Covered Fuel Suppliers

Natural gas utilities (local distribution companies)

Suppliers of gasoline, diesel, kerosene, and propane with emissions that meet or exceed the threshold for inclusion

GHG Emission Limits

The 2022 base cap is 28.1 million metric tons of carbon dioxide equivalent (MT CO_2e), based upon average 2017 to 2019 emissions. DEQ lowers this threshold every year, reaching a 90% reduction in emissions by 2050. As the cap declines, so will the amount of compliance instruments (e.g., allowances) given to covered fuel suppliers.

Figure 2 identifies the fuel suppliers covered by the CPP. For the first compliance period (2022-2024), the threshold of inclusion for covered fuel suppliers is set at 200,000 MT CO_2e or more for any year since 2018. This will decrease to 100,000 MT CO_2e in 2025 and will lower to 25,000 MT CO_2e by 2031, thus expanding the program to more fuel suppliers.

On March 31, 2022, DEQ issued 2022 compliance instruments to the covered fuel suppliers currently covered by the program (e.g., those at or above the threshold of 200,000 MT CO_2e). These are then distributed to covered fuel suppliers based on the following formula:

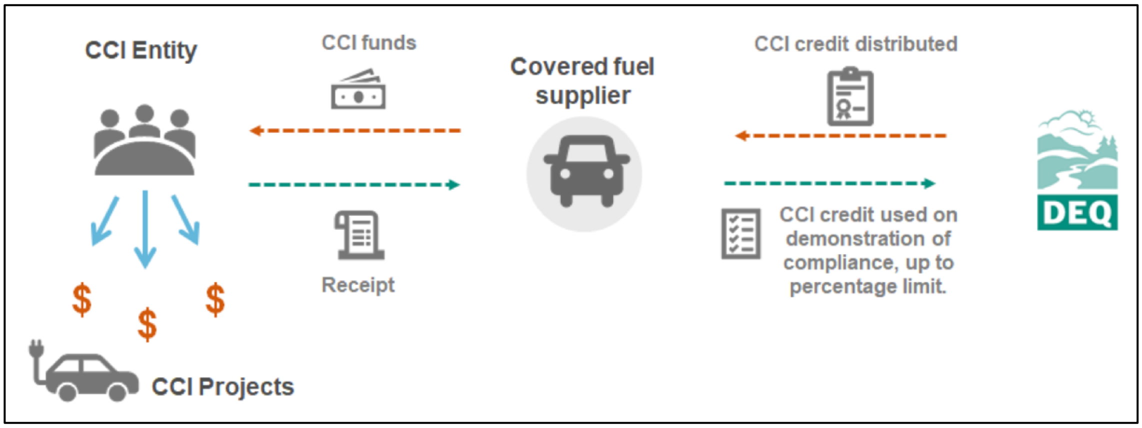
Number of Compliance Instruments = Total Compliance Instruments to Distribute * ([Covered Fuel Supplier Covered Emissions + Covered Fuel Supplier Biofuel Emissions]/Total Emissions)

In total, 27,681,327 2022 compliance instruments were distributed to eighteen covered fuel suppliers. Fossil fuel suppliers can trade unused compliance instruments or bank them for future use.

Community Climate Investments

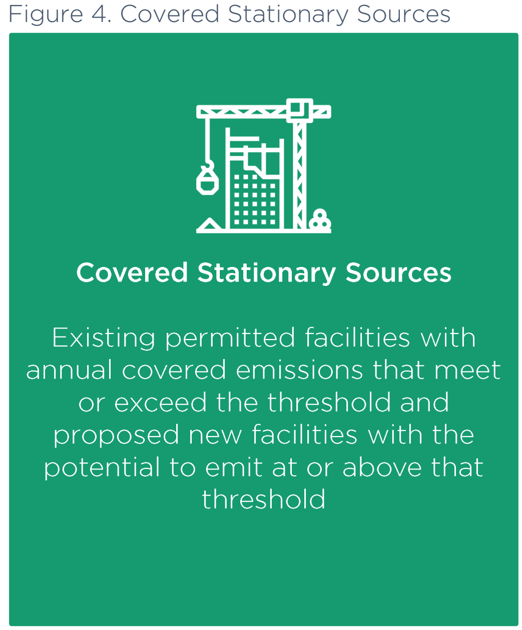
Rather than rely upon traditional offset credits, the CPP allows covered fuel suppliers to earn Community Investment Credits (CCI) credits which contribute funds to third-party entities who implement programs that reduce GHG emissions in Oregon. This alternative mechanism was selected primarily in conjunction with the program's environmental justice concerns, as well as criticism of traditional offsets outlined previously.

Figure 3. CCI Credit Overview



These credits allow an entity to demonstrate up to 10% of its compliance obligation for the first compliance period, increasing to 15% and 20% for the second and third periods. In 2022, one CCI credit is purchasable at $107 (2021$), with that rate increasing a dollar (2021$) per year adjusted for inflation. Once purchased, CCI credits can be banked for two compliance periods.

Figure 4. Covered Stationary Sources



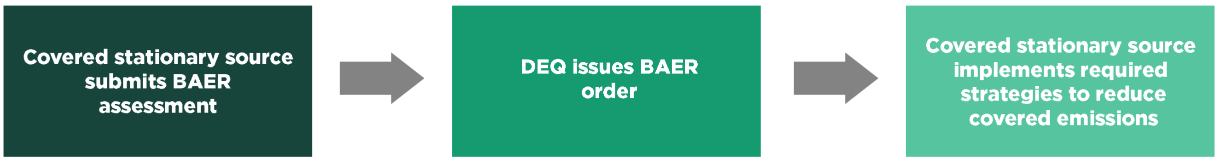
In turn, CCI entities– nonprofit organizations approved by DEQ– are given funds for CCI projects that seek to achieve the greatest benefit for environmental justice communities. This relationship is demonstrated in Figure 3.

BAER Assessments

Covered stationary sources, as outlined in Figure 4, are required to submit a BAER assessment that highlights available strategies to reduce emissions. Upon receiving a BAER assessment, DEQ then issues a BAER order, which considers available strategies, technical feasibility, commercial availability, cost-effectiveness, environmental and public health impacts, and potential impacts to the private provision of goods. Any stationary sources who emitted at or above 25,000 MT CO_2e since 2018 are covered by the CPP.

From that point forward, stationary sources must submit an annual report on progress toward implementing requirements of the BAER order, along with a completion report. Covered stationary sources must also submit a five-year review report to identify all strategies to reduce covered emissions available at that time, and DEQ may require a new BAER assessment if new emission reduction strategies are identified as part of this review process. Figure 5 highlights the process in which covered stationary sources are compelled to implement BAER strategies.

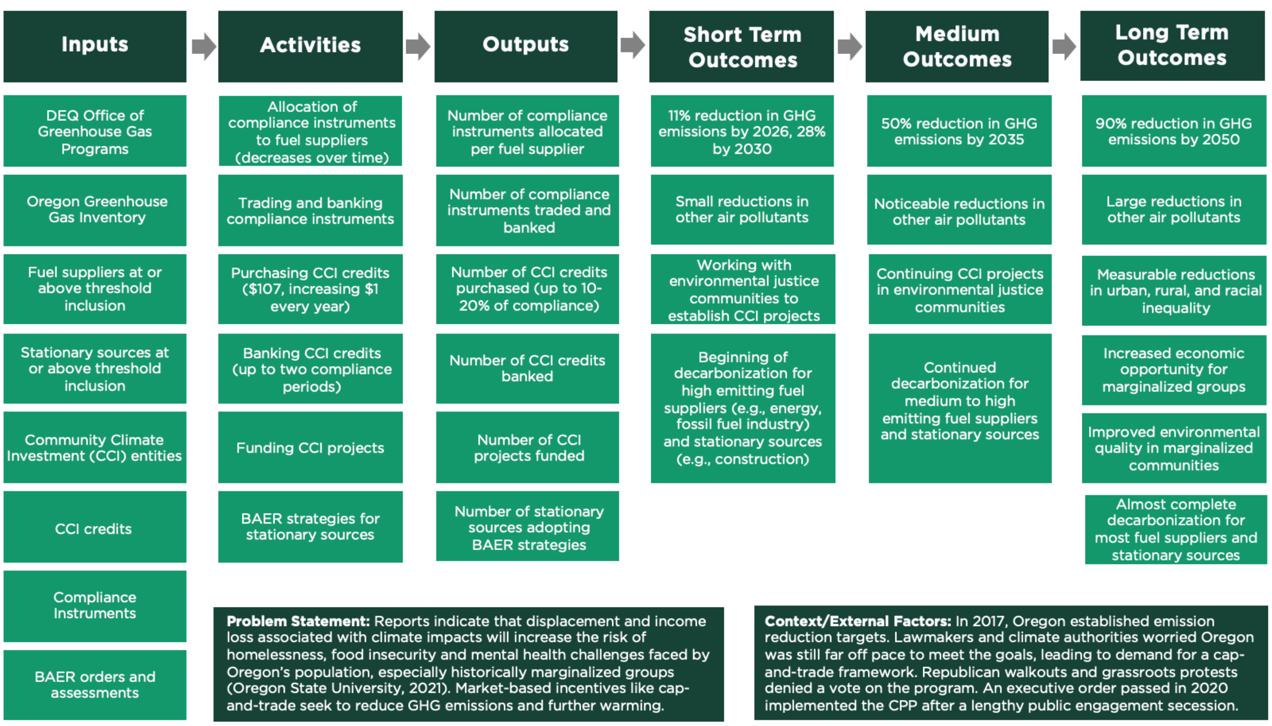
Figure 5. BAER Process



Logic Model

A logic model is a device that explains the causal logic behind a program– a crucial dimension in understanding the CPP and evaluating its effect. The model, shown in Figure 6, is split into five key sections: inputs, activities, outputs, short-term outcomes, medium-term outcomes, and long-term outcomes. Each pertains to the goals of the program: to reduce GHG emissions, achieve co-benefits from other air contaminant reductions, and enhance public welfare.

Figure 6. Logic Model



Inputs

The inputs section of the logic model highlights entities impacted by the program and key mechanisms intended to accomplish CPP goals and carry about activities. The primary agency implementing the program is the Office of Greenhouse Programs within DEQ. The agency uses the Oregon Greenhouse Gas Inventory– a sector-specified database that measures anthropogenic GHG emissions produced within Oregon– to calculate allotted compliance instruments for fuel suppliers on a yearly basis.[6] Covered stationary sources– which are not party to the cap-and-trade mechanism of the CPP– are compelled to reduce GHG emissions by conducting BAER assessments, receiving BAER orders, and adapting BAER strategies. CCI entities receive funding from DEQ upon the purchase of CCI credits from covered fuel suppliers, who are allowed to demonstrate compliance with CCI credits up to 10% (for the first compliance period) of total allowances.

Activities

The logic model highlights activities, or the processes, tools, and actions used to bring about intended program changes and results. A significant activity is the yearly allocation of compliance instruments to covered fuel suppliers and the adjustment of the base cap over time. As mentioned previously, the 2022 base cap is 28.1 million MT CO_2e, and will decrease until a 90% emissions reduction is achieved by 2050. When these instruments have been allocated to respective fuel suppliers, they are able to trade amongst themselves or bank them for future use.

By setting a limit on GHG emissions (cap) and allowing for transactions between entities (and trade), the goal is to reduce GHG emissions in a cost-effective manner. Issuing compliance instruments sets an enforceable cap and allowing for trade creates a system that guarantees a set level of overall reductions, while rewarding the most efficient companies and ensuring that the cap can be met at the lowest possible cost to the economy.

As mentioned before, covered fuel suppliers can purchase CCI credits at $107 (2021$), increasing a dollar (2021$) per year adjusted for inflation. These credits can be used to demonstrate compliance for the current period or can be banked for up to two compliance periods. Purchases are then used to fund CCI projects, which are carried out by DEQ approved CCI entities. These projects seek to elevate environmental justice issues (e.g., unequal stressors associated with climate change for marginalized populations) and establish infrastructure and climate mitigation projects that level the playing field in terms of resource access, economic opportunity, and employment.

Another significant activity is the implementation of BAER strategies, of which is required for stationary sources covered by the CPP. Examples of potential strategies include retrofitting buildings used for operations, the procurement of goods with low levels of embodied carbon, and an increased reliance on sustainable supply chains.

Outputs

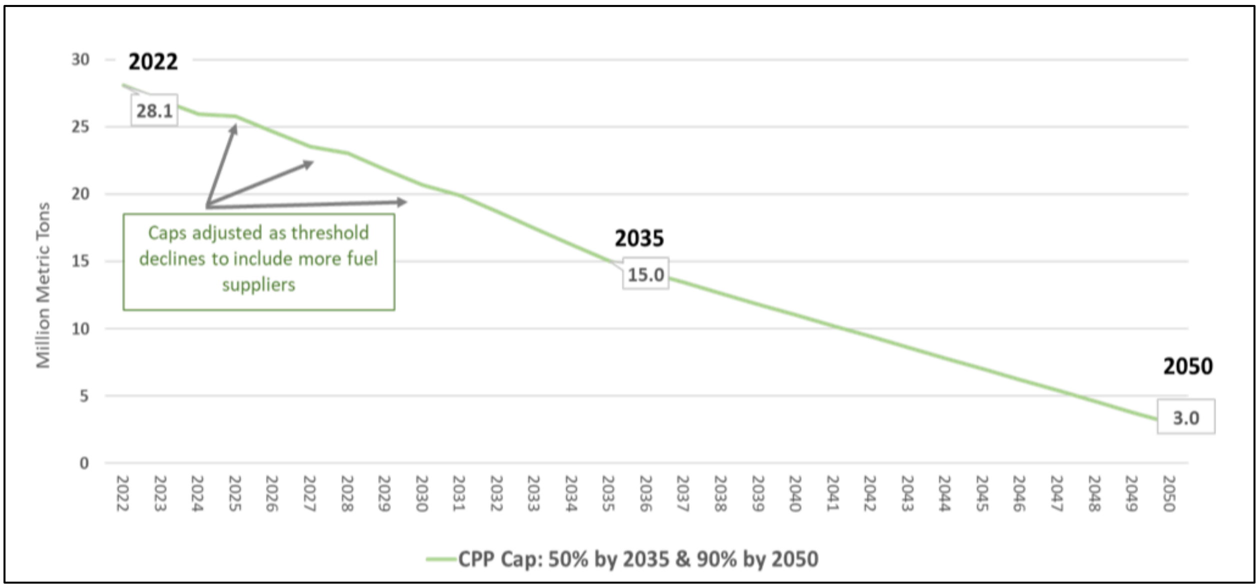
The outputs displayed in the logic model are direct results of CPP activities. Examples include the number of compliance instruments allocated for each fuel supplier, as well as the number of banked and traded instruments. The number of CCI credits purchased, banked, and traded is also a significant program output. Additionally, the number of CCI projects funded and the number of stationary sources with adopted BAER strategies are essential to understanding future outcomes.

Outcomes

Short-term, medium-term, and long-term outcomes show expected changes in the population as a result of the program. There is a clear causal link between these elements: before long-term outcomes can be achieved, substantive changes must occur in the short- and medium-term.

The CPP outlines an 11% emission reduction by 2026, and a 28% decrease by 2030, as demonstrated by Figure 7. As a result, co-benefits in the form of small reductions for other air pollutants (e.g., nitrogen oxides, ozone, particulate matter, sulfur dioxide) are predicted. Additionally, CCI funds will be used to establish justice-focused projects in marginalized communities. All this will lead to the beginning of decarbonization for high emitting fuel suppliers and stationary sources covered by the program.

Figure 7. Covered Fuel Supplier GHG Emissions Reductions



In terms of medium-term outcomes, the program hopes to achieve a 50% reduction in GHG emissions by 2035. Thus, further GHG emissions may serve as an opportunity for more noticeable reductions in other harmful air pollutants. CCI projects will have started to address environmental and economic disparities across the state, moving to ensure equitable resource access and infrastructure renewal for a low-carbon future. Finally, decarbonization will continue, drawing in medium-sized fuel suppliers and stationary sources as the threshold of eligibility lowers.

In the long-term, the CPP seeks to achieve a 90% reduction in emissions by 2050, coupled with large reductions for other air pollutants. CCI projects will have translated into measurable reductions in urban, rural, and racial inequalities persisting as a result of environmental degradation and a racially biased built environment. Indeed, increased economic opportunity for historically marginalized groups and improved environmental conditions are goals to ensure the program is sustainable in the long-term. Lastly, decarbonization will have been achieved for most fuel suppliers and stationary sources.

Literature Review

CPP Program Reviews

Given the short life of the program, DEQ has never conducted an impact evaluation of the CPP. However, DEQ plans to conduct "reviews" of CCI every two years, with broader CPP reviews every five years.

CCI Reports

As outlined by program rules, the CCI report will include a review of investment projects, as well as any necessary recommendations to ensure reductions of approximately one MT CO_2e or more of GHG for the average CCI credit distributed.[7] Specifically, each CCI review will examine the:

1. Distribution of CCI to covered fuel suppliers
2. Use of CCI credits to demonstrate compliance
3. Estimates of annual GHG emissions reductions anticipated by completed CCI projects
4. Estimates of annual non-GHG air contaminant emissions reductions anticipated by completed CCI projects
5. Calculation of the average GHG emissions reductions achieved per CCI credit distributed
6. Benefits accrued to communities

CPP Reports

Broader examinations will include a review of the overall CPP, the distribution of compliance instruments, trading activities, BAER strategies, emission reductions, and average annual statewide fuel prices in comparison to nearby states. Each CPP review will outline the:

1. Compliance for covered fuel suppliers, including caps, compliance obligations, compliance instruments submitted, and CCI credits submitted for each year and compliance period
2. Distribution of compliance instruments, including the size of the reserve at the start and end of each program year
3. Activities relating to trading of compliance instruments
4. Covered stationary source requirement activities that have occurred
5. Emissions reductions as a result of BAER orders
6. Current list of covered entities by name and whether each is a covered fuel supplier or covered stationary source
7. Enforcement actions taken that involved civil penalties, if applicable
8. Recommendations for program changes
9. Average annual statewide retail cost of gasoline, diesel, or natural gas in comparison to Washington, Idaho, and Nevada

California Cap-and-Trade

One of the first U.S. states to adopt cap-and-trade was California, which adopted its program with the goal of reducing GHG emissions 40% below 1990 levels by 2030.[8] Since then, several evaluations have been conducted to examine its impact on GHG emissions and environmental equity, making it one of the most studied programs to date.

GHG Emissions

A ProPublica analysis conducted in 2019 revealed that carbon emissions in the California oil and gas industry have risen 3.5% since the inception of the program.[9] Critics question the integrity of offsets, stating that California regulators have "oversold the climate benefit of offsets by underestimating how protecting one patch of forest pushes logging into other forests," which may provide to be fatal to the program. Indeed, offsets could account for half of all emissions cuts expected to be achieved by cap and trade from 2021 to 2030.[10]

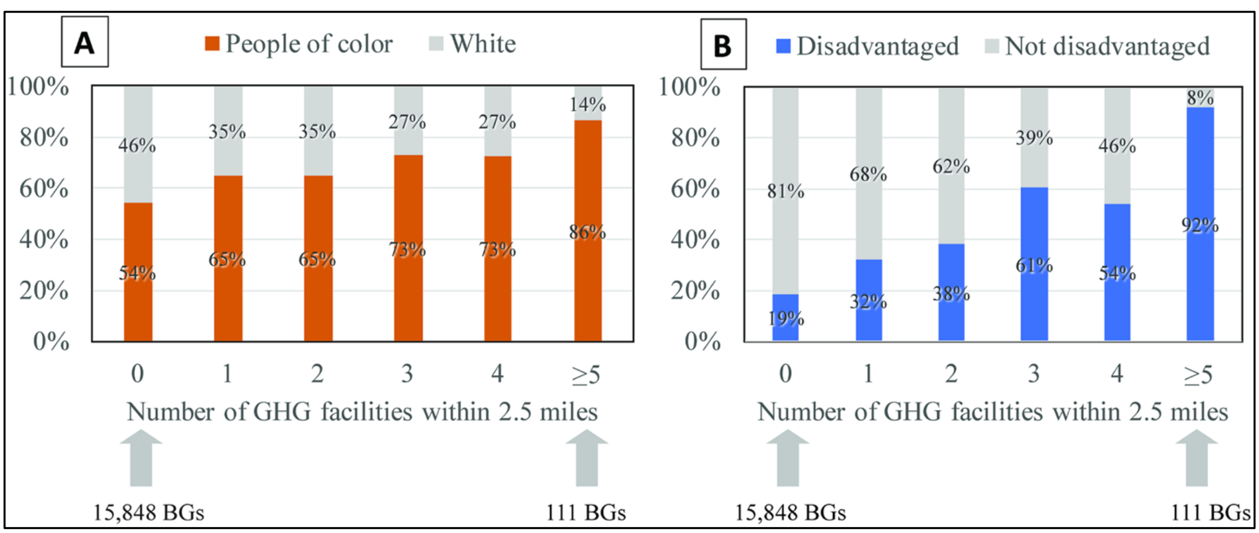
The report also highlights another key weakness of the program: the low market price of carbon. At the most recent auction, carbon traded for $28.26 per ton– drastically lower that the $40-100 per ton market valuation necessary to limit global warming above 2°C.[11 12 13]

Finally, the ProPublica analysis highlights what critics consider a key design flaw: the ability to bank allowances indefinitely. This leads to low-cost excess allowance credits, making it harder to meet emission reduction goals. A 2021 report by the Independent Emission Market Advisory Committee (IEMAC) states that companies in California have bought and saved 321 million allowances, which could make it difficult for the state to force these companies to lower their emissions.

Environmental Equity

In a 2018 peer-reviewed article, Cushing et al. (2018) examine the relationship between neighborhood disadvantages (e.g., poverty, low educational attainment, linguistic isolation) and the location of GHG and co-pollutant emissions from facilities regulated under California's cap-and-trade program.[14] Their study finds that regulated facilities are disproportionately located in disadvantaged neighborhoods. Statistical analysis found that most regulated facilities reported higher annual average local (in-state) GHG emissions after the initiation of trading– even though total emissions remained well under the cap established by the program, demonstrating the ability of covered facilities to avoid localized emission reductions through offsets.

Figure 8. Disadvantaged Neighborhoods and GHG Facilities



Additionally, the study reveals that neighborhood who experienced increases in annual average GHG and co-pollutant emissions nearby had higher proportions of poorer, less educated, and linguistically isolated residents, and people of color in comparison to neighborhoods that experienced decreases in GHG emissions, as shown in Figure 8.

In light of these findings, Cushing et al. (2016) suggest that environmental equity could be enhanced if there are more emissions reductions among firms located in disadvantaged communities, stressing that many high emitting companies using offset projects located outside of California to meet their compliance obligations.[15]

Evaluation Proposal

General Design

This impact evaluation proposal measures the effectiveness of the CPP in the first compliance period (2022-2024) based upon its main commitment of reducing GHG emissions. While achieving co-benefits from other air contaminant reductions and strengthening environmental justice communities are key factors influencing future outcomes, it is unlikely that these effects will be felt to a significant degree during the first compliance period. Thus, GHG emissions will be used as the single indicator of program effectiveness for this proposal.

This proposal relies upon a difference-in-differences regression (DID) model to determine program impact, with the same model used to examine the covered fuel suppliers and covered stationary sources separately. A DID design will allow DEQ to analyze the effect of the CPP while removing biases in post-intervention period comparisons between the treatment and control group that could be the result from permanent differences between those groups. The specifics of the models will be discussed in upcoming sections.

Data Collection

For this model, the treatment group consists of covered entities just above the threshold of eligibility (200 MT CO_2e for fuel suppliers, 25,000 MT CO_2e for stationary sources), while the control group consists of entities just below the threshold of eligibility. I recommend plotting all fuel suppliers and stationary sources on a scatter plot to visualize which firms should be selected for these groups. Next, data is collected for both groups from multiple sources.

Firm-level GHG emissions data from 2010 to 2020 is accessible through the Oregon Greenhouse Gas Inventory.[16] Although not presently available, emissions data from 2021 through 2024 should be collected for the purposes of this evaluation. Figure 9 displays a segment of current firm-level information available from the database.

Once this information has been collected and treatment and control have been identified, program analysis can begin. But before conducting a DID regression, it is important to check a key assumption.

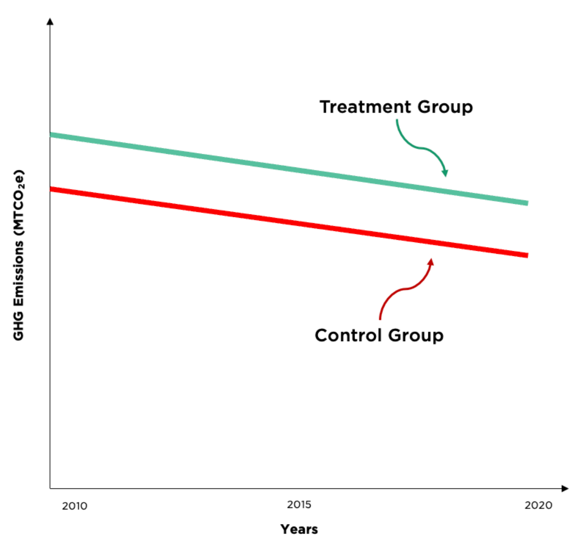
Figure 9. Fuel Supplier GHG Emissions (2010-2020)

Company	2010 ($mtCO_2e$)	2011 ($mtCO_2e$)	2012 ($mtCO_2e$)	2013 ($mtCO_2e$)	2014 ($mtCO_2e$)	2015 ($mtCO_2e$)	2016 ($mtCO_2e$)	2017 ($mtCO_2e$)	2018 ($mtCO_2e$)	2019 ($mtCO_2e$)	2020 ($mtCO_2e$)
A & B Enterprises, Inc.	42,173	47,645	61,673	28,815	26,085	36,886	34,309	49,931	72,996	73,066	40,468
A.H. Schade	60,886	54,664	46,798	20,241	21,548	21,847	23,456	23,368	26,086	24,588	
Albina Fuel Company	104,568	98,295	48,200	26,228	28,577						
Alsaker Corporation	16,268	14,480	6,663	9,740	5,071	5,792	91				
Amerigas Propane	62,815	62,791	67,570	78,448	75,001	67,430	72,226	78,286	72,930	33,960	78,227
AOT Energy Americas LLC								485	26,201		
Apex Oil Company, Inc	132,607	118,059	76,015	30,952	63,641	68,899	82,913	80,409	89,057	111,330	104,412
Ars Fresno	8,044	7,251	6,525	6,708	7,801	10,122	10,160	11,542	20,832	14,100	12,388
Associated Petroleum Products	4,972	5,741	440	6,882	90,227	106,890	129,302	29,596	70,347	264,182	108,225
Avfuel Corporation	4,855	6,046	6,722	4,235	4,020	5,425	2,282	3,647	5,924	3,453	4,797
Baird Oil Company	232	247	109	315	524	254	52	275	16	12	
Bend Oil Company	12,678	17,947	28,999	3,335	3,205						
Biosphere Fuels, LLC											2,918
BP Products North America, Inc.	4,312,599	4,185,817	3,523,943	3,476,662	3,358,990	4,382,612	5,020,382	6,190,739	5,720,127	4,266,278	3,218,641
Bretthauer Oil Co.	1,845	5,282	3,525	2,070	871	2,303	14,264	1,442	16,302	18,277	6,530
Byrnes Oil Co	114,372	129,163	120,461	131,150	119,687	130,488	130,140	114,835	98,955	100,536	93,716
Campo & Poole Distributing, LLC	52,503	65,995	56,777	60,901	73,057	66,789	75,411	58,096	211,861	213,387	35,400
Capital City Companies, Inc.				598	693	399	36				
Cargill, Incorporated		9									
Carson Oil Co., Inc., dba Carson	924,733	1,015,489	962,301	188,608	153,201	146,742	55,642	53,672	76,644	95,294	164,117
Central Petro Inc			285	1,140	21	210					
Chevron Products Company	3,479,705	2,831,012	2,487,081	2,856,250	2,965,991	2,585,309	2,592,044	2,790,992	2,721,691	2,700,675	2,185,048
CHS Inc. of Minnesota	41,857	70,879	135,129	74,745	43,816	29,063	33,957	24,136	17,562	21,747	15,501
CityServiceValcon, LLC	3,351	9,988	2,937	1,830	1,793	3,404	1,913	2,553	1,437	1,449	566
Coleman Oil Company	2,905	2,282	4,044	1,566	1,171	9,524	14,168	14,095	12,398	34,980	41,725
Colvin Oil I, LLC	17,003	13,298	20,290	59,605	62,202	62,324	33,473	39,924	28,766	31,389	34,516
Connell Oil, Inc. Distributiing	1,318	2,363	4,455	6,227	4,237	6,288	5,834	10,141	16,688	19,106	17,532
Conrad & Bischoff							14,095	15,113	2,240	15,625	13,686
Costco Wholesale Corporation			499	5,410	9,251	5,186	3,280	1,545	1,074	27,616	37,941
DCC Propane			15,271	15,082	14,003	13,577	14,121	16,565	16,349	18,544	17,412
Deluxe Fuel Company		73	732	752	923						
Devin Oil Co., Inc.	91,238	84,630	51,373	41,574	60,564	85,191	76,120	49,401	59,189	49,171	60,696
Don Small & Sons Oil Dist Co.	3,727	2,961	2,718	3,515	3,715	2,596	3,689	3,857	4,568	823	
Eastern Aviation Fuels, Inc	2,889	3,440	3,161	17,131	16,089	21,894	28,082	48,856	72,457	126,737	62,658
Ebar Oil Company	74	297	147	503	656	290	795	942	652		
Eco-Energy LLC											
Ed Staub and Sons Petroleum, Inc.	87,179	114,902	152,903	97,309	89,330	76,055	93,440	97,952	87,735	107,750	155,088
Elbow River Marketing USA Ltd.					867	44,474	15,304	36,300	111,327	94,369	106,933
EPIC Aviation	129,362	24,088	72,108	2,805	2,682	2,144	1,677	6,562	8,437	5,933	3,827
Equilon Enterprises LLC	2,401,038	2,235,315	2,146,402	2,548,768	3,101,124	3,662,141	3,474,253	3,731,469	3,761,882	3,976,828	3,784,986

Parallel Trends Assumption

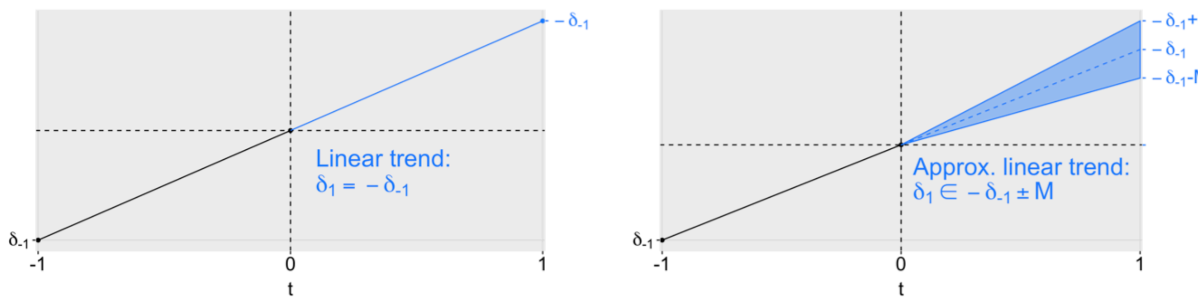
The parallel trends assumption requires that– in the absence of a policy intervention– the difference in trends between the control and treatment groups is consistent over time.[17] This proposal recommends "testing" this assumption by examining trends for the treatment and control groups, using data from 2010 to 2024. If the parallel trends assumption holds, as demonstrated in Figure 11, then a key assumption of the DID regression model is satisfied and estimates should be unbiased.

Figure 11. Parallel Trends Assumption



If pre-intervention trends for the treatment and control groups are not consistent over time, this proposal recommends considering the plausibility of parallel trends violations and examining said robustness. In a recent paper by Rambachan and Roth (2022), they note that one approach would be to extrapolate pre-existing differences in trends.[18] The paper goes on to emphasize that researchers should consider robustness to some degree of deviation for pre-existing trends to allow for approximately correct linear trends. As shown in Figure 12, allowing deviation by amount *M* allows more or less deviation from the pre-existing trend.

Figure 12. Linear Trends and Approximately Linear Trends



Difference-in-Differences Analysis

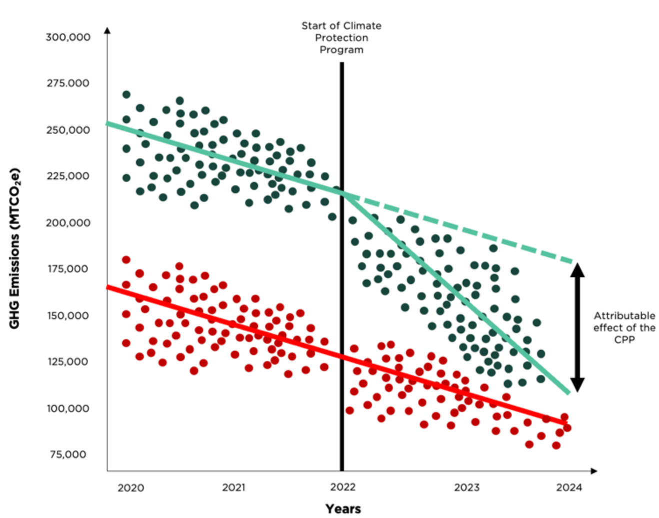
This proposal suggests using the following model to evaluate the effectiveness of the first compliance period of the CPP. Again, this model should be used separately for both covered fuel suppliers and covered stationary sources.

$$\text{emissions}_{it} = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_i \text{cpp}_i + \boldsymbol{\theta}_t + \boldsymbol{\varphi}_i + \boldsymbol{\lambda}\text{post}_t + \boldsymbol{\delta}_{it}(\text{cpp}_i{*}\ \text{post}_t) + \boldsymbol{\alpha}_{it}(\text{cpp}_i{*}\ \boldsymbol{\theta}_t) + \boldsymbol{\epsilon}_{it}$$

The variable *emissions* represents the total annual GHG emissions emitted by a covered fuel supplier or stationary source. Meanwhile, *CPP* is a dummy variable that indicates whether a firm is covered by the program. It equals one when a firm is at or above the threshold of eligibility for the first compliance period (200,000 $MTCO_2e$ or 25,000 $MTCO_2e$) and equals zero for entities who are below the threshold.

θ_t is an dummy variable for time fixed effects. A baseline year is selected as the reference point, and other program years are included as a control for all year-specific effects. φ_i is a dummy variable that controls for all firm fixed effects. Very much like the time fixed effect dummy, a reference firm is selected, and all other firms are included in the regression model. *Post* is also a dummy variable, representing the aggregate effect of the pre-intervention and post intervention periods. It is equal to one to reflect the post period, and zero for the pre-intervention period.

Figure 13. DID Model



Finally, (cpp_i*$post$) and (cpp_i*θ_t) are interaction variables representing the differences in changes between the pre- and post-intervention periods, and the differences in changes between each program year.

Figure 13 displays a hypothetical DID output. The treatment group (green line) and the control group (red line) satisfy the parallel trends assumption in the pre-intervention period. The divergence between the observed trend and counterfactual (dashed green line) represents the attributable effect of the program on GHG emissions.

The attributable effect of the CPP on emissions– the DID estimator– is the key measure of effectiveness for this proposed impact evaluation. If the DID estimator is large and statistically significant, we can assume that the program has had a positive impact on GHG emissions from covered fuel suppliers and stationary sources. However– if the DID estimator is statistically insignificant, we cannot claim that the CPP has had an effect on emissions with certainty. This later outcome would indicate that the program is not effective and needs adjustments (e.g., alternative credit allocation, different CCI projects) to reach Oregon's goal of net-zero emissions by 2050.

Finally, the impact evaluation should discuss any differences between covered fuel suppliers and covered stationary sources. For instance, it could be possible that the program has a statistically significant effect on GHG emissions from fuel suppliers, but not stationary sources. This could point to discrepancies between the cap-and-trade mechanism and BAER elements of the CPP, showing that BAER strategies are not effective in comparison. Such interpretation will be evaluable for program administrators and covered entities alike.

Challenges and Recommendations

The greatest challenges of this impact evaluation relate to sampling, the neighborhood effect, model assumptions, and the evaluation timeframe. For future evaluations, I recommend including other indicators of effectiveness.

Sampling

A small sample size could make it difficult to obtain an accurate estimate of the program effect. As of 2022, there are only 18 fuel suppliers and 13 stationary sources covered by the CPP.[19] While more firms will be added in consequent years, it is not certain if there will be enough to obtain a large enough sample size for both covered entities.

In a similar vein, the entrance of new covered entities at the beginning of every year might lead to some biased estimates. While year and firm fixed effects have been included, it is worth observing.

Figure 14. List of Covered Fuel Suppliers (2022)

Company Name	Type of Covered Fuel Supplier
Avista Utilities	Local distribution company
Cascade Natural Gas	Local distribution company
Northwest Natural Gas	Local distribution company
Associated Petroleum Products	Supplier of liquid fuel(s) and/or propane
BP Products North America, Inc.	Supplier of liquid fuel(s) and/or propane
Campo & Poole Distributing, LLC	Supplier of liquid fuel(s) and/or propane
Carson Oil Company, Inc.	Supplier of liquid fuel(s) and/or propane
Chevron Products Company	Supplier of liquid fuel(s) and/or propane
Equilon Enterprises LLC	Supplier of liquid fuel(s) and/or propane
Idemitsu Apollo Corporation	Supplier of liquid fuel(s) and/or propane
Jacksons Food Stores Inc.	Supplier of liquid fuel(s) and/or propane
P C Energy, LLC	Supplier of liquid fuel(s) and/or propane
PacWest Energy, LLC	Supplier of liquid fuel(s) and/or propane
Phillips 66 Company	Supplier of liquid fuel(s) and/or propane
Shell Trading (US) Company	Supplier of liquid fuel(s) and/or propane
Space Age Fuel. Inc.	Supplier of liquid fuel(s) and/or propane
Tesoro Refining & Marketing Company LLC	Supplier of liquid fuel(s) and/or propane
World Fuel Services, Inc.	Supplier of liquid fuel(s) and/or propane

Figure 15. List of Covered Stationary Sources (2022)

Source ID	Facility Name
01-0029	Ash Grove Cement Company
05-0005	United States Gypsum Company Rainier Plant
24-5398	Covanta Marion, Inc.
25-0027	Lamb Weston, Inc. Boardman East Plant
26-0027	SemiConductor Components Industries, LLC ON Semiconductor
26-1865	EVRAZ Inc. NA
26-3240	Microchip Technology Incorporated
26-9537	Owens Corning Corp. dba Owens Corning Foam Insulation, LLC
34-0055	Qorvo US
34-2681	Intel Corporation Aloha and Ronler Campuses
34-2804	Maxim Integrated Products, Inc. Maxim Fab North
34-2813	Jireh Semiconductor Incorporated
36-5034	Cascade Steel Rolling Mills, Inc.

Neighborhood Effect

The neighborhood effect is a theory that suggests that proximate entities have direct and indirect effects on each other's behavior. It has become a popular approach after the publication of the book *The Truly Disadvantaged* by William Wilson in 1987, in which he suggests that living in an impoverished neighborhood affects a wide range of individual outcomes (e.g., economic self-sufficiency, violence, drug use).[20]

A similar phenomenon may be occurring in relation to the coverage threshold. For instance, the threat of coverage might compel currently uncovered entities to adopt voluntary emission reductions in order to avoid statutory regulation. Thus, the neighborhood effect could mask the true effect of the CPP if these indirect behavioral anomalies are not considered.

Model Assumptions

As previously discussed, a critical assumption of the DID model is the parallel trends in the pre-intervention period. However, there are other significant assumptions underlying the model that must hold to achieve unbiased and consistent estimators.

First, the intervention must be unrelated to the outcome at baseline– the allocation of the intervention must not be determined by the outcome.[17] In the case of our proposed DID model, there is a potential relationship between CPP coverage and total firm emissions in a given year between 2018 and 2020. That is, if a covered fuel supplier has emitted more than 200,000 $MTCO_2e$ in that time period, they are covered by the program. I attempt to control for this possible relationship through fixed effects and a linear time trend, but this may still bias the results of the evaluation.

Second, the Stable Unit Treatment Value Assumption (SUTVA) requires that the composition of the treatment and control groups be stable for a repeated cross-sectional design, and that there are no spillover effects.[17] Again, the fixed firm and year effects attempt to control for any potential bias, but it should be noted that capturing spillover effects is difficult for a program heavily reliant on several economic and behavioral mechanisms and actors to achieve its goals.

Other Indicators

Although other indicators were not used to evaluate the first compliance period, the importance of measuring co-benefits achieved from other air contaminant reductions and impacts to environmental justice cannot be highlighted enough. As the literature review shows, understanding these dimensions can contextualize any GHG emission reductions by indicating where these reductions are occurring and who is being most impacted by adjacent activities. Indeed, I recommend that future evaluations focus heavily on the impact of CCI projects and their effect relative to traditional offset projects (e.g., California Cap-and-Trade). This will provide evaluators and program administrators with valuable insight about the essential relationship between emission reductions and regenerative societal benefits– both of which are key to the long-term success (both politically and economically) of any cap-and-trade program.

Conclusion

Climate change is a global threat multiplier that has already begun to alter our natural and human-built environment.[21] Without addressing the issue, global warming will continue to exacerbate poverty, food and energy insecurity, deforestation, and international peace. Cap-and-trade programs have increasingly gained popularity, with proponents arguing that market-oriented solutions are the most efficient and equitable way to reduce GHG emissions and prevent catastrophic warming.

The recent establishment of the Climate Protection Program (CPP) in Oregon offers an opportunity to understand how well these claims hold up to empirical evidence. In this proposal, I outline the basic design of cap-and-trade programs and the CPP specifically. Then, I present a logic model and review prior studies for related programs. Finally, I propose my evaluation technique and describe how to conduct a DID analysis with available data to determine how effective the CPP is at reducing GHG emissions.

I believe that conducting this evaluation will not only be beneficial to program administrators but will also provide knowledge regarding the impact of cap-and-trade programs in the U.S. more broadly. This will be of increasing importance to scientists, policymakers, and the general public as we attempt to mitigate the worst effects of climate change and protect our planet.

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