

JCCTRP Report 2022

Comparison of the Canadian Clean Fuel Regulations with Fuel Carbon Intensity Standards in California, Oregon and British Columbia

BY

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ABOUT THE JCCTRP

The Joint Clean Climate Transport Research Partnership (JCCTRP) is a research partnership that brings together leading universities, private research institutes, businesses and non-profit organizations from Quebec, California, Ontario and New England working on transport and climate policy. The JCCTRP Secretariat is based at the Chair in Decarbonization at the École des sciences de la gestion (ESG) of the *Université du Québec à Montréal* (UQAM). The ultimate goal of the JCCTRP is to identify technical, economic and political factors shaping the potential for environmentally effective, economically efficient, and politically viable low-carbon transport and climate mitigation policy.

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À PROPOS DU JCCTRP

Le Partenariat de recherche conjoint sur le climat et les transports (JCCTRP) est un partenariat de recherche qui réunit des universités de premier plan, des instituts de recherche privés, des entreprises et des organismes sans but lucratif du Québec, de la Californie, de l'Ontario et de la Nouvelle-Angleterre qui travaillent sur la politique des transports et du climat. Le secrétariat du JCCTRP est basé à la Chaire sur la décarbonisation de l'École des sciences de la gestion de l'Université du Québec à Montréal (UQAM). L'objectif ultime du JCCTRP est d'identifier les facteurs techniques, économiques et politiques qui déterminent le potentiel d'une politique de transport à faible émission de carbone et d'atténuation du climat efficace sur le plan environnemental, efficace sur le plan économique et politiquement viable.

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ABSTRACT

Written as part of the Joint Clean Climate Transport Research Partnership (JCCTRP), this report compares the Canadian Clean Fuel Regulations (CFR) with similar instruments that have been developed in British Columbia, Oregon and California. The report describes the instruments (or “standards,” as they all involve performance standards) in detail to highlight their similarities and differences. Aspects of the standards compared include program objectives and mandated carbon intensity (CI) reduction trajectories, scope of regulated fossil fuels and firms, life cycle assessment (LCA) methods for assigning CI ratings to fuels and associated credit-generating protocols, the credit market and related compliance mechanisms, as well as governance and administrative issues. We also briefly address key topics associated with harmonization and linkage of programs, before concluding. Overall, broad compatibilities in program design may work to incentivize a larger pool of lower carbon fuels, even though jurisdictions may sometimes compete for existing fuels. At the same time, differences in program design, trajectory, policy environment, and implementation might complicate any initiative to combine programs into a single low-carbon fuel standard in North America. Jurisdictions who have taken the lead on establishing North American fuel CI standards have rightfully focused on harmonizing standards, and should do so to the extent possible while recognizing regional differences. However, a common North American clean fuel credit market appears unlikely, and perhaps unnecessary, in the near- to mid-term.

RÉSUMÉ

Rédigé dans le cadre du Partenariat de recherche conjoint sur le climat et les transports (JCCTRP), ce rapport compare le Règlement canadien sur les combustibles propres (RCP) à des instruments similaires qui ont été élaborés en Colombie-Britannique, en Oregon et en Californie. Le rapport décrit les instruments en détail afin de mettre en évidence leurs similitudes et leurs différences. Les aspects des normes comparées comprennent les objectifs du programme et les trajectoires de réduction de l'intensité de carbone (IC), le champ d'application des combustibles fossiles et des entreprises réglementés, les méthodes d'analyse du cycle de vie (ACV) permettant d'attribuer des notes d'IC aux combustibles et les protocoles de génération de crédits associés, le marché des crédits et les mécanismes de conformité connexes, ainsi que les questions de gouvernance et d'administration. Nous abordons également brièvement des sujets clés associés à l'harmonisation et à la liaison des programmes, avant de conclure. Dans l'ensemble, les grandes compatibilités dans la conception des programmes peuvent inciter à l'utilisation d'un plus grand nombre de carburants à faible teneur en carbone, même si les juridictions peuvent parfois se faire concurrence pour les carburants existants. En même temps, les différences dans la conception, la trajectoire, l'environnement politique et la mise en œuvre des programmes pourraient compliquer toute initiative visant à combiner les programmes en une seule norme de carburant à faible teneur en carbone en Amérique du Nord. Les juridictions qui ont pris l'initiative d'établir des normes nord-américaines sur les carburants propres se sont concentrées à juste titre sur l'harmonisation des normes, et devraient le faire dans la mesure du possible tout en reconnaissant les différences régionales. Cependant, un marché nord-américain commun de crédits pour carburant propre semble peu probable, et peut-être même inutile, à court ou à moyen terme.

1. INTRODUCTION

The US and Canada, along with various states and provinces, have committed to deep reductions in greenhouse gas (GHG) emissions over the next decade and beyond. In the transportation sector, the decarbonization of fuels and energy systems will play a critical role in this process. Transportation fuel carbon intensity (CI) standards— often described as “low-carbon” or “clean” fuel standards—target lifecycle CI reductions through various mechanisms. This report compares the Canadian *Clean Fuel Regulations* (CFR) with similar instruments implemented elsewhere in North America. The CFR were finalized in spring 2022 by the Canadian federal government (Government of Canada, 2022) and came into partial force at that time: firms could begin generating clean fuel credits once the final regulations were registered in the Canada Gazette though carbon reduction obligations do not begin until July 2023. The CFR are flexible regulations designed to reduce the average CI of transportation fuels used in Canada. More specifically, the CFR are designed to lead to an approximately 15% reduction in *average* CI of these fuels relative to a 2016 base year by 2030. This is expected to reduce annual emissions by as much as 18.0 MtCO_{2e} by 2030, the final scheduled year of the program (Government of Canada, 2022: 2902, 2907).

This report considers the CFR relative to similar fuel CI standards in North America, including British Columbia’s *Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR)*, Oregon’s *Clean Fuels Program (CFP)* and California’s *Low Carbon Fuel Standard (LCFS)*. Our principal objective is to describe the standards in detail to highlight their similarities and differences. Aspects of the standards compared include program objectives and mandated CI reduction trajectories, scope of regulated fossil fuels and firms, life cycle assessment (LCA) methods for assigning CI ratings to fuels and associated credit generating protocols, the credit market and related compliance mechanisms, as well as governance and administrative issues. We then briefly address key topics associated with harmonization and linkage of programs, before concluding.

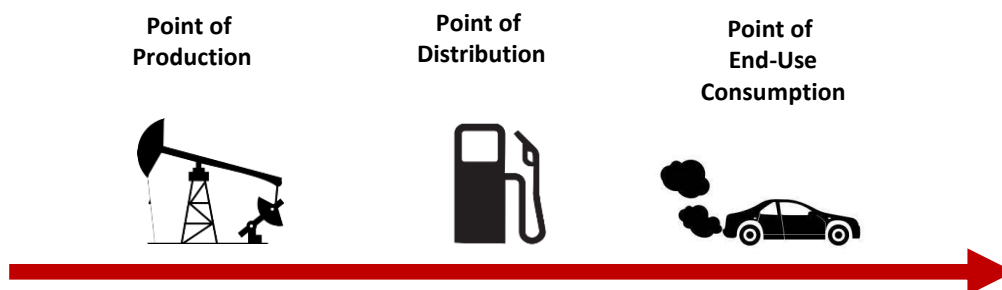
Overall, broad compatibilities in program design may work to incentivize a larger pool of lower carbon fuels, even though jurisdictions may sometimes compete for existing fuels. At the same time, differences in program design, trajectory, policy environment, and implementation might complicate any initiative to combine instruments into a single, or hard-linked low-carbon fuel regulation in North America. Jurisdictions who have taken the lead on establishing North American fuel CI standards should focus now on harmonizing standards to the extent possible while recognizing regional differences. However, a common North American clean fuel credit market appears unlikely, and perhaps unnecessary, in the near-to mid-term.

OVERVIEW OF TRANSPORTATION FUEL CARBON INTENSITY STANDARDS

A fuel CI standard is a regulatory instrument intended to incentivize greater production and use of low-carbon fuels within a jurisdiction. It creates financial incentives for the provision of lower carbon fuels by assessing high-carbon fuels with “deficits” representing tonnes of emissions above each year’s target resulting from their use, and requires deficits to be matched with credits generated by the use of low carbon fuels. The implementing agency tracks trades and compliance. The scheme is intended to reduce the cost differential between existing high-carbon fuels, especially petroleum, and lower-carbon alternatives. Such a regulatory instrument simultaneously reduces emissions through existing lower-emission technology, while stimulating innovation in advanced low-carbon fuel options (Farrell and Sperling, 2007).

Importantly, the regulation avoids mandating the use of any particular fuel, technology, or compliance strategy. Rather, it sets an average CI standard, measured in grams CO₂ equivalent per megajoule of fuel energy (gCO₂e/MJ), that must be achieved across all fuels consumed within a jurisdiction in a given year. A transportation fuel CI standard encompasses all transportation fuels including, but not limited to, fossil fuels (gasoline, diesel, natural gas), electricity, hydrogen, and renewable fuels (biogas, biofuels). CI ratings are estimated for the full lifecycle of a given fuel pathway from “upstream” production and distribution, to “downstream” consumption (Figure 1 gives a fossil fuel example). This is a complex technical exercise given the number of different potential pathways for producing fuels.

FIGURE 1 : LIQUID FOSSIL TRANSPORT FUEL LIFECYCLE



The regulation requires a gradual reduction in a jurisdiction’s average CI across all covered transportation fuels over time. A transportation fuel CI standard creates incentives for two groups: (i) firms producing or distributing liquid fossil or other high carbon fuels and (ii) those producing and distributing low-carbon alternative fuels (Table 1). The two groups are not mutually exclusive; some firms supplying fossil fuels also supply low-carbon fuels and others are expected to transition towards supplying low-carbon fuels. All transportation fuel CI intensity standards anticipate that it will be easier for some firms to reduce the CI of fuels they provide than others, and use credit markets to harness this flexibility. Firms that supply high carbon fuels used in a jurisdiction, typically liquid fossil fuels, accrue program deficits, while lower carbon fuels generate program credits. These credits are in accordance with the jurisdiction’s credit-generating protocols, regulatory tools designating how an alternative fuel’s CI rating is determined and/or how credits are generated. To comply with a fuel CI standard, liquid fossil fuel providers may generate credits through credit-generating protocols, switch to fuels that carry credits with them, or buy credits in the market. Broadly speaking, each regulated party demonstrates that they meet the annual average CI standard via a balance of program deficits and credits (with some additional flexibilities that vary per program, as explored later in the paper). That is, they ensure that debits incurred from supplying higher carbon intensity fuels are offset by credits generated from supplying lower carbon fuels. Because credits are tradable amongst firms within a jurisdiction, a clean fuel credit market is created.

TABLE 1: POLICY ACTORS TARGETED BY FUEL CARBON INTENSITY STANDARDS

Liquid fossil fuel producers and distributors	Firms producing or distributing alternative low-carbon fuels and energy sources
<ul style="list-style-type: none"> • Participation required • Incumbent firms providing liquid fossil fuels within a jurisdiction • Their activities lead to market deficits 	<ul style="list-style-type: none"> • Participation voluntary in most jurisdictions • Might include new entrants but also incumbent firms currently providing both liquid fossil fuels and low-carbon ones • Their activities produce market credits

2. THE CFR AND OTHER NORTH AMERICAN STANDARDS

2.1. Canadian Clean Fuel Regulations

The CFR were announced by Environment and Climate Change Canada (ECCC) in November 2016 (ECCC, 2016a) and referenced in the *Pan-Canadian Framework for Clean Growth and Climate Change* adopted by Canadian federal and provincial governments at a First Minister's Meeting in December 2016 (ECCC, 2016b). They arose out of the deliberations of a "Working Group on Specific Mitigation Opportunities", itself established following the *Vancouver Declaration on Clean Growth and Climate Change* issued at a March 2016 First Ministers' Meeting (FMM, 2016). Such meetings of provincial and federal leaders are unique to Westminster federal systems and typically viewed as amongst the most authoritative of political institutions in Canada (Papillon and Simeon, 2004). The CFR are not the first fuel carbon intensity standard in Canada, however. That distinction belongs to British Columbia's Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR), which came into effect in 2010.

The federal CFR were developed as a new regulatory instrument under the *Canadian Environmental Protection Act* in a manner that builds on the federal *Renewable Fuels Regulations* that have been in operation since 2010. These are effectively a biofuel blending mandate that requires fuel producers and importers to include average renewable content in various liquid fuels (5% per volume of gasoline, 2% for diesel heating oil). In contrast to a fuel carbon intensity standard like the proposed CFR, the *Renewable Fuels Regulation* does not require reductions in GHG emissions on a lifecycle basis, nor does it contain sustainability requirements. The CFR will largely replace the *Renewable Fuels Regulation*, whose repeal is set for 2024 (Government of Canada, 2022: 2787-2789). However, fuels used under the Renewable Fuels Regulation will retain a compliance benefit under the CFR due to their relatively low CI rating (Government of Canada, 2022: 2860.)

ECCC began the consultative process for the CFR by releasing a discussion paper in early 2017 (ECCC, 2017) a regulatory design paper in December 2018 (ECCC, 2018) and a proposed regulatory approach for liquid fuels in June 2019 (ECCC, 2019). A draft of Clean Fuel Standard regulations for liquid fuels was planned for publication in early 2020 though, with the COVID-19 pandemic, this was pushed back until late 2020 (Government of Canada, 2020). As indicated above, final *Clean Fuel Regulations* were published in the Canada Gazette in July 2022 though CI reduction obligations come into force in July 2023.

2.2. California: Low Carbon Fuel Standard

The California Low Carbon Fuel Standard (LCFS) was approved by the California Air Resources Board (CARB) in 2009, implemented in 2011, amended in 2013, and re-adopted in 2015 (CARB, 2022c). In 2018 the program was extended, setting targets until 2030 in alignment with California's 2030 GHG emission reduction target (CARB, 2022c). The program broadly works as described above, via deficits that must be offset by credits to achieve compliance, with deficits and credits generated for fuel volumes based on their CI ratings. The 2018 amendments also added crediting opportunities for zero emissions vehicle fuelling infrastructure capacity, alternative jet fuels, and carbon capture and sequestration (CARB, 2022c). The California LCFS aims to reduce transportation fuel carbon intensity, with targets currently set at a 20% reduction from 2010 values by 2030, after an initial target of 10% reduction by 2020, through incentivizing low carbon fuel technological innovation and deployment. However, additional expected benefits include diversification of the fuel pool, reduction in petroleum dependency, and reduction of emissions of other air pollutants (CARB, 2020c). Since the start of the program alternative fuel volumes and shares in California

have increased (CARB, 2022b). In 2021 the main credit-generating fuels were renewable diesel, ethanol, and electricity (CARB, 2022b).

The California LCFS complements other climate policies such as California's carbon market, Advanced Clean Cars Program, and SB-375 (Purdon et al., 2021b). A number of these other policies are worth mentioning. CARB's carbon market includes a declining limit on major sources of GHG emissions throughout California including transportation. Furthermore, the Advanced Clean Cars (ACC) and, the recently adopted, Advanced Clean Cars 2 (ACC2) programs regulate criteria and GHG emissions from light- and medium- duty vehicles and set Zero Emission Vehicle (ZEV) sales requirements (CARB, 2018a). Under ACC2, all new sales after 2035 are required to be ZEV (CBS News, 2022). Finally, SB-375, The Sustainable Communities and Climate Protection Act of 2008, sets regional GHG emissions reductions targets for counties and cities in California (Mawhorter et al., 2020).

2.3. British Columbia: Renewable and Low Carbon Fuel Requirements Regulation

The BC Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR) implements requirements of the *BC Greenhouse Gas Reduction (Renewable and Low Carbon Fuel Requirements) Act* (British Columbia, 2019). Passed in 2008, the Act required the implementation of a low carbon fuel standard by 2010 (Shaw, 2010). The original goal of the RLCFRR was to reduce the average carbon intensity of BC transportation fuels by 10% by 2020; this was subsequently extended to 20% in 2030 (British Columbia, 2021b). At the time of publishing this report (October 2022), the BC government is preparing amendments under the current RLCFRR as part of the CleanBC Roadmap to 2030 for consideration later this year. These amendments are expected to implement a new schedule of CI reductions to achieve a 30% reduction in the existing fuel pools by 2030 (Government of British Columbia, 2021: 28). The Act also includes a minimum 5% annual average renewable content in gasoline and 4% annual average renewable content in diesel (British Columbia, 2021b).

Like the Canada CFR and the California LCFS, the RLCFRR generates revenue for low carbon transportation fuel suppliers, which is expected to aid investment in clean fuels and vehicles. The BC program is complemented by clean transportation programs in the province such as multiple policies targeting Zero Emission Vehicle (ZEV) deployment. These include the *Zero-Emissions Vehicle Act*, which requires an increasing percentage of light-duty ZEVs in sales and leases, reaching 10% by 2025, and 100% by 2040, the SCRAP-IT program which provides rebates to scrap older vehicles and replace them with ZEVs, and the CleanBC Go Electric program, which reduces ZEV prices, and supports ZEV charging infrastructure (British Columbia, 2021b). The jurisdiction also has a carbon tax that includes transportation fuels.

2.4. Oregon: Clean Fuels Program

The Oregon Clean Fuels Program (CFP) started development in 2009 after the Oregon Legislature adopted HB 2186, authorizing the Environmental Quality Commission to adopt rules to reduce the carbon intensity of Oregon's transportation fuels (SODEQ, 2022a; b). After development by Oregon's Department of Environmental Quality (DEQ), the program was adopted in two stages. Recordkeeping requirements started for companies under the program in December of 2012; standards came into force in 2016 that set a 2025 CI reduction of 10% below 2015 baseline levels. In September 2022, the Oregon government adopted amendments extend the programme to achieve a 20% reduction by 2030 and a 37% reduction in 2035 (Oregon, 2022).

The Oregon Clean Fuels Program shares the same basic goals and structure as the California LCFS, currently targeting a 20% reduction in CI from 2015 levels by 2020. Since the start of the program, fuels that substitute for gasoline and diesel in Oregon have seen both a reduction in CI, and increase in supply volume. The program works in conjunction with other Oregon DEQ programs to reduce greenhouse gas (GHG) emissions from the transportation sector as part of Oregon’s Climate Strategy. These include Oregon’s Zero Emission Vehicle programs, which require an increase in the proportion of sales of battery-electric or fuel cell vehicles and include light-, medium-, and heavy-duty vehicles, and the Climate Protection Program, a cap-and-trade regulation set to start in 2022, which sets state-wide limits on GHG emissions from fossil fuels, and allows a proportion of credits to be met through community climate investments. The programs are complementary in that incentives for action through one, like the CFP, will lower the necessary incentives required in another to meet its targets, compared to if that program were in effect without the CFP.

3. COMPARISON OF POLICY TARGETS AND RATES OF CI REDUCTION

Both the CI policy targets and average fuel CI rate of decline over time are potentially important differentiating characteristics of the transportation fuel CI standards investigated. In this section we demonstrate that while 2030 policy targets between jurisdictions differ in nominal terms, the rate at which CI is to be reduced is similar across jurisdictions.

3.1. Policy Targets across Jurisdictional Standards

Table 2 compares 2030 policy targets set for the CFR with those for California, BC and Oregon. The lowest emission reduction targets in nominal terms are found in BC followed by California while those of Oregon and Canada’s CFR are similar. However, the lower nominal targets in BC and California should not necessarily be interpreted as reflecting more stringent policy instruments than that proposed in Canada, because jurisdictions have different “base years” (“anchor” for the CI reduction targets to be achieved against), CI ratings for the base year of the programmes (known as the “baseline CI”, as well as different percentage reduction targets from the base year. For example, the average CI ratings of fuels produced and distributed in California and Oregon in the base year of the programme were lower, and in BC higher, than those in Canada. In addition, the jurisdictions have different base years and CI percentage reduction targets, as explained further below. It should also be noted that percentage reduction targets are periodically updated: Oregon is in the final stages of extending its program to 2035 with a 37% CI reduction target, California will begin an LCFS rulemaking in 2023 during which program targets will be reviewed and likely increased.

Before going further, it is important to highlight the relationship between a baseline and base year. A baseline is the estimate of the CI for the reference fuel type or types (against which the CI reductions are compared and measured for compliance) for a program’s base year. We note that Canada’s program has a base year of 2016, Oregon’s is 2015 while for BC and California, it is 2010. Also note that the measurement of the baseline CI for a particular base year might be modified as measurement technology and administrative systems evolve, as we discuss below. In Table 2 we report on the most recent versions of baseline estimates for gasoline and diesel for each of the jurisdictions covered in this report.

TABLE 2: SUMMARY OF POLICY TARGETS FOR FUEL CARBON INTENSITY STANDARDS

Jurisdiction	Instrument Name	Base Year	Gasoline CI Baseline (gCO ₂ e/MJ)	Diesel CI Baseline (gCO ₂ e/MJ)	First Year of Obligation under Regulation	2030 Average CI Reduction	Gasoline CI 2030 Target (gCO ₂ e/MJ)	Diesel CI 2030 Target (gCO ₂ e/MJ)
California	Low Carbon Fuel Standard	2010	99.44	100.45	2011	-20%	79.55	80.36
British Columbia	Renewable and Low Carbon Fuel Requirements Regulation	2010	88.14	94.76	2011	-20% (-30% anticipated)	70.51	75.81
Oregon	Clean Fuels Program	2015	98.06	98.74	2016	-20%	78.45	78.99
Canada	Clean Fuel Regulations	2016	95.00	93.00	July 2023	app. -15%	81.00	79.00

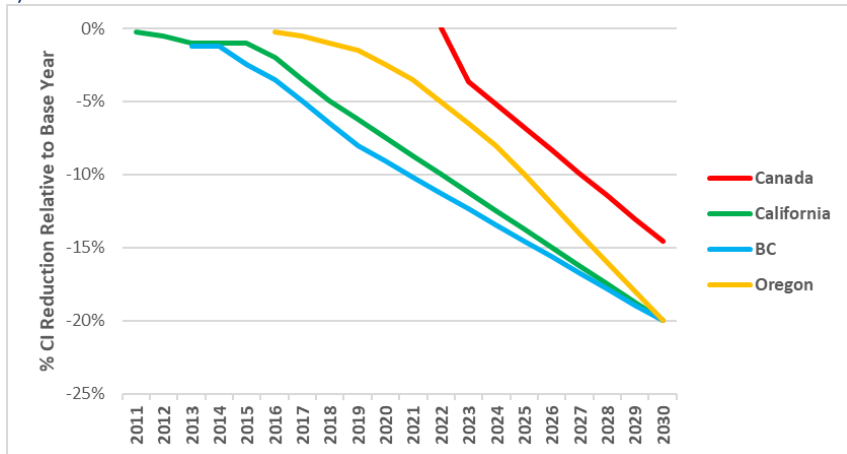
Note. Sources : (Cal. Code Regs. tit. 17 § 95484); CARB (2020d); (Government of Canada, 2022: 2663); Smith (2021); British Columbia (2021b); (Oregon, 2020; 2022). Baseline CI is an official measure of the reference fuel CI for a particular base year. While the base year remains fixed in regulation, its measurement might change over time as technologies and administrative systems evolve. Baselines in the table are those estimated as of 2022, as discussed in the text

3.2. Carbon Intensity Reduction Rates across Jurisdictional Standards

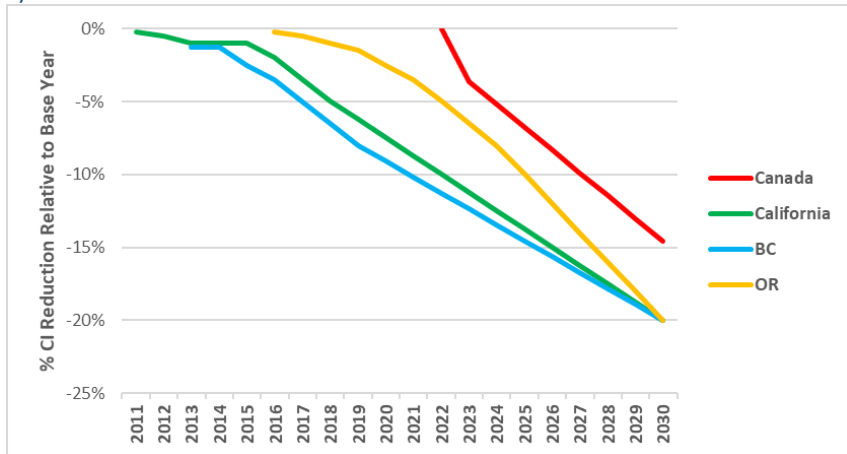
Arguably, rather than focusing on 2030 nominal CI policy targets, a better way to compare fuel CI standards across jurisdictions is to consider the mandated CI reduction percentage for transportation fuels in each. Table 2 reports this, but also see Figure 2 for the percent annual CI reduction relative to each jurisdiction’s baseline CI for gasoline and diesel pools (Figure 2, a&b) as well as the trajectory of the annual nominal CI benchmark for each jurisdiction (Figure 2, c&d). These figures demonstrate that the incremental change in required annual CI reductions across jurisdictions is almost identical from 2023 onwards. For example, the slope of the curves is similar among jurisdictions, whether in relative or nominal terms. However, the CFR demonstrate a sharper reduction between 2022 and 2023; delay in implementing the policy instrument meant that reductions needed to be accelerated in the first year.

FIGURE 2: COMPARISON OF CI REDUCTION TARGETS AND CI BENCHMARKS FOR GASOLINE AND DIESEL POOLS IN CANADA, CALIFORNIA, BC AND OREGON THROUGH 2030

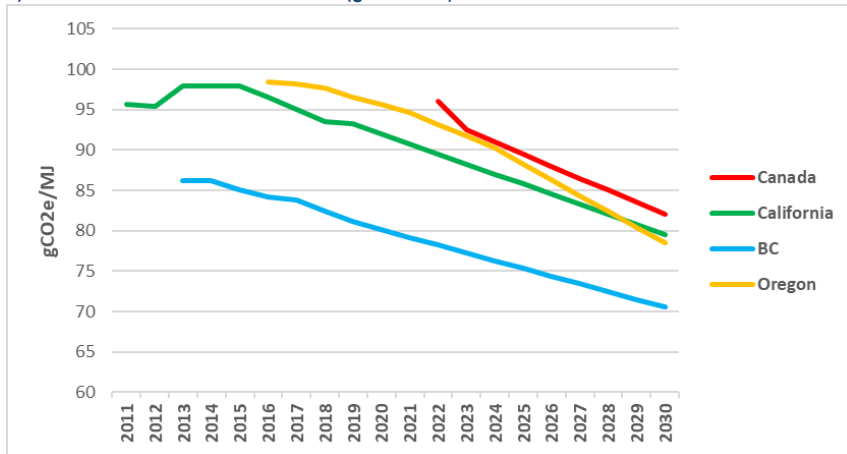
a) Gasoline: % CI Reduction Relative to Baseline



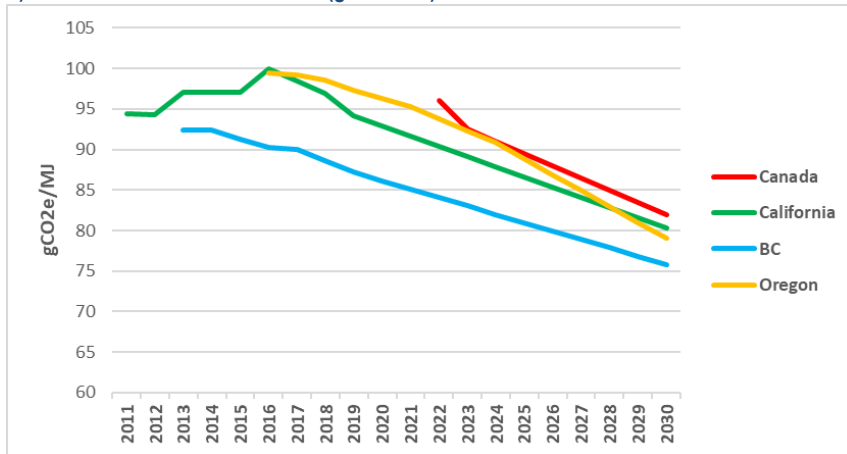
b) Diesel: % CI Reduction Relative to Baseline



c) Gasoline: Nominal CI Benchmark (gCO2e/MJ)



d) Diesel : Nominal CI Benchmark (gCO2e/MJ)



Sources : (Cal. Code Regs. tit. 17 § 95484); CARB (2020d);(Government of Canada, 2022: 2663); Smith (2021); British Columbia (2021b); (Oregon, 2020; 2022).

Note: These figures do not include the amendments that, at the time of publishing this report (October 2022), the BC government is considering for January 2023 that would accelerate the schedule of CI reductions to achieve a 30% reduction in the existing fuel pools by 2030.

3.3. Determination of Baseline Carbon Intensity Values across Jurisdictional Standards

The close reader will note that in Figure 2 above, the lines showing the percent CI reductions relative to the baseline are smoother than those showing the nominal CI reductions. Indeed, nominal CI benchmarks increased in California from 2011 through 2016, which can be attributed to model and data updates that led to a different result for the base year CI, and thus the relevant percent reduction from that CI (court cases surrounding the LCFS in its earlier phase led to the flat lines).

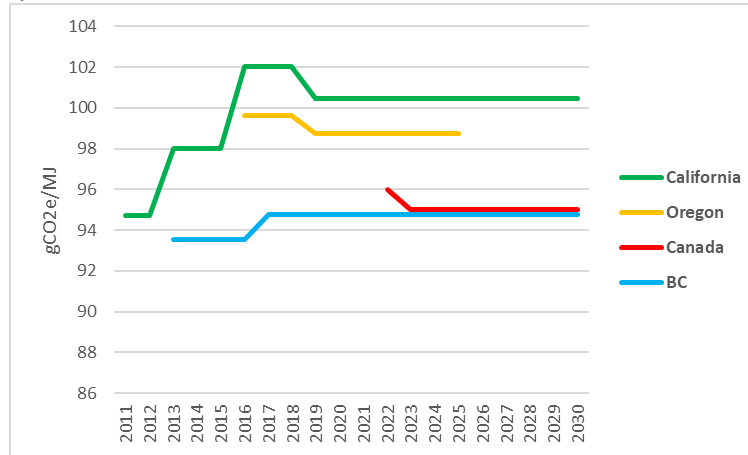
The baseline CI values for reference fuels like gasoline, diesel and other refined petroleum products are derived from the average CI of all types of crude oil used in the jurisdiction in its base year, as well as averages for the refining process. Where a biofuel blend was the typical fuel available on the retail market in the base year, such as E10 in California and E10 and B5 in Oregon, the biofuel CI rating is also used in calculating the baseline CI. As noted above, jurisdictions update their baseline CI values periodically as better base year data become available or modeling techniques improve. The new base year CI values then hold for calculation of program credits and deficits moving forward. As can be seen in Figure 3, the baselines in California and BC have increased, most significantly in California's diesel pool. Initial regulations, in effect over the 2011-2012 period, estimated that California's base year diesel pool had a CI of 94.72 gCO₂e/MJ though later regulatory changes saw this increased to 102.01 gCO₂e/MJ during the 2016-2018 compliance period. With respect to the CFR, baseline CI values for both gasoline and diesel are 95.0 gCO₂e/MJ for gasoline and 93.0 gCO₂e/MJ for diesel in the final regulations (slightly down from what appeared in the 2020 draft).

California also tracks its annual crude average CI value, and charges “incremental” deficits to suppliers of petroleum fuels if the volume-weighted average CI value of crude supplied to California refineries over the previous three years increases over a minimum threshold. It is estimated using the Oil Production Greenhouse Gas Emission Estimator (OPGEE) Model (SEEEES, 2020). The incremental deficit provision accounts for the global trend towards increased use of heavy, sour, or difficult-to-extract crudes, which usually require more energy and emissions to bring to market. Based on these annual reports, the annual crude average CI value in California has increased from 11.36 to 12.52 gCO₂/MJ from 2012 to 2019, a 10.1% increase—though the volume of crude oil produced in California has declined by 0.7% (CARB, 2020a). The increase was enough to trigger incremental deficits accruing for the first time in 2020, and likely at least through 2023 in California (CARB, 2022a). There is no reduction of deficits, however, if the statewide average crude CI value declines.

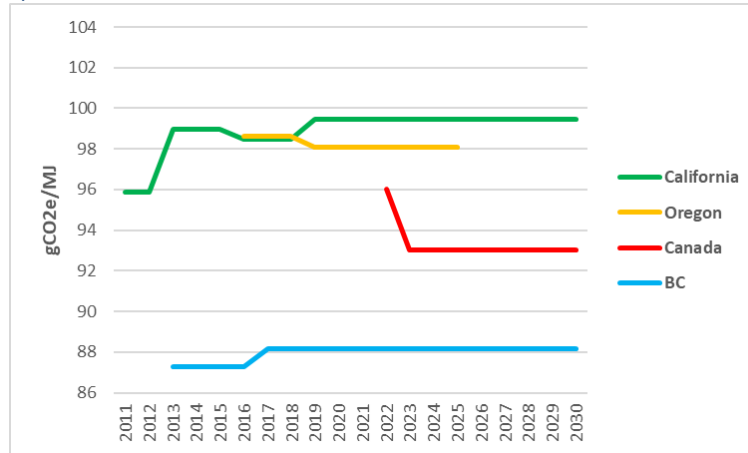
Oregon and BC do not currently track changes in reference fuel CI value over time, so their impact on program carbon savings is unknown. In Canada, the crude average CI value will be reviewed every five years, at which time the program goals might be reassessed for adjustment. For natural gas-derived fuels, the CFR does not differentiate between sweet and sour gas, or by origin of the gas. Similarly, a Canadian average CI value for natural gas and propane produced, imported and consumed in Canada is determined.

FIGURE 3: COMPARISON OF THE EVOLUTION OF CI BASELINES FOR GASOLINE AND DIESEL POOLS IN CANADA, CALIFORNIA, BC AND OREGON THROUGH 2030*

a) Gasoline Baseline Evolution



b) Diesel Baseline Evolution



Sources : (Cal. Code Regs. tit. 17 § 95484); CARB (2020d); ECCC (2019: 20); ECCC (2019: 20); (Government of Canada, 2020; 2022); Smith (2021); British Columbia (2021b); (Oregon, 2020).

The use of a jurisdiction-wide average as the basis for calculating the CI of refined liquid petroleum products is intended to avoid shuffling “cleaner” crudes to jurisdictions with transportation fuel CI standards without appreciably changing GHG emissions worldwide. It is an important feature for Canada’s CFR given that the lifecycle emissions of fuels produced from Canada’s oil sands are generally recognized to be higher than the baseline averages used in the U.S. by the EPA (Guo et al., 2020; Sleep et al., 2020). The use of an average CI value reduces the risk that petroleum producers with large oil sands reserves would be disproportionately impacted by the proposed CFR, despite the generally higher CI associated with oil sands products.

4. COMPARISON OF THE SCOPE OF REGULATED FOSSIL FUELS AND PARTIES

4.1. *Scope of Regulated Fossil Fuels across Jurisdictional Standards*

All fuel CI standards cover a number of different fossil fuels that are included in the calculation of a jurisdiction's *average* CI target. However, the scope of fuels covered is important as different fossil fuels have different CI profiles and some are also easier to replace with cleaner alternatives.

When first announced in 2016, the CFR were intended to cover a broad suite of fossil fuels, including liquid, gaseous, and solid fuels in the transportation sector as well as those for industry, homes and buildings (ECCC, 2016a; b: 18). However, its scope was then narrowed to only focus on liquid fossil fuels: a total of six different types of liquid fossil fuels were targeted by the CFR as per draft regulations released in late 2020 (ECCC, 2020: 27). The 2020 draft regulations therefore contained some ambiguity as whether all liquid fossil fuels were included or only those in the transportation sector. For the final regulations, the scope of the CFR was further narrowed to almost exclusively focus on transportation fuels. This narrowing of the CFR's focus to transportation fuels is consistent with other jurisdictions.

In summer 2021, the CFR saw a further reduction in scope, with ECCC dropping kerosene as well as light and heavy fuel oils that have uses beyond transportation such as stationary heating (Government of Canada, 2022: 2864). These fuels are not covered by the fuel CI standards in any of the other standards considered. However, while the Renewable Fuels Regulation is to be repealed, its 2% low CI fuel content requirement will be retained for light fuel oil (Government of Canada, 2022: 2860). The incorporation of biodiesel in light fuel oil is likely to be a credit generating pathway under Compliance Category 2 (Government of Canada, 2022: 2919), described in more detail below.

As for other transportation fuels, the inclusion of domestic jet fuel under the CFR remained to be determined as of spring 2022; however, the final rules do not include an obligation on jet fuel (Rabson, 2022). Jet fuel is not included as a deficit generator under the other programs considered, though alternative jet fuel loaded in state is optional for crediting purposes in California and Oregon, whether for domestic or international flights. International air travel jet fuel use is subject to regulation by the International Civil Air Organization, ICAO (Larsson et al., 2019). This is seen as a constraint to inclusion of petroleum-based jet fuel used for international travel in a standard like the CFR, though intra-jurisdictional jet fuel may be allowed under jurisdictional law or policy. The voluntary "opt-in" status of alternative jet fuel in the California LCFS and Oregon CFP does not run afoul of any prohibition on regulation of fuels used in trans-border flight.

The 2020 draft regulation for the CFR included domestic maritime fuels, although these were dropped in the final regulations. Since heavy fuel oil is the main fuel used for international maritime shipping, the CFR appears to leave the international maritime fuels to regulation by the International Maritime Organization (IMO). Under increasing pressure, the IMO considered broader regulations to decarbonize international shipping (Psaraftis, 2019); in 2021, the IMO adopted measures to align with its initial strategy goal of 40% reduction in international shipping carbon intensity by 2030, relative to 2008 (IMO, 2021).

We compare the main categories of fossil fuels for which compliance obligations for CI reduction exist across the four standards considered in Table 3. We see that on-road gasoline and diesel are covered by the standards of all four jurisdictions investigated. However, the role of other fossil fuels in the CFR was considerably modified over the course of rule development.

There are a few additional unique features of the CFR that distinguish its scope from fuel CI standards in other jurisdictions. Canada is a large country with many remote communities, especially in its northern regions, that have higher-than-average demands for energy, particularly for heating during intense winters and for long-distance transportation. Consequently, the CFR will exempt remote communities in Canada, though not the industrial use of regulated fuels in remote communities. Finally, similar to other jurisdictions but important given Canada’s status as a significant exporter of oil, the CFR does not apply to liquid fuels exported from Canada but does include imports. Oil and gas extraction is the largest source of emissions in Canada, comprising 105 MtCO₂e in 2019 (ECCC, 2021: 8). We note that 81% and 45% of oil and natural gas produced domestically in Canada are exported, almost exclusively to the US (NRCan, 2020: 52, 79-80).

TABLE 3: SCOPE OF COVERED FOSSIL FUELS OF VARIOUS FUEL CARBON INTENSITY STANDARDS

	Canada CFR	California LCFS	BC RLCFRR	Oregon CFP
Liquid Fossil Fuel				
1) Gasoline	✓	✓	✓	✓
2) Diesel	✓	✓	✓	✓
3) Kerosene	Not Included	Not Included	Not Included	Not Included
4) Light Fuel Oil	Optional as credit generator in final regulations	Not Included	Not Included	Not Included
5) Heavy Fuel Oil	Not included	Not Included	Not Included	Not Included
6) Jet Fuel	Not included	Loaded in state optional as credit generator	Not Included	Loaded in state optional as credit generator

4.2. Scope of Regulated Firms across Jurisdictional Standards

In order to mitigate administrative costs, transportation fuel CI standards generally set minimum sizes for the firm participation. Firms that produce or import more than 400 m³ (400,000 litres) of gasoline or diesel fuel are required to comply with the CFR (Government of Canada, 2022: 2662). Oregon similarly has a small volume fuel cut-off for producers of less than 10,000 gallons (~37,800 litres) of liquid fuel per year, or those who solely produce liquid fuel for motor vehicles at a volume of less than 50,000 gallons (~189,300 litres) per year (OSOS, 2022). Oregon also exempts fuels with small overall supply, of under an aggregate 360,000 gallons (~ 1,362,700 litres) of liquid fuel annually. Both the CFR and Oregon standard have a lower threshold for exemption than currently observed in BC where the threshold starts at 75 million litres until 2020, though it is expected to be further reduced to producers and importers of fuels in amounts below 200,000 litres for 2022 and subsequent years. In contrast, California does not have a cut-off related to supplier size across the board (but does exempt fossil compressed natural gas at stations with up to 150,000 gasoline gallon equivalents per year (~567,800 litre equivalents per year)), but does exempt alternative fuel types that are supplied, for transportation, in California at a total amount of less than 420 million MJ per year (Cal. Code Regs. tit. 17 § 95482).

5. COMPARISON OF CREDIT GENERATING PROTOCOLS

The CFR contrast with other transportation fuel CI standards in terms of the range of the fuel pathways and policy actors that it incentivizes to produce low-carbon fuels and alternative energy sources through credit generating protocols. Table 4 provides a summary of the credit generating protocols used in each jurisdiction for various alternative fuels and energy sources. These protocols go by different names and group slightly different activities across jurisdictions. Under the CFR, three so-called “categories of compliance credit creation” have been developed. In California, for example, three types of “credit generation activities” are recognized under the LCFS while the BC RLCFRR covers similar activities through only two compliance protocols, one including fuel-pathway credit balance and the other, which can cover activities beyond those covered in California, going by the name of “Part 3 Agreements”. To be consistent, within this document we refer to all of these as credit generating protocols. In this section, we discuss protocols existing across the four jurisdictions considered in this working paper, though organizing around those established under the final CFR.

TABLE 4: CREDIT GENERATING PROTOCOL CATEGORIES ACROSS JURISDICTIONAL STANDARDS

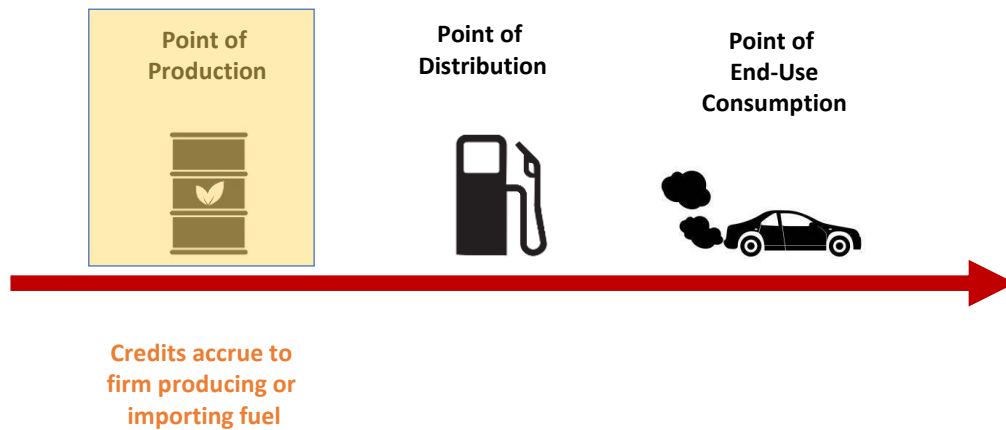
	Canada CFR	California LCFS	BC RLCFRR	Oregon CFP
Alternative Fuel or Energy Source	Compliance Protocol			
Supplying low-carbon alternative liquid fuels for transport <ul style="list-style-type: none"> • Biofuels • Synthetic Fuels 	Compliance Category 2	Fuel Pathway-based Crediting	Fuel Pathway-based Crediting	Fuel pathway-based crediting
Switching fuels and energy for advanced transportation technologies <ul style="list-style-type: none"> • Natural Gas • Propane • Hydrogen • Renewable natural gas • Renewable propane • Electricity 	Compliance Category 3			
Supplying low-carbon liquid fossil fuels <ul style="list-style-type: none"> • Carbon capture and storage • Refinery efficiency improvements • Low carbon crude production, including EOR • Co-processing biofuels in refineries and upgraders 	Compliance Category 1 (Project-based, but coprocessing with biofuel is treated equivalently to low carbon alternative energy)	Project Based Crediting, except coprocessing, which is treated under fuel pathway-based crediting*	No, except coprocessing, which is treated under fuel pathway-based crediting	No, except coprocessing, which is treated under low carbon alternative energy
Low-carbon supporting infrastructure	Not Available	ZEV Fuelling Infrastructure Crediting	Can be covered in Part 3 Agreements	Credits for ZEV adoption and fuelling infrastructure can be advanced for certain publicly beneficial end uses

Sources: Analysis by authors. *Carbon capture and storage can also be credited as part of a low carbon fuel-based pathway (e.g., at an ethanol plant).

5.1. Low-carbon Liquid Alternative Fuels (CFR Compliance Category 2)

Compliance Category 2 is intended to incentivize the production and importation of low-carbon alternative liquid fuels, such as biofuels and synthetic fuels, which might directly replace gasoline and diesel in conventional internal combustion engines (Figure 4). At the time of writing, the only alternative liquid fuels commercially available are biofuels, such as ethanol, biodiesel, or renewable diesel. Other synthetic fuels, such as those made from the CO₂ captured directly from the air or syngas generated from waste resources have been demonstrated at small scale and may play a larger role in the future. Essentially all low-carbon alternative liquid fuels supplied to the Canadian market would be able to create credits. The number of credits generated would be based on the amount of fuel supplied (in MJ), and the difference between its lifecycle CI rating and the annual CI target for the fuel that is being displaced, e.g., gasoline, diesel, or jet fuel. If the fuel/vehicle combination has a different efficiency than the conventional fuel used in an internal combustion engine (beyond energy content), that efficiency difference is also accounted for in the crediting.

FIGURE 4: PRODUCTION OF CREDITS FROM LOW-CARBON LIQUID ALTERNATIVE FUELS (CFR COMPLIANCE CATEGORY 2)



5.2. End-use Fuel Switching in Transportation (CFR Compliance Category 3)

The last compliance protocol type in Canada, Compliance Category 3, focuses on incentivizing the replacement of liquid fossil fuels for road transportation (rail is excluded) with low-carbon and non-liquid energy sources such as hydrogen, propane and electricity. Also known as end-use fuel switching, activities of this compliance protocol reduce GHG emissions by displacing a liquid fossil fuel with an energy carrier that has a lower lifecycle CI value, such as low-carbon electricity and hydrogen. Energy efficiencies of new fuel/vehicle combinations relative to fossil fuel in an internal combustion engine (ICE) vehicle are also accounted for, further distinguishing fuels under Compliance Category 2 from those for Compliance Category 3.¹

¹ Category 2 fuels, such as biofuels, are consumed by the same vehicles as conventional fuels, resulting in same or similar net efficiencies of converting fuel energy to useful work. Category 3 fuels use a different powertrain technology and typically have greater efficiency.

The CFR recognize five types of policy actors and associated pathways for generating credits through Compliance Category 3, which might vary by type of fuel (electricity and other low-carbon fuels) and, for electricity, type of charging facility (residential/public and private). See Table 5. Residential/public charging are the available options for switching to electricity, with credits accruing to a “charging network operator”. As defined by the CFR, this is a firm that operates a communication platform that collects data on the electricity supplied to a charging station and who is the owner of that data (Government of Canada, 2022: 2654). Private firms might supply electricity as charging site hosts or alternative fuels as owners of fueling stations. Figure 5 demonstrates how firms and other organizations might generate credits for electric vehicle charging through both residential/public and private charging facilities.

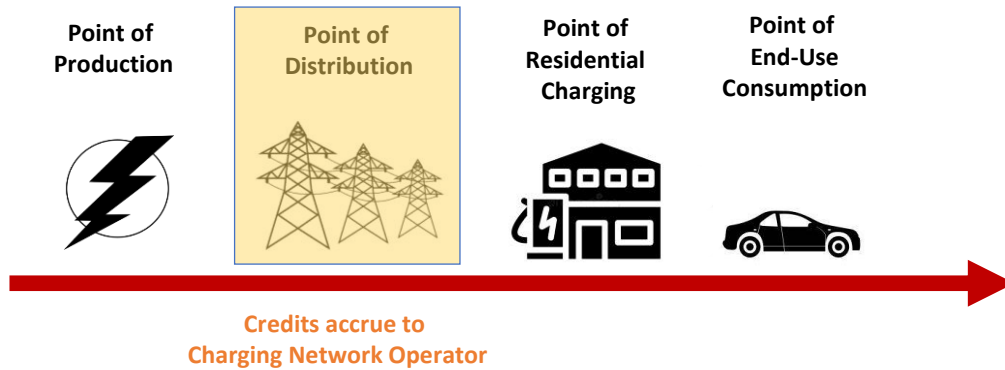
Significantly, credits for charging electric vehicles are calculated using 2018 lifecycle CI electricity values by province (Government of Canada, 2022: 2933). ECCC’s plan is to update the CI values approximately every two years (ECCC, CFR Question and Answer Session, Aug. 2022). In 2016, the data year used for the CFR Regulatory Impact Analysis, the average Canadian electricity CI value was 180.4 tonnes CO₂e per gigawatt hour (tCO₂e/GWh); provincial averages, in regulatory units, ranged from a low of 2 gCO₂e/MJ in PEI to a high of 313 gCO₂e/MJ in Nunavut; the regulatory values reflect 2018 values and are unchanged (Table 6). In contrast, as discussed earlier, the determination of CI values for gasoline, diesel and other refined petroleum products is conducted on the basis of a Canadian national average crude CI value. However, CI values for hydrogen produced through electrolysis are set at 25 gCO₂e/MJ when the electricity source has a CI value of 50 gCO₂e/MJ and 150 gCO₂e/MJ for hydrogen produced from any other source of electrolysis (Government of Canada, 2022: 2799). Note that Oregon also allows deviation from the state-wide average for electricity; utilities can opt-in to a utility-specific CI value on an annual basis. California assesses electricity CI at the state-wide level, but allows utilities or charger operators to contract for low carbon electricity in excess of state mandates and claim credits for the additional avoided emissions. Both Oregon and California update their electricity assessments annually.

TABLE 5: POTENTIAL CREDIT GENERATING ORGANIZATIONS FOR CFR COMPLIANCE CATEGORY 3

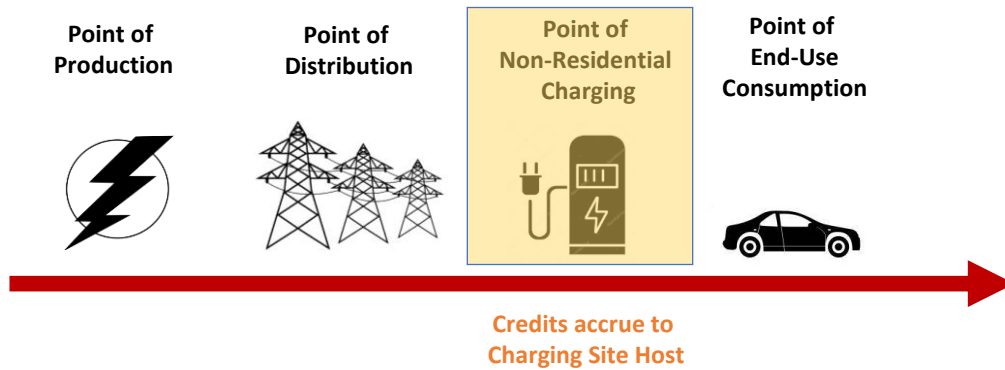
Residential/Private Facility	Type of Fuel Switching	
	Electric Fuel Switching	Alternative Fuel Switching
Residential and Public Facilities	Charging network operators (Hydro-Québec, FLO, Alberta Electric System Operator, etc.) supplying electricity for residential and public charging stations for electric vehicles	
Private Facilities	Charging station hosts for private charging stations for electric vehicles	<p>Owners or operators of fuelling stations that supply low CI alternative fuels for transportation (natural gas, renewable natural gas, propane, renewable propane)</p> <p>Producers and importers of low CI alternative fuels used for transportation purposes (renewable natural gas and renewable propane)</p> <p>Owners or operators of hydrogen fuelling stations for hydrogen fuel cell vehicles</p>

FIGURE 5: PRODUCTION OF CREDITS FROM SWITCHING TO ELECTRIC VEHICLE CHARGING: EXAMPLE OF (A) RESIDENTIAL AND (B) NON-RESIDENTIAL CHARGING (CFR COMPLIANCE CATEGORY 3)

(A) RESIDENTIAL CHARGING



(B) NON-RESIDENTIAL CHARGING



Note: In California, OEMs of EVs can earn a portion of credits for residential charging if metered data are supplied and below-the-grid CI charging is being credited. In Oregon, electric utilities get credits for residential charging, and charging site host gets non-residential credits. A Backstop Aggregator receives unclaimed credits and must use revenue to forward EV adoption and use.

TABLE 6: DEFAULT CARBON INTENSITY VALUES OF ELECTRICITY BY PROVINCE AND TERRITORY

Province	gCO ₂ e/MJ
PEI	2
Quebec	5
Manitoba	7
BC	11
Ontario	14
Newfoundland & Labrador	16
Yukon	30
Northwest Territories	71
New Brunswick	89
Alberta	218
Nova Scotia	224
Saskatchewan	237
Nunavut	313

Source: Government of Canada (2022: 2800-2801)

5.3. Low-carbon Liquid Fossil Fuels (CFR Compliance Category 1)

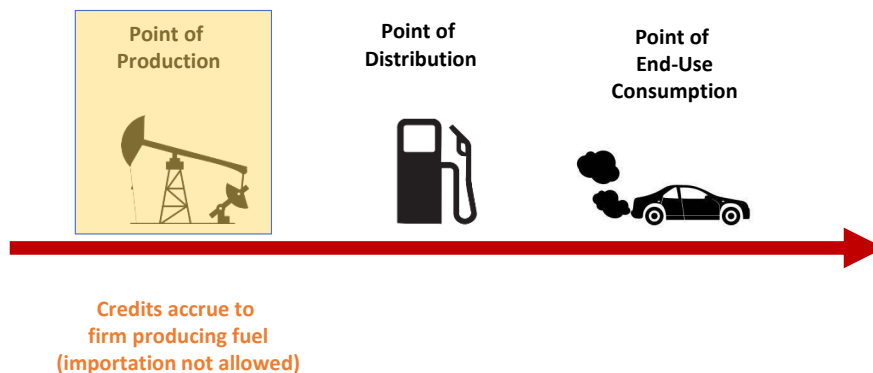
Compliance Category 1 of the CFR seeks to reduce the lifecycle CI of liquid fossil fuels in Canada through projects that reduce upstream GHG emissions associated with their production (Figure 6). Importantly this compliance category was originally only intended for fuels produced in Canada, though the final regulations permit facilities outside Canada to also participate. In order to do so, jurisdictions outside of Canada might enter into an agreement with ECCC in order to ensure that their projects are comparable in terms of effectiveness to ones in Canada (Government of Canada, 2022: 2874).

While a wide range of project types are within the scope of the proposed CFR, ECCC is prioritizing development of protocols for the following five types of projects: (i) carbon capture and permanent storage, (ii) low-CI electricity integration (iii) enhanced oil recovery with CO₂ capture and permanent storage, (iv) co-processing of biocrudes in refineries and upgraders and (v) low-CI hydrogen integration (Government of Canada, 2022: 2873). For example, if a refinery producing gasoline were able to switch from using primarily coal-based electricity to electricity derived from renewables, the lifecycle CI of the gasoline produced will be rated lower even if the tailpipe GHG emissions are the same. The producer would gain credits for the switch, equivalent to the total emissions reduced by the switch. ECCC is also prioritizing a template for regulated parties to propose their own quantification methodology for projects in this category.

A credit generating protocol similar to CFR Compliance Category 1 does not exist in Oregon nor BC, though California has developed a protocol for lowering the CI of petroleum and other types of fuels within a broader crediting category known as “Project-based Crediting”. Innovative methods to lower the CI rating of petroleum production, such as use of solar steam in oil recovery, or refinery investments, can thus generate credits in California. The initial production set-up serves as a baseline.

The emphasis on specific projects with the CFR Compliance Category 1 to reduce upstream emissions in the production of fossil fuels instead of producing alternative low-carbon liquid fuels requires a different quantification approach. While LCA results compared to a standard are integral to credit generation for Compliance Category 2, the approach for Compliance Category 1 involves comparison to a project baseline and assessment of additionality. For example, a project would be credited for generating emission reductions that are “additional” – that is they would not have happened without the policy incentive – and measured against a reference scenario where the project had not been introduced rather than the annual CI target. Credits could be generated for 10 years for emission reduction projects, except for carbon capture and storage projects, which could create credits annually for a minimum of 20 years.

FIGURE 6: PRODUCTION OF CREDITS FROM LOW-CARBON LIQUID FOSSIL FUELS (CFR COMPLIANCE CATEGORY 1)



5.4. Low-carbon Supporting Infrastructure (No Equivalent CFR Compliance Category)

Finally, we identify an additional category of credit generating protocols that has no direct counterpart in the Canadian CFR. California and BC allow credits to accrue to support the development of low-carbon infrastructure. California recently created a Zero Emission Vehicle Infrastructure (capacity-based) crediting compliance protocol to incentivize hydrogen refueling and direct current (DC) fast charging infrastructure for electric vehicles. Both can gain credits based on unused station capacity, up to some limits. Similarly, so-called “Part 3 Agreements” in BC can recognize compliance through *potential* decarbonization activities such as achievement of pre-specified milestones in a project with a reasonable possibility of reducing CO_{2e} emissions from fuels. These projects could relate to low carbon supply infrastructure, or more directly to production facilities themselves, or to vehicles. There is considerable latitude. These protocols also use baseline and credit systems to generate clean fuel credits, akin to carbon offsets.

6. COMPARISON OF METHODS FOR ASSIGNING CI RATINGS TO FUELS

In this section we compare technical methods for determining CI ratings in the four jurisdictional standards considered. Lifecycle assessment (LCA) models of GHG emissions are integral to this process as they provide the essential information for determining the CI rating of each fuel type. LCA models are employed in an ongoing manner to assess new fuels as they apply to the program or appear in a jurisdiction, and are also used as part of ex ante regulatory analyses to explore the potential for different fuel mixes to meet compliance targets (Farrell et al., 2007). Different jurisdictions make use of different LCA methods and analytical approaches.

Jurisdictions also differ with regard to how they handle the prospect of generating emissions through indirect land-use change (ILUC) from the production of alternative fuels, particularly biofuels (Wicke et al., 2012). Diverting land towards the production of biofuel feedstocks and away from food production or forest conservation can have a considerable impact on GHG emissions, as some of the diverted production gets backfilled by new land conversion, perhaps far away from where the biofuel feedstock is being grown. According to some modeling, the potential for increased emissions from biofuels vis-à-vis their petroleum counterparts exists in some situations, for example if agricultural change leads to conversion of peatland forest to palm oil. The main difference between instruments currently being used in the U.S. and Canada is the inclusion of ILUC emissions estimates in standards developed for both California and Oregon, and their omission in BC and the Canada regulation.

Table 7 summarizes the main differences between jurisdictional standards in terms of LCA methods and approach to ILUC. Note that CI estimates for ILUC, where included, are added to the primary LCA model results to yield the CI rating for the feedstock-fuel type “pathway”.

TABLE 7: LCA MODEL CHOICE AND INCLUSION OF INDIRECT LAND USE CHANGE (ILUC) IN EACH JURISDICTION

	Canada CFR	California LCFS	BC RLCFRR	Oregon CFP
Primary LCA Models	Model being developed by ECCC	CA – GREET + OPGEE	GHGenius	OR-GREET + OPGEE
Addressing Indirect Land Use Change (ILUC)	Land use and biodiversity criteria but no provisions for ILUC	GTAP-BIO+AEZ_EF Models	No ILUC	GTAP-BIO+AEZ_EF except +CCLUB for corn ethanol

6.1. LCA Models across Jurisdictional Standards

California and Oregon both assess fuel lifecycle emissions for alternative fuels using a version of the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) model developed by Argonne National Lab. The regulatory versions of the generic model have been calibrated for state-level conditions, including the California version, CA-GREET (CARB, 2020b), and Oregon version, OR-GREET. In these jurisdictions, most fuel “pathways” – the physical supply chain for specific fuel volumes – receive their own CI ratings based on the particularities of production facilities and mode of distribution to the states.² For petroleum fuel CI ratings, both U.S. jurisdictions supplement the GREET model with the Oil Production Greenhouse gas Emissions Estimator (OPGEE) model (CARB, 2020a) to generate state-wide average CI ratings for petroleum fuels. The models are updated periodically (e.g., California and Oregon recently transitioned to CA-GREET and OR-GREET 3.0, and an updated version of the OPGEE model). In 2018, California added third party verification and validation of inputs to calculating CI ratings as part of its LCFS, and Oregon followed.

Turning to the standards developed in Canada, we find different LCA methods being used. BC relies on default CI values determined by the BC government (often conservative from a CI perspective), though then allowing producers to use the GHGenius model comparable model to submit a pathway-specific CI rating subject to government approval. GHGenius, like GREET, is a model associating emission factors with particular inputs and production process, though more tailored to the Canadian situation. In BC, the provincial government has verification authority, but no third-party process is in place. The CFR will rely on an approved lifecycle CI database envisioned as giving the same result in any lifecycle analysis software. The LCA model for the CFR became available alongside the final regulation in July 2022. There also will be an independent verification process for data inputs to ensure they align with the real-world situation. Note that for jurisdictions that do not account for ILUC, the primary LCA modeling tool covers any land conversion occurring in order to product the feedstock (for those that consider ILUC, direct land conversion is subsumed within the ILUC analysis).

Regulated parties can use the fuel lifecycle assessment (LCA) model to estimate the lifecycle CI for their fuel “pathway” using facility-specific data (and particular transport modes to the jurisdiction), and submit to the regulatory authority for processing, verification, and approval. This is the system developed for the CFR by ECCC, and also in place in the other jurisdictions. Default CI values are also made available for specific types of low carbon alternative fuels, based on more generic pathways, and usually conservative (relatively high CI) to guard against higher CI pathways being incorrectly assessed.

6.1. Indirect Land-Use Change (ILUC) across Jurisdictional Standards

There are some important differences between the four transportation fuel CI standards considered in terms of how they address ILUC. To model ILUC emissions, California and Oregon both use a version of the Global Trade Analysis Project (GTAP) model developed at Purdue University, a computable general

² If the pathway is well understood, the fuel provider applies for a CI rating via a “Tier 1” process that makes use of a spreadsheet where pathway-specific input can be applied and be associated with GREET emission factors. If a pathway is less understood, the fuel provider must apply via a “Tier 2” process that allows closer working with the regulatory authority to tailor the inputs and associated emissions. For some fuels, such as state-level grid electricity, and reference fuels gasoline and diesel, there is also a “look-up table” of default CI values that can be used.

equilibrium economic model. The version used, GTAP-BIO, contains more detail in the biofuel sector and for agricultural products used as feedstocks. It estimates a global market response in terms of increased agricultural production in particular areas to the biofuel policy, modeled as a shock of increased demand for a particular feedstock, such as corn. A separate model, developed by experts for California, the Agroecological Zone Emissions Factor (AEZ-EF) model, translates GTAP-BIO output into estimates of land conversion GHG emissions around the world. Oregon uses the same system and values as California, except for corn ethanol, where rather than the AEZ-EF emissions factor model, it uses the Carbon Calculator for Land Use Change from Biofuels Production model (CCLUB), developed at Argonne National Lab.

In contrast, the modeling tools currently being used in the CFR and BC-RLCFRR only assess emissions for land use conversion for the biofuel feedstock itself, ignoring any larger market impacts. This means the policies may tally GHG benefits from biofuels in excess of their actual emissions-reducing effect. In order to address ILUC, the CFR lays out land use and biodiversity (LUB) criteria for the use of biofuels and biomass feedstocks regardless of geographic origin (i.e., imported from outside Canada) as part of Compliance Category 2 (Government of Canada, 2022: 2694-2719). These distinguish between criteria for forest feedstock, those specific to agricultural feedstock, and those that apply to all feedstock. These criteria also impose requirements for supply chain declarations, including for foreign suppliers if low-CI fuels are sourced from outside of Canada. The onus for demonstrating LUB criteria adherence rests with the low CI fuel producers, but compliance with the criteria need to be demonstrated at the feedstock producer level or through an approved certification scheme.

The LUB criteria bar the use of feedstocks from protected and other environmentally sensitive areas, and include a ban on use of feedstocks deemed to be at high risk of ILUC, taking the definition used by the EU for its renewable energy policy (RED), which refers to global land expansion for the feedstock, and currently lists palm oil as high risk (average annual production area having expanded by more than 1%, and more than 10% of expansion has been into areas classified by the EU as protected or high carbon). However, the CFR did not adopt the other part of the EU regulations to safeguard against ILUC, namely caps on food- and feed-based crops for use as feedstocks. The portion of a fuel produced from feedstock associated with land-use change that does not meet the criteria will not count for CFR credit creation.

7. COMPARISON OF CREDIT MARKETS AND RELATED COMPLIANCE MECHANISMS

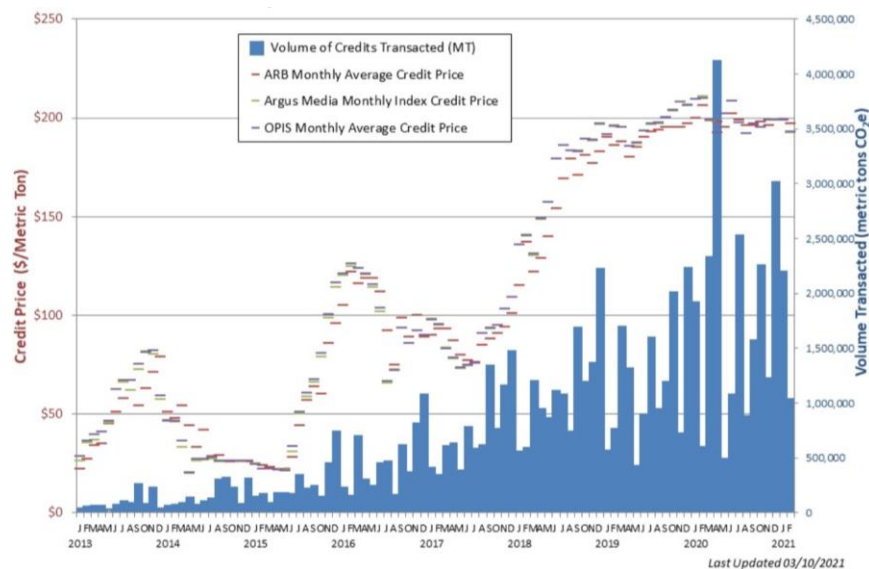
As discussed earlier, all existing North American transportation fuel CI standards have established clean fuel credit markets. Credits for supplying fuels at a CI rated lower than the standard, and program deficits for fuels, like fossil fuels, with a CI rated higher than the standard are delineated in metric tonnes of CO₂ equivalent (tCO₂e) emitted by the fuel/vehicle combination relative to the standard at the time. Credits can be bought to offset deficits for compliance. Credits are typically fully fungible towards program standards across fuel pools—for example, credits generated from diesel substitutes can satisfy obligations generated from the sale of gasoline—and bankable for use in future years.

In this section we first discuss observed credit prices in other jurisdictions, which might shed light on future CFR prices. We next compare the CFR's credit clearance market and various price control mechanisms with similar measures undertaken elsewhere, before also discussing the compliance fund unique to CFR. We close this section with a comparison of clean fuel credits markets and carbon markets, another policy instrument based on similar units (tCO₂e).

7.1. Credit Prices

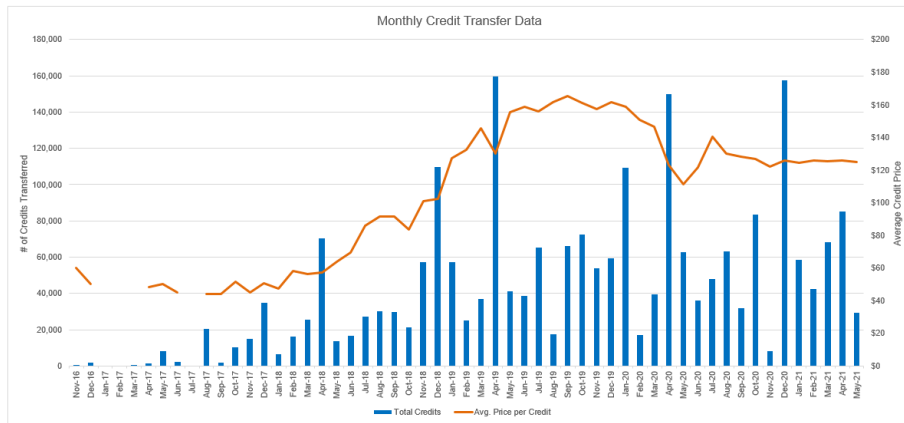
Clean fuel credit market prices have attracted considerable attention as they have grown significantly in recent years, surpassing most existing carbon pricing mechanisms such as carbon taxes and cap-and-trade. For example, prices on the California LCFS credit market started at under \$50 USD per tCO₂e in 2013 and rose thereafter, reaching close to \$200 USD per tCO₂e in 2019, and ranging between \$150 and \$200 USD in 2021 (Figure 7). More recently, average monthly California credit prices (July 2022) dipped to \$117 USD. Similarly, prices for clean fuel credits under Oregon’s CFP rose from under \$60 USD at the start of the program in 2016 to above \$120 in early 2021 (Figure 8), and were close to that (\$117 USD) in July 2022. In BC, the average price for credits has risen from \$170 CDN in 2015 to \$421 CDN (~\$330 USD) in 2021 (Figure 9), and averaged \$406 (~\$316 USD) in June 2022. The significantly higher credit prices observed in BC might be attributed to the absence of price control mechanisms found in other jurisdictional standards, as discussed in the next section.

FIGURE 7: MONTHLY CALIFORNIA LCFS CREDIT PRICE AND TRANSACTION VOLUME



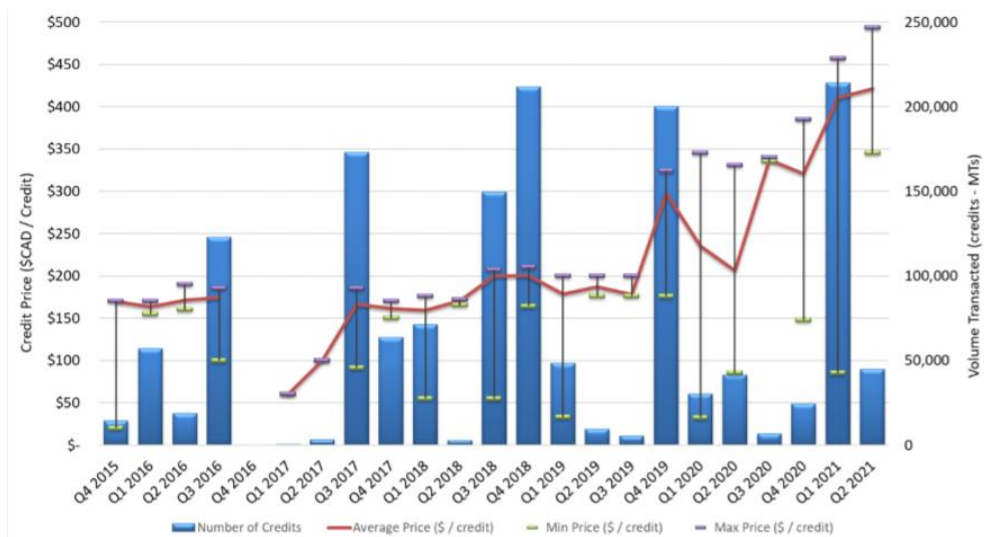
Source: CARB (2022b)

FIGURE 8: MONTHLY OREGON CFP CREDIT PRICE AND TRANSACTION VOLUME



Source: State of Oregon (2021)

FIGURE 9: QUARTERLY BC LOW CARBON FUEL CREDIT MARKET CREDIT PRICE AND TRANSACTION VOLUME



Source: (British Columbia, 2021a)

As the CFR is only beginning to come into force, it is not possible to directly compare CFR credit prices with those of existing jurisdictional standards. However, economic modeling conducted by ECCC estimated that GHG reductions achieved by the CFR over 2022-2040 period would come at a cost per tCO_{2e} of \$205 (Government of Canada, 2022: 2947). Variation in the costs per credit in 2030 is expected to vary across compliance pathways, ranging from \$0 to \$343 (Table 8).

TABLE 8: SUMMARY OF ESTIMATED CFR COMPLIANCE PATHWAY COSTS AND OVERALL CREDITS IN 2030

Pathway	Credits (millions)	Estimated Cost per credit (\$CDN/credit)
Banked Credits	-	-
Low carbon fuels from current mandate	6.4	-
Supplying fuel or energy to advanced vehicle technologies (EVs)	7.0	-
Supplying fuel or energy to advanced vehicle technologies (NGVs and propaneVs)	0.1	-
Baseline carbon capture and storage	1.1	-
Biodiesel (5%) in light fuel oil	0.2	\$41
Biodiesel (5%) in diesel	1.8	\$79
Incremental carbon capture and storage	3.0	\$125
Hydrogenation-derived renewable diesel (6%) in light fuel oil	0.1	\$134
Ethanol in gasoline (10%)	0.5	\$152
Hydrogenation-derived renewable diesel (6%) in diesel	2.4	\$158
Compliance Fund	3.4	\$343
Emerging technology	8.3	\$343
Total credits created (quantity of credits supplied)	34.3	NA

Source: Government of Canada (2022: 2941)

7.2. Compliance Mechanisms

Given the prospect of high clean fuel credit prices, many standards have included various compliance mechanisms, as well as a credit price control mechanism to limit potential costs due to the policy. The CFR will use a credit clearance market structured similarly to those in effect in California and Oregon, as well as a unique compliance fund. We note that while BC currently has no such mechanism in place, it does include a financial penalty for non-compliance, and is currently developing amendments that might introduce increasing that penalty.³

7.2.1. Credit Clearance Markets

Credit clearance markets established in California and Oregon provided the blueprint for the CFR proposal, the first credit clearance market in operation in Canada (Table 9). With a maximum selling price and rollover provisions, the credit clearance markets in the two U.S. fuel CI standards serve to help contain costs in the instance of a shortfall of available credits, playing a clearinghouse function to match any unbought but offered credits with buyers needing to comply at up to a set price cap, and outlining how compliance can be achieved in the absence of sufficient offered credits in a given year. Because it does not involve selling paper credits to meet compliance, a credit clearance market acts as a soft credit price cap.

³ Note also that Part 3 agreements can serve as an ad-hoc mechanism to generate additional credits if market prices rise too far, although there are limits on their use as a mode of compliance.

More specifically, in California and Oregon, regulated parties not in compliance at the designated time to show compliance must buy a pro-rated share of any credits offered for sale on the credit clearance market. “Not in compliance” means having any outstanding deficits in California, and over 5% of owed deficits in Oregon (Oregon allows these “small deficits” to roll forward to the next year without penalty). The credit clearance market is held with a maximum credit price set at \$200 per tCO₂e (in 2016 USD for California, and 2017 USD for Oregon, adjusted for inflation thereafter).

In California, the ceiling on the credit clearance market price was generalized to apply to all credit trades, though Oregon has not followed. Furthermore, credits offered for sale on the California credit clearance market, if insufficient to cover needs, can be supplemented via issuing advanced credits on future electricity charging to the utilities, up to a limit, and subject to a payback schedule. The utilities then enter the advanced credits into the credit clearance market. Remaining deficits can be carried over to the next compliance period but accrue interest of 5% in a year (charged in deficits). The deficit and interest must be repaid within 5 years. In Oregon, if parties have recourse to consecutive credit clearance markets, the government must undertake a root cause analysis for the shortfall; if the situation is widespread, it can undertake a broader root cause analysis and propose a remedy, including the possibility of issuing an emergency deferral under one of the provisions specified for that purpose.

Canada’s CFR credit clearance market is modeled after the others so that buyers must buy a pro-rated share of offered credits up to their compliance level (but no further), sets a maximum price of \$300 CAD per credit, indexed to inflation after 2022 (Government of Canada, 2022: 2878). Like California, the CFR includes an option to defer compliance with a 5% annual interest penalty on uncovered deficits, to be paid within 5 years. In Canada’s case, this option is open to regulated parties who have satisfied 10% of their compliance obligation (possibly through the compliance fund option, see below) and have not reached the limit on deferrals of 10% of compliance.

Finally, we note that while there is currently no credit clearance market in BC, at the time of publishing this report (October 2022), the BC government is preparing amendments to the regulations under the current RLCFRR for consideration later this year and to take effect in 2023. These amendments are expected to recommend increasing a penalty above \$200 for non-compliance with the CI requirements.

TABLE 9: CREDIT CLEARANCE MARKETS ACROSS JURISDICTIONAL STANDARDS AND ASSOCIATED PRICES

	Canada CFR	California LCFS	BC RLCFRR	Oregon CFP
Credit Clearance Market Price	\$300 CDN (~\$230 USD)	\$200 (2016 USD)	No Credit Clearance Market (but penalty above \$200 CDN anticipated for 2023)	\$200 (2017 USD)

7.2.2. CFR Compliance Fund

The CFR compliance fund, an option unique to Canada, would allow companies to meet 10% of their CI compliance obligation for a given year with a contribution to a specified fund, set at \$350 CAD per credit and indexed to inflation (Government of Canada, 2022: 2878). Entities not able to meet compliance due to insufficient credits being offered in the credit clearance market must pay into the compliance fund to meet compliance, up to the 10% limit, before deferral as described above becomes an option. The credits generated through this contribution would be applied to the given year and would be non-tradeable and non-bankable. The funds themselves are registered through ECCC, and must use these contributions for projects or activities that lower emissions within 5 years. The compliance fund mechanism is expected to

act as a price cap, since the contribution value per deficit paid can be set, although the limit on the outlay prevents it from performing as a hard price cap.

7.2.3. Other Compliance Mechanisms of the CFR

The CFR includes a number of additional mechanisms to ensure credit market flexibility and stability in order to facilitate compliance by regulated firms. First is a mechanism to allow compliance units issued under the existing federal *Renewable Fuels Regulations*, which represent liters of renewable fuel, to be converted into credits that can be used in the CFR for compliance purposes. Recall that the *Renewable Fuels Regulation*, in operation since 2010, is intended to be replaced by the CFR at the end of September, 2024. A compliance unit bank rollover mechanism will allow primary suppliers with surplus credits under the *Renewable Fuels Regulation* to convert these credits under the CFR. This will be a onetime occurrence, and once converted the credits will be treated the same way as other CFR credits.

A second mechanism to facilitate compliance is a CFR credit banking mechanism. This mechanism allows producers and suppliers to bank all surplus credits that they accumulate as the credits have no expiry date. These banked credits can be used to meet reduction requirements for up to 100% of a firm's reduction requirement. This mirrors the use of banked credits in other jurisdictions. The mirror image of saving (banking) credits for future use, "borrowing" credits against the future, only occurs in the two U.S. programs considered. In California, the use of advanced credits from residential EV charging as a backstop for the credit clearance market is permitted while, in Oregon, the ability to receive advanced EV credits from certain fleets transitioning to EVs based on estimates of likely use. Both types of advances are subject to repayment.

Third, an option exists under the proposed CFR to use credits from other streams for liquid fuel stream compliance allows meeting 10% of the liquid fuel stream CI compliance obligation with credits from solid or gaseous fuel streams. Particular credit generation opportunities for lower carbon alternatives in these areas still exist despite the narrowing of the regulation, as all the credit generating opportunities described up to the point of the regulatory change will still be allowed.

7.3. Clean Fuel Credit Markets versus Carbon Markets

Given the important role of carbon pricing in the Canadian federal government climate action plan (most recently, Canada's 2030 Emissions Reduction Plan), it is useful to compare carbon pricing with a clean fuel standard. Here we compare credit prices on California's LCFS credit market with emission allowance prices on the California-Quebec carbon market. While LCFS credit prices have ranged from \$117 to \$200 USD over the period 2021-2022, as discussed above, carbon prices on the California-Quebec carbon market reached approximately \$18 USD in early 2021 (Purdon et al., 2021a).

However, while both policy instruments trade in units denominated in tCO_{2e}, the two represent different measures that are neither directly interchangeable nor representative of the same effect on total GHG emissions. Relative to carbon pricing, California's LCFS introduces a more focused carbon price that is applied only towards emissions relative to the CI standard and only applicable within the transportation fuel sector. In contrast, carbon pricing puts a price on all in-jurisdiction GHG emissions in covered sectors from regulated entities (except biogenic carbon, as we discuss below). This leads to a second major difference: the LCFS penalizes the production of high-CI fuels while subsidizing low-CI fuels, whereas carbon pricing merely penalizes low-CI fuels less than high-CI ones. This carries some politically attractive

features as the LCFS directly provides revenue to low-carbon fuel producers, rather than just giving them a competitive advantage in the market (Purdon et al., 2021b).

A numerical example in Table 10 below contrasts a hypothetical fuel CI standard with carbon pricing using two fuels, one with characteristics similar to diesel and the other similar to renewable diesel. Absent any policy, these two fuels cost a hypothetical \$3 and \$4 USD per gallon to supply, respectively. In the example, the LCFS is set at 90 gCO₂e/MJ, which is approximately a 10% reduction relative to diesel, and CI ratings for the fuels are the same in both programs (whereas assessment methods can and do vary across the two policy types, as explained below). We walk through two different carbon price scenarios: first at \$20 USD per tCO₂e, which reflects current cap-and-trade allowance market price, and the second at \$200 USD per tCO₂e. This is close to peak LCFS credit prices in California, experienced in much of 2019 and 2020.

Results point to politically salient outcomes. First, regardless of the price put on carbon, the overall cost of bringing this hypothetical diesel to market is higher under cap-and-trade than under the fuel CI standard whereas the cost of supplying the hypothetical renewable diesel is lower under the LCFS than cap-and-trade. Second, the increased cost of supplying diesel under the fuel CI standard at a cap-and-trade price of \$200 USD per tCO₂e is \$0.27/gallon, similar to the additional cost of diesel at a cap-and-trade price of \$20 USD per tCO₂e. Third, given our initial production cost assumptions, the impact of both policies is to shift the relative cost of supplying fuels in favor of low-carbon ones. But the price change felt at the pump is muted for diesel under the fuel CI standard relative to cap-and-trade. Both the LCFS and cap-and-trade at \$200 USD per tCO₂e bring the cost of renewable diesel below diesel, but the LCFS does so at a lower cost to consumers, due to its subsidizing of emissions from low carbon fuels.⁴

⁴ For a historical look at actual cost reductions (implied subsidies) from the LCFS in California, see the fuel-specific and feedstock tabs in a UC Davis-hosted LCFS visualization tool: <https://asmith.ucdavis.edu/data/LCFS>.

TABLE 10: COMPARISON OF HYPOTHETICAL CHANGES TO THE COST OF SUPPLYING TRANSPORT FUELS BETWEEN A CAP-AND-TRADE AND A FUEL CI STANDARD AT A 10% CI REDUCTION LEVEL

Fuel Type	Carbon Price	Carbon Intensity	Energy Density	Supply Cost	Change to Cost of Supplying Fuel		Total Supply Cost after Policy	
					Cap-and-Trade	CI Standard	Cap-and-Trade*	CI Standard**
	\$USD/tCO _{2e}	gCO _{2e} /MJ	MJ/gallon	\$USD/gallon	\$USD/gallon	\$USD/gallon	\$USD/gallon	\$USD/gallon
Carbon Price of \$20 USD per tCO_{2e}								
Diesel	\$20	100	135	\$3.00	+\$0.27	+\$0.027	\$3.27	\$3.03
Renewable Diesel	\$20	40	125	\$4.00	+\$0.10	-\$0.125	\$4.10	\$3.87
Carbon Price of \$200 USD per tCO_{2e}								
Diesel	\$200	100	135	\$3.00	+\$2.70	+\$0.27	\$5.70	\$3.27
Renewable Diesel	\$200	40	125	\$4.00	+1.00	-\$1.25	\$5.00	\$2.75

Notes: (*) For cap-and-trade, carbon price is applied to carbon amounts in a gallon of fuel, converted to tons from grams: $Price * ED * CI * 10^{-6}$; (**) For CI Standard, carbon price is applied to carbon amounts in a gallon of fuel relative to the standard, converted to tons from grams: $Price * (CI - CI_{standard}) * ED * 10^{-6}$. ED is the energy density of the gallon of fuel.

8. PROGRAM GOVERNANCE AND ADMINISTRATION

All transportation fuel CI standards have established monitoring, reporting, and verification systems for their governance and administration. Such systems offer greater transparency, promote compliance and, ultimately, allow for the evaluation of the effectiveness of standards. In this section we briefly compare the governance and administration system of the CFR with that of other standards, particularly California's LCFS. California is widely considered to have the most well-developed governance and administrative system thus far. The interested reader might also consult specific guidance documents. For example, the California LCFS has developed an *Annual Reporting and Verification User Guide* (CARB, 2021b) while the CFR has released *Methods for Verification and Certification for the Clean Fuel Regulations* (ECCC, 2022b).

8.1. Reporting and Verification

All fuel CI standards require that a considerable amount of information be regularly reported. For example, the LCFS requires that all regulated entities report transportation fuel transactions and credit transfers to the CARB. This includes submitting, as appropriate, an Annual Compliance Report, Annual Fuel Pathway Report, Quarterly Fuel Transactions Report, and Annual Marketable Crude Oil Volume Report, amongst other reporting requirements. To help manage such reports and associated data, the LCFS has created a data management system comprised of (i) LCFS Reporting Tool (LRT), (ii) Credit Bank and Transfer System (CBTS) and (iii) Alternative Fuel Portal (AFP) (CARB, 2018b; 2021a). Similarly, participating firms in the CFR need to submit a number of different reports to ECCC. Required reports include, amongst other, Quarterly and Annual Credit-Creation Reports (specific for each Compliance Category), CI Pathway Report, Compliance Report registration and various compliance and verification reports. Firms generating fuels under Compliance Category 2 need to demonstrate that any feedstocks used in the process respect land-use and biodiversity criteria by adhering to a third-party certification system. Also, similar to the LCFS, the CFR has built a Credit and Tracking System (CTS): a web platform to enable registration, reporting, credit creations, credit transactions for regulated firms and those generating clean fuel credit, both in Canada and abroad (ECCC, 2022a).

In order to verify the often highly technical information contained in such reports, all standards have also all developed rules to ensure that entities undertaking third-party verification and certification are reliable and can be held to account. Reports need to state whether the information submitted is complete, compliant with the requirements, and credits and obligations are accurate and without material error. In 2018, the California LCFS adopted a system of third-party verification that includes mandatory rotations of auditors after defined periods with a given facility/company and mitigation measures for potential conflicts of interest. CARB trains auditors; regulated parties are responsible for paying for necessary audits. The CFR will also make use of third-party verification, though an accreditation program for third-party verifiers is still being developed (Government of Canada, 2022: 2985).

8.2. Disclosure and Enforcement

Existing fuel CI standards in BC, Oregon and California publish regular data on the low-carbon fuel instruments in operation including compliance, approved CI ratings as well as projects generating clean

fuel credits.⁵ The California government created an LCFS “Data Dashboard” that publishes periodic data on the LCFS credit market as well as information on credit breakdown by fuel type and average CI of reported fuels.⁶ They also publish weekly and monthly credit market reports that include traded volumes, prices, transfers, and parties buying/selling credits.⁷ In contrast, Oregon as well as, since 2022, BC publish monthly credit market reports.⁸ The timing and nature of public data for the CFR is not yet clear.

Enforcement under current CI standards can range from publishing notices of violation, suspending accounts, and revoking or adjusting credits, or other enforcement actions. The CFR final rule includes a list of violation types (Government of Canada, 2020: 2786-2789). Given that the CFR have been made under the Canadian Environmental Protection Act (CEPA), enforcement provisions would see the application of CEPA’s Compliance and Enforcement Penalty. The CFR also amends the Environmental Violations Administrative Monetary Penalties Regulations, allowing for a monetary penalty to be administered for certain violations.

8.3. Periodic Review

All of the fuel CI standards considered require periodic review. CARB staff fulfilled the requirement in California via a presentation to the Board that summarized progress and trends in the program in 2018. Oregon’s CFP has two reviews between 2015-2025, the first of which, also given as a presentation by staff to the regulating authority, in this case Environmental Quality Commission, occurred early in 2022. There is no explicit public review of the BC instrument. The CFR will be subject to a five-year review, with the intention of updating the regulations by 2030 (Government of Canada, 2022: 2879).

8.4. Stakeholder Engagement and Transparency

Finally, it is important that fuel CI standards create administrative systems to engage with stakeholders and promote transparency. Many of the dimensions of fuel CI standards are politically salient, from modeling assumptions to environmental justice implications. For example, there has been considerable debate about the appropriateness of modeling ILUC and its inclusion in fuel CI standards (Breetz, 2017; Khanna et al., 2017; Plevin et al., 2017). All existing CI standards have implemented reporting and verification systems to ensure the accuracy of data fed into modeling tools as well as to ensure that CI values are approved and regularly updated. To make the policy process more transparent, stakeholder meetings on proposed amendments are webcast in California and Oregon, presentation materials and public comments are made available for all, and data on program metrics are made available regularly. Similarly, the CFR has established a Stakeholder Technical Advisory Committee (STAC) to provide advice on technical

⁵ California: <https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard> ; Oregon: <https://www.oregon.gov/deq/ghgp/cfp/Pages/default.aspx>; British Columbia: <https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels>

⁶ California LCFS Data Dashboard: <https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard>

⁷ California LCFS Credit Transfer Activity Reports: <https://ww2.arb.ca.gov/resources/documents/lcfs-credit-transfer-activity-reports>

⁸ Oregon: <https://www.oregon.gov/deq/ghgp/cfp/Pages/Monthly-Data.aspx>; British Columbia: <https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/renewable-low-carbon-fuels/credits-market>

recommendations pertaining to the ongoing advancement and maintenance of the Fuel LCA Model (Government of Canada, 2022: 2899).

9. HARMONIZATION BETWEEN MARKETS

The presence of several fuel CI standards sharing similar fundamental design and implementation characteristics creates opportunities for synergistic effect that could be enhanced through coordination between programs. At present, coordination largely occurs through regular contact between regulatory staff across jurisdictions involved. The Pacific Coast Collaborative (PCC), a coordinating agreement between California, Oregon, Washington, and British Columbia, laid out shared goals relating to a variety of climate policies and explicitly pledging each jurisdiction to adopt a fuel CI reduction policy like the LCFS, CFP, or Canada's CFR. The PCC supports a working group of clean fuel regulatory staff from the constituent jurisdictions that has served as a coordinating venue for regular discussion and collaboration. Other regionally-focused workgroups have emerged as a venue for discussion among jurisdictions considering similar policies.

Given the comparative novelty and high complexity of fuel CI standards, coordination between jurisdictions is critical to align CI assessment methods, verification practices, and reporting requirements, so that fuel producers do not face an onerous administrative burden complying with patchwork regulations between the markets they serve. Formal harmonization of policies between markets is comparatively rare at present. Oregon, for example, recognizes California LCFS CI scores provided they are adjusted to reflect the different transport distances to each market. This is facilitated by the fact that both use a version of the GREET model, localized for their state. Oregon has also largely adopted California's third-party verification protocols, allowing verification bodies to serve in both states more easily. This sort of "one-way" harmonization, in which measurement or administrative procedures from existing programs are adopted by subsequent ones can minimize costs for obligated parties without requiring formal negotiated agreement between jurisdictions.

More formalized harmonization, such as regional agreement on measurement methodology, administrative practices, or program design is conceptually possible, though few policy makers have indicated interest in this. While there are potential economies of scale and opportunities to reduce administrative costs by such harmonization, most jurisdictions have adopted provisions targeted at fuels, markets or technologies of particular local interest, which may complicate potential efforts to formally harmonize program provisions.

Discussion of harmonization of standards lends itself to discussion of formal linkage of programs in such a way that would allow credit trading between jurisdictions, similar to emission trading systems like the one linking California and Quebec. Our review of the CFR and other North American fuel CI standards suggests that there are significant administrative, legal, and political hurdles that would have to be overcome. The mechanism of fuel CI standards means that credit generation is a function of fuel CI rating and the target level in the consuming jurisdiction. This is to say that a given quantity of fuel would generate a different number of credits in California and Oregon, even for fuels that have received nearly-identical CI ratings in both programs. This is because the CI target is more stringent in California than Oregon, and a given fuel will generate more credits per unit in a jurisdiction with a less-ambitious target at any given time. Formal linkage would need to address the differential "value" of the GHG savings represented by a credit in each jurisdiction. Credit trading among jurisdictions would, by creating a new, system-wide credit value, erase advantages of having one jurisdiction "out in front", such as lengthening the useful credit-generating period of any lower carbon fuel, which could help incentivize investment, and encouraging earlier technological development or deployment (in the most stringent jurisdiction). In a formally linked system, overall

program compliance costs would go down, since those jurisdictions best able to draw the low carbon fuels (at lowest cost) would be the ones receiving them. While some environmental benefits might be gained by this system, which would allow fuels to come to market closer to where they are produced, reducing the distance they would be transported, this could also result in fuels being consumed in jurisdictions with lower CI targets, which reduces the air quality co-benefit that would normally accrue as a result of ambitious climate policy.

10. CONCLUSION

This paper has examined how Canada's CFR compares to other fuel CI standards in North America. We find considerable policy similarity across all four jurisdictional standards, in large part by design, through coordination of jurisdiction implementing agencies. However, there are also substantial differences in terms of program protocols, targets, and approaches.

Among the key similarities across jurisdictional standards is the program scope. The scope of the CFR narrowed during its development to focus on liquid transportation fuels, bringing it more in line with other jurisdictions considered. The jurisdictional standards are also largely similar in exempting maritime, aviation and military fuels from regulations, though California and Oregon allow for low-carbon jet fuel when loaded in state to also serve as a credit generator. All jurisdictions rely on CI as a key metric and rely on LCA methods for its estimation and assessment across fuel types. While different LCA modelling tools are used in each jurisdiction, they are similar in having standard pathways and an application procedure for non-standard pathways and novel fuels. CI reduction targets and trajectories for meeting them are also comparable: while the initial CI assessments of gasoline and diesel pools across jurisdictions differed, the rate of mandated CI reductions across them suggests similar levels of ambition. All four jurisdictions have also created clean fuel credit markets, which suggests potential for a more formal link among the programs. Governance and administrative systems are also similar, including broadly similar reporting requirements, a reliance on third-party verification as well as web platforms for data management.

As noted, despite these similarities, the programs also differ in important ways, so that clean fuel credits are not completely equivalent across standards. Some differences are of relatively minor consequence. For the example, the CFR features a few unique exemptions including low cut-off for small volume providers and remote communities' exemption. However, differences in credit generating protocols are of more importance. The most straightforward example is that the regulatory framework for credit generation differs across jurisdictions in terms of its anchoring ("base") year for CI reduction targets to be measured against, which also means jurisdictions differ in how far along the CI declining-target trajectory each is at any given time. This in itself creates a disparity among what a credit represents in terms of reductions in each jurisdiction. In addition, while LCA models underpinning standards are broadly similar across jurisdictions, the analytical boundaries of the LCA differ considerably. In California and Oregon, LCA has included emissions associated with indirect land-use change (estimated as a global effect, that is, regardless of where such emissions occur in the world), whereas the CFR and British Columbia regulation currently do not. In short, differences in how the jurisdiction assign a CI value to a particular fuel generates a difference in credits that will be associated with a particular volume of fuel depending upon which jurisdiction uses the fuels.

Beyond the regulatory framework, rules covering who can generate and receive credits, and how credit revenue can be used also differ across programs. First, different entities receive electricity fueling credits and different rules govern revenue from electricity credits across programs, as does the extent to which electricity infrastructure or vehicles can directly receive credits under the program. Second, programs differ

in how they treat action to lower emissions within the petroleum sector, with Canada and then California offering credit-generating options for the provision of low-CI fossil fuels. We also note that the CFR recognizes different default CI values of electricity across Canadian provinces and territories. Given the large geography of Canada and variation in hydroelectric resource endowments across provinces (Macdonald, 2020), the CI value of electricity varies considerably depending upon where a CFR credit generating project under Compliance Category 3 is established in Canada. Such geographical (and ultimately political) variability is not found in electricity CI values of other jurisdictional standards, whose geographical scopes are more limited, although Oregon does permit utilities to opt to use their own-area CI rating rather than the statewide average.

The jurisdictional standards considered also differ in terms of price control mechanisms and compliance flexibilities. While the CFR will establish a credit clearance market similar to ones in California and Oregon; BC currently does not have a similar price control mechanism. This might explain why observed prices in BC have risen to over \$400 CDN (~\$310 USD) in recent years, well above credit clearance prices set in other jurisdictions. The CFR has also established a compliance fund, set at \$350 CAD (~\$270 USD) and triggered if the credit clearance market in Canada is exhausted, which has no complement in other jurisdictional standards considered, and considerably strengthens the \$350 CAD as a price ceiling.

Overall, there remain important technical differences between the CFR and other North American fuel CI standards, though climate mitigation stringency and ambition are broadly similar. While fuel CI standards are likely to incite the growth of low-carbon fuels across North America, technical differences between programs might require further attention to make sure inconsistencies do not deter market growth. Into the foreseeable future, trading of clean fuel credits across North America seems highly unlikely. Rather, jurisdictions might continue to work towards harmonizing standards across North America, ensuring environmental integrity in each segment of the North American low carbon fuel credit market while also continuing to recognize regional differences.

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