Opportunities for Additional Credit Generation

Draft Final Report

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Table of Contents

Abbreviations and Acronyms

CCS	Carbon Capture and Sequestration
CFP	Clean Fuels Program
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CI	carbon Intensity
CO2	Carbon Dioxide
DAC	Direct Air Capture
DEQ	Department of Environmental Quality
EO	Executive Order
LCFS	Low Carbon Fuel Standard
RNG	Renewable Natural Gas
SMR	Steam Methane Reforming

Introduction

The clean fuel standard in Oregon, implemented as the Clean Fuels Program (CFP), requires a 10 percent reduction in the baseline carbon intensity (CI) of gasoline and diesel over a ten-year period (to 2025). In addition to CI reduction, the CFP helps Oregon reduce its consumption of conventional petroleum fuels. Low carbon fuels include but are not limited to ethanol, biodiesel, hydrogen, electricity, natural gas, propane, and renewable natural gas (RNG). In March 2020, Gov. Kate Brown directed the Department of Environmental Quality through Executive Order (EO) 20-04 to expand the CFP to achieve a 20% reduction in the average CI of Oregon's transportation fuels from 2015 levels by 2030 and a 25% reduction by 2035 though the rulemaking to expand the program has not yet been completed.

This report and analysis are designed to assist DEQ in its efforts to expand the Clean Fuels Program and comply with EO 20-04 by seeking to characterize avenues for CFP credit generation that are not currently included in the Program but may be commercially deployable in the 2035 timeframe. ICF reviewed the most recent technologies, fuels, and feedstocks in the lower carbon fuel marketplace. Based on this review, ICF has identified a subset of potential areas for CFP credit generation, including a description of each area, estimated the credit generation from each, and outlined the timeframe for implementation and the potential quantity/use in Oregon as part of CFP compliance.

ICF's review of potential areas for CFP credit generation included:

- Upstream CI improvements for ethanol
- Carbon capture and storage
- Refinery investment projects
- Refinery hydrogen projects

Upstream CI Improvements for Ethanol

In work for the United States Department of Agriculture (USDA), ICF characterized the potential for high efficiency-high conservation (HEHC) projection of the CI profile of ethanol. More specifically, ICF considered CI reductions in the lifecycle of ethanol attributable to the following:

- Domestic farm inputs and fertilizer N_2O: yield increases and conservation technologies and practices.
- Domestic land use change: reduced tillage decreases soil disturbance during field operations and leaves a large proportion of plant residues on the field.
- Fuel production: process fuel switching to biomass, increased corn to ethanol yield, and other process efficiencies in the ethanol plant.

More specifically, ICF incorporated the farm-level adoption of three conservation practice standards (CPSs) in the production of corn used to produce ethanol that USDA's Natural Resources Conservation Service (NRSC) has recognized as having GHG benefits. These are:

- CPS 345—Residue and Tillage Management, Reduced Till;
- CPS 590—Nutrient Management: Improved Nitrogen Fertilizer Management; and
- CPS 340—Cover Crops.

In that work for USDA, ICF bundled the considerations for CI reductions by process efficiencies and agronomic practices. For the former, ICF assumed that a 0.7-1.7% per year decrease in the CI of ethanol is attributable to process efficiencies during ethanol fuel production. However, ICF has estimated that a more substantial CI reduction of nearly 20-25% from baseline ethanol CI could be achieved through agronomic practices. Furthermore, we found that with the right price signal, as many as 55% of farms would implement the aforementioned agronomic practices by 2030. For the sake of reference, ICF reported that the *maximum* achievable CI reduction through the implementation of agronomic practices is about 30-32%.

Previously, ICF estimated that ethanol could reduce its CI to around 48.5 g/MJ by 2028 from current levels of about 52-55 g/MJ, which is a modest, but marked improvement of 10-12%. If we assume that the implementation of agronomic practices that could yield CI reductions for ethanol, then the CI would probably decrease by about another 5 g/MJ. ICF estimates that this would generate an additional 60,000 to 80,000 credits annually.

Carbon Capture and Sequestration

Carbon capture and sequestration (CCS) is a process where large volumes of carbon dioxide (CO_2) are captured, compressed, transported, and sequestered. CCS has the potential to deliver GHG emission reductions for processes that produce reliable streams of CO_2, with eligible CCS projects involving the on-site capture of CO_2, and geologically sequestered either on-site or off-site. Sequestration sites may include saline reservoirs, depleted oil and gas reservoirs, and oil and gas reservoirs used for CO_2-enhanced oil recovery. Alternatively, the captured CO_2 could be used and sequestered in industrial processes, such as in concrete production or food processing. Over the long-term CCS is a potentially significant technology for reducing CO_2 emissions from large stationary sources, including refineries and other fuel producers.

Eligible entities for CCS could include alternative fuel producers, refineries, and oil and gas producers. CO_2 can be captured from a variety of streams depending on the project and fuel type, including:

- Ethanol production, with CO_2 captured during fermentation;
- CO_2 streams from the production of renewable diesel, renewable gasoline and alternative jet fuel;
- Production of CO_2 during the anaerobic digestion process to produce biogas; and
- Capture of CO_2 from power plants that generate electricity consumed in transportation applications.

ICF also notes that direct air capture (DAC) projects are eligible under California's CCS Protocol of the LCFS program. DAC is the process of separating and storing CO_2 directly from ambient air, and therefore has the potential to deliver a net reduction in atmospheric CO_2 concentrations. And like other CCS-eligible projects, the resulting captured CO_2 needs to be geologically sequestered or used in industrial processes. DAC typically involves chemical separation, with two technology approaches used to capture CO_2 from the air: liquid and solid DAC. Liquid systems pass air through chemical solutions, which isolates and removes the stream of CO_2. Solid DAC technology makes use of solid sorbent filters that chemically bind with CO_2. When the filters are heated and placed under a vacuum, the concentrated CO_2 is released and captured for sequestration. As a technology, DAC is currently at the early stages of commercialization, with 19 DAC plants in operation across North America and Europe. Carbon Engineering and Occidental Petroleum are developing the first large-scale DAC plant, located in the Permian Basin and scheduled to come online in 2024.

There have been many developments in the CCS space over the past decade, with marked progress in the past several years. On the policy front, technology providers were largely reliant on the 45Q tax credit. The 45Q tax credit was introduced under the Energy Improvement and Extension Act of 2008 and subsequently amended under the Bipartisan Budget Act in 2018. It provides CCS operators with credits for each ton of carbon stored or utilized, including for CO_2-EOR, which can be used to reduce the operator's tax liability. The market perked up further in 2018 as CARB developed and ultimately adopted a CCS protocol (effective January 1, 2019) as part of its Low Carbon Fuel Standard.

Although there are many low carbon fuel pathways for which CCS is eligible, ethanol production the most likely near-term application for CCS because of the purity of the carbon emitted at the facility (>99%). However, the scale of the facilities presents an infrastructure challenge, and requires a dedicated CO_2 pipeline for aggregation and distribution to ultimate storage. The CI benefit of CCS at an ethanol facility is approximately a 40% reduction from the direct emissions component of the lifecycle. ICF anticipates that these types of projects will start to come online in the 2024-2025 timeline at the earliest. For instance:

- Summit Carbon Solutions announced in February 2021 that it is targeting a system capable of capturing 10 million metric tons of CO_2 emissions.
- Navigator Energy Services has partnered with BlackRock and Valero Energy to announced in March 2021 a proposed CCS pipeline across five Midwestern States with an initial design capacity for 5 million metric tons of CO_2 with the potential to expand to 8 million metric tons.

ICF assumes that a larger cluster of facilities (about 30-40 facilities) would be required to aggregate carbon capture for beneficial use into an enhanced oil recovery application (e.g., in Texas). In other words, for there to be sufficient economic opportunity for the carbon sink (at an oil field), there needs to be a significant amount of carbon captured from ethanol facilities—and the discrepancy between the size of an oilfield and an ethanol facility dictates the economics of the opportunity.

For illustrative purposes, ICF assumes that there are about 160-165 million gallons of ethanol consumed annually in Oregon (mostly blended with gasoline) and that the average CI of ethanol is currently 52-55 g/MJ. The table below shows the number of CFP credits generated for each additional 10 percent of the ethanol supply that is sourced from ethanol facilities using CCS.[1] For the sake of reference, ethanol today generates about 550,000 to 600,000 credits annually in the CFP program.

[1] ICF assumed an annual volume of 160 million gallons of ethanol and a 40% reduction in the CI of ethanol from 53 g/MJ to 32 g/MJ, attributable exclusively to CCS.

Table 1. Estimated Annual CFP Credit Generation from Ethanol Facilities using CCS

% EtOH in Oregon w/ CCS	10%	20%	30%	40%	50%	100%
Additional CFP Credits, Annually	27,000	55,000	82,000	110,000	137,000	274,000

CCS at ethanol facilities could have a material impact on ethanol credit generation, with an upper limit of about 274,000 credits annually, representing nearly a 50% increase compared to current annual ethanol credit generation.

There are certainly other opportunities for credit generation by incorporating CCS into lower carbon fuel production pathways beyond ethanol production, as outlined previously. Similarly, the earliest most of these types of projects would likely come online is in the 2024-2025 timeline. While there are certainly many CCS pathways that can be considered for eligibility into the CFP, ICF estimates that the upper limit on credit generation via this pathway is around 300,000-400,000 credits annually by 2035 assuming that proportionality constraints are taken into account (i.e., that only the portion of the overall fuel that is produced is accounted for in the determination of credits).

Refinery Investments Projects

A refinery has the potential to reduce GHG emissions through improved facility operations, processes and inputs, and generate credits from those reductions. Eligible investments could include:

- CO_2 capture at refineries, or at hydrogen production facilities that supply hydrogen to refineries, and subsequent geologic sequestration;
- Use of renewable or low-emissions electricity supplied behind the meter at the refinery;
- Use of low-CI process energy such as biomethane, renewable propane, and renewable coke, to displace fossil fuel used in the production process;
- Electrification at refineries that involves substitution of high carbon fossil energy input with grid electricity; and
- Other process improvement projects that deliver a reduction in baseline refinery wide GHG emissions, excluding curtailment, maintenance, and crude oil switching.

Beyond refinery investment projects, improved upstream operations and innovative projects for crude oil production and transport also have the potential to deliver GHG emission reductions, and subsequently become a source of credit generation if the improvements or projects meet the necessary criteria. Innovative methods for crude production typically use a combination of the following technologies:

- Onsite solar steam generation with a quality of not less than 45 percent quality or greater.
- Solar or wind electricity generation that is produced and consumed onsite or provided directly to the crude oil production or transport facilities from a third-party generator and

not through a utility owned transmission or distribution network. Energy storage can be eligible to increase the quantity of electricity supplied from intermittent solar and wind electricity generation sources.
- Solar heat generation including, but not limited to, boiler water preheating and solar steam generation with a steam quality of less than 45 percent. The heat must be used onsite at the crude oil production or transport facilities.
- Renewable natural gas (RNG) or biogas energy, where the RNG or biogas must be physically supplied directly to the crude oil production or transport facilities
- CCS, where the carbon capture must take place onsite at the crude oil production or transport facilities (in contrast to the CCS projects discussed in the previous section).

For the sake of reference, California's LCFS program has a handful of approved refinery investment projects, generating between 10,000 and 12,000 credits per quarter. There are two key considerations when characterizing the potential credit generation from refinery investment projects: 1) the boundary conditions of the analysis and 2) the extent to which a regulated party can use refinery investment credits to comply. Regarding the former, the California LCFS has set a precedent for limiting credit generation to the volumes delivered into the market as a proportion of total fuel produced at a particular facility. With regard to the latter, the California LCFS has set a precedent for limiting credit generation to no more than 10% of a regulated party's compliance in any given year. ICF estimated the upper limit for CFP credit generation from refinery investment projects based on these two constraints and volumes from previously developed compliance scenarios, shown for years 2025, 2030 and 2035 in the table below.

Table 2. Estimated Annual CFP Credit Generation Range from Refinery Investment Projects

Limitation	2025	2030	2035
Proportional volume to OR	30,000-150,000	35,000 to 200,000	60,000 to 200,000
10% of obligation (max)	280,000-320,000	380,000-420,000	400,000-440,000

Refinery Renewable Hydrogen Projects

Hydrogen is used by refiners in hydrocracking—converting high-boiling constituents in crude oil to lower boiling constituents like gasoline and diesel—and in catalytic hydrotreating to reduce the sulfur content of diesel. Refinery use of hydrogen has increased in recent years and is typically produced via steam reformation of natural gas. About 35% of natural gas use at refineries is attributable to hydrogen production, presenting significant opportunities for refiners to generate credits. Eligible renewable hydrogen production processes include from RNG that displaces conventional natural gas in a steam methane reformation unit, electrolysis using renewable electricity, and syngas from biomass gasification.

Renewable hydrogen for use at refineries has garnered a significant amount of attention and investment in Europe. Shell has deployed a 5 MW electrolyzer for renewable hydrogen production at the H&R Olwerke Schinder refinery (in 2018) and a 10 MW electrolyzer system to produce hydrogen at its Rhineland refinery complex (operational in mid-2021). Further, no fewer than a third of Germany's refineries have announced some sort of investment or intent to invest in a transition to renewable hydrogen, including at BP's Lingen refinery (a 50 MW system). The International Energy Agency (IEA) notes that there has been an announced capacity of 1.3 GW of electrolyzer capacity at European refineries to be deployed by 2025. In parallel to this announcement related to renewable hydrogen production via electrolysis, the Spanish refiner Repsol has committed to a pathway that uses both electrolysis and biomethane in steam reforming. There are no public announcements by refiners in California or Washington with plans to deploy renewable hydrogen via electrolysis or via biomethane steam reforming.

Under California's LCFS, renewable hydrogen projects are not subject to the same limit of credit generation, quantified as 10% of a regulated party's compliance in any given year. However, they are subject to the same proportionality considerations i.e., the reductions are pro-rated based on the amount of fuel sold into the region compared to its overall production. For the sake of reference, steam methane reforming (SMR) accounts for about 1.2 g/MJ of the total carbon intensity of gasoline. This helps to characterize the upper limit for renewable hydrogen production. If natural gas is displaced in the SMR process with biomethane or renewable natural gas, then the reduction will depend on the source of the RNG. ICF assumes that because RNG from animal manure will generate considerably more value as a transportation fuel than as an input fuel for SMR at a refinery, that the more likely outcome is RNG from landfills, for instance. In this case, the maximum carbon intensity reduction for a refinery will be more like 0.6 g/MJ. The table below shows the estimated CFP credit generation from renewable hydrogen projects as an upper limit assuming a 0.6 g/MJ and 1.2 g/MJ reduction in the carbon intensity of gasoline due to RNG into SMR and the deployment of electrolysis using renewable electricity generation, respectively. These values assume that all the volumes shipped into Oregon under the compliance scenarios developed previously achieve these carbon intensity reductions due to renewable hydrogen projects. The values decrease over time because there is less gasoline consumed in Oregon over time, as outlined in the compliance scenarios.

Table 3. Estimated Annual CFP Credit Generation Range from Renewable Hydrogen at Refineries

Renewable H2 Project	2025	2030	2035
RNG into SMR	90,000-100,000	75,000-85,000	55,000-65,000
Electrolysis with renewable electricity	175,000-200,000	150,000-170,000	105,000-125,000

Conclusions

Oregon's Clean Fuels Program has a diverse range of compliance options consistent with the spirit of the regulation. As Oregon's Department of Environmental Quality contemplates EO 20-04, there are select opportunities to incorporate additional credit generation opportunities. Many of the technological innovations that have been deployed in the low carbon fuel sector (focused on transportation fuels) are already eligible to generated credits in the Clean Fuels Program. ICF contemplated the potential of four areas where additional credits could be generated in the 2035 timeframe, including from upstream improvements at ethanol production facilities and agronomic practices that reduce GHG emissions attributable to the feedstocks, CCS projects, refinery investment projects, and refinery hydrogen projects.

The table below summarizes the estimated annual CFP credit generation for the opportunities considered in this analysis. The estimates include both a low and a high estimate and are shown in millions of CFP credits annually. We also included the deficits estimated for each corresponding year in the last row of the table for the sake of reference.

Table 4. Summary of Annual CFP Credit Generation from Additional Opportunities Considered

Additional Credit Generation Opportunity		2025	2030	2035
Upstream Ethanol	low	0.038	0.044	0.033
	high	0.076	0.087	0.065
CCS	low	0.014	0.082	0.137
	high	0.027	0.137	0.275
Refinery Investment Projects	low	0.030	0.035	0.060
	high	0.150	0.200	0.200
Refinery Renewable Hydrogen Projects	low	0.090	0.075	0.055
	high	0.200	0.170	0.125
Additional Credit Generation	***low***	***0.171***	***0.236***	***0.285***
	high	***0.453***	***0.594***	***0.665***
Deficits*		2.95	4.06	4.22
Deficits are shown as the average of deficits from Scenario A and Scenario B from compliance scenario modeling completed previously.				

In the upper limit, ICF is assuming that in aggregate, the additional credit generating opportunities could amount to 7-16% of compliance needed by 2035 depending on how the eligibility is incorporated into the CFP and how the technology advances over the next 15 years.