



MSCE Energy Infrastructure

Brief on the Price of Carbon

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Topics

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Introduction to Carbon Pricing

This brief will focus on direct carbon pricing as done through Emissions Trading Systems (ETs) and carbon taxes. There are other types of carbon pricing such as carbon credits and indirect or internal carbon pricing which are only briefly mentioned in this document.

Why carbon pricing. To avoid the most severe impacts of climate change, the US is committed to achieving a 50 to 52% reduction from 2005 levels in GHG pollution by 2030, and GHG composition is about 80% CO₂ [DOE (2024) and EPA, "Overview of GHG"].

Carbon taxes and markets. **Carbon taxes** are fees paid by organizations due to their carbon related emissions. This encourages lower emissions to reduce or avoid the tax. The other approach to reducing carbon is pricing carbon through markets. Carbon markets can be classified as regulated or voluntary. **Regulated** carbon markets are also a focus of this brief (such as cap-and-trade). **Voluntary** carbon markets are where a company or organization buys carbon credits from those that are reducing carbon through various types of projects (such producing carbon free electricity or reforestation). Voluntary carbon markets are briefly described in this document. For carbon taxes or markets, units of carbon are either in terms of CO₂/tonne or CO_{2e}/tonne.

A bit of terminology:

- **Carbon:** Elemental carbon should not be confused with CO₂ which is a compound or CO_{2e} which is a calculated estimate by combining several types of emissions.
- **Carbon Dioxide (CO₂):** About **37 billion tonnes** emitted per year worldwide.
- **Greenhouses Gases (CO_{2e}):** This term is used to describe the emissions from various greenhouse gases weighted by their global warming potential into one term (CO_{2e}). The base gas is CO₂ and the other GWP gases are added by summing the mass of the pollutants

multiplied by their global warming potential factors. About **59 billion tonnes** are emitted per year worldwide. [EPA estimate]

- **IPCC:** The Intergovernmental Panel on Climate Change is the “United Nations body for assessing the science related to climate change. The objective of the IPCC is to provide governments at all levels with scientific information that they can use to develop climate policies.” [IPCC (2024)]
- **Tonnes:** A commonly used unit in this brief (metric tons and tonnes mean the same).
- **Carbon tax:** “A type of penalty that businesses must pay for excessive greenhouse gas emissions. The tax is usually levied per ton of GHG emitted ... The tax is a fee imposed on companies that burn carbon-based fuels, including coal, oil, gasoline, and natural gas” or have processes that generate GHG emissions. [as modified from Investopedia (2024)] A **carbon fee** can be defined in a similar manner.
- **Emissions trading system (ETS):** This is a system where emitters can trade emission units to meet their emission targets. To comply with their emission targets at least cost, regulated companies/organizations can either implement internal abatement measures (reduce emissions) or acquire emission units in a carbon market. By creating supply and demand for emissions units, an ETS establishes a market price for GHG emissions. This quote from a World Bank citation is well-stated: “An ETS – as opposed to a tax – is a quantity-based policy, i.e., it offers certainty over the environmental outcome (i.e., the “cap”) but leaves it to the market (i.e., the “trade”) to set the price of carbon.”
- **Cap-and-Trade:** A cap-and-trade system is a type of **ETS** and is managed by a governing jurisdiction (typically a country or a state such as California) that sets a limit (a cap) on a selection of emissions emitted by specific types of companies/organizations. Companies/organizations can either reduce emissions or buy allowances, are more typically both, all in terms of cost per tonne CO₂e.
- **Cap-and-Invest:** For Washington State, it is an **ETS** program that over time sets lower limits for pollution from GHGs, and requires emitters to steadily decrease their emissions, or purchase pollution allowances. [after WA State Dept of Ecology, “Washington's Cap-and-Invest Program,”].
- **Social Cost of Carbon (SCC):** SCC is used to evaluate policy options and assists in determining whether a policy designed to curb emissions is justified (sometimes referred to as cost-benefit analyses). More specifically, if a policy to prevent one ton of carbon emissions costs less than the SCC, then the policy pays for itself. SCC estimates are used by the US federal government and agencies such as the EPA as well as several states.

Carbon Taxes

The term carbon tax covers the broad range of taxes that can be applied to GHGs. The carbon tax price can be set at a price per unit of GHG (e.g., tonnes) or a price per unit of fuel, which is then proportional to resulting CO₂ emissions. The general goal is to encourage the reduction in the use of fossil fuels, and, for some governments, to increase revenue. [partial source: OECD (2023)]

Example. British Columbia (BC) implemented the first board-based carbon tax in North America. The carbon tax on CO₂e emissions in 2008 was set at C\$10/tonne. As of 2023 their carbon tax increased from C\$65/tonne to C\$80/tonne. The carbon tax applies to the purchase and use of fossil fuels and covers approximately 80% of provincial GHG emissions. A tax set at C\$80/t = 17.61 cents/liter (or 49.3 cents/gal (US)) [British Columbia (2024)]

British Columbia also has other carbon reduction options.

How would a carbon tax affect gasoline prices? The current BC tax, as shown above, is about \$0.49/gal. Another scenario is to examine how a carbon tax, if enacted in the US (which is unlikely) and fully applied to gasoline, would affect gasoline retail prices? Here are a few examples starting with tax level of \$1/tonne CO₂:

Carbon Tax (\$/tonne CO ₂)	Added Cost (\$/gal gasoline)	Comments
1	0.009	A rough equivalency is each \$1/tonne CO ₂ adds about 1¢ to the price of a gallon of gasoline.
20	0.178	A carbon tax of \$20/tonne CO ₂ would be similar to the current federal gasoline tax of \$0.184/gal. Although, the current federal fuel tax, when initiated, had nothing to with carbon pricing but to aid state funding of highway infrastructure (that tax was last changed in 1993). At that time, the average US gasoline price was a bit more than \$1.00/gal.
100	0.888	A carbon tax of \$100/tonne CO ₂ if applied to gasoline, would roughly add a \$1/gallon price increase to retail gasoline which, as noted above, was the average fuel price in 1993.

Social Cost of Carbon

From Brookings (2023): “The social cost of carbon (SCC) is an estimate of the **cost**, in dollars, of the damage done by each additional ton of carbon emissions. It also is an estimate of the **benefit** of any action taken to reduce a ton of carbon emissions.”

SCC rate. To describe SCC, it requires both a **price per tonne of CO₂e** based on **future economic impacts of climate change**, and a **discount rate** to bring future impacts back to the present or as stated in the Brookings reference ... different discount rates measure how much we value the present compared to the future. More broadly, SCC is an estimate of the economic impact of carbon related emissions and represents the monetary value of the long-term damage of yearly emissions. This includes changes in agricultural productivity, human health, flood risk, and more. Regulations to reduce carbon emissions are used by the policy developers to estimate the benefits. For example, if a policy to reduce emissions costs less than the SCC, it is considered economically beneficial. [Brookings (2023)]

Discount rate. So, what discount rate to use for the SCC? A high discount rate suggests the impacts are of little importance in the future and a low discount rate suggests the impacts are important. The Biden Administration, through the EPA and reported in 2023, has set the SCC discount rate at 2%...a lower rate than used in private sector decisions but logical given the impacts being estimated. The table below illustrates discount rates from 0 to 7% over a period of 100 years (which is a period appropriate in addressing climate impacts which span long time periods). To illustrate, if you start with a future impact worth \$1,000 then discount over the 100-year period, you can quickly see the effect of both low and high rates. A high rate, such as 7%, implies that future carbon related climate impacts are meaningless today in terms of value.

Discount rate	Present Value of \$1000 discounted over 100 years (rounded values)
0%	\$1,000
2%	\$138
3%	\$52
7%	\$1 calculated by $PV = \$1,000 / (1 + 0.07)^{100}$

Federal SCC and discount rates. The Biden administration released interim values for the social costs of carbon dioxide, methane and nitrous oxide on February 26, 2021 (\$51/tonne CO₂ @ 3% discount rate), and subsequent final values almost three years later (November 2023) which are about 4X larger for SCC. The social cost of CO₂ can be stated as **\$190/tonne at 2% on a 2020 basis**. Other gases were priced separately. [EPA, “Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances”] “The EPA’s \$190/tonne estimate uses a 2% discount rate. When they use a higher discount rate of 2.5%, thus valuing the future less, the SCC reduces to \$120. When they use a 1.5% discount rate, valuing the future more, the SCC shoots up to \$340.” [Brookings (2023)].

Examples of use. The SCC has been used to determine fuel economy standards in the U.S., and five states require electric utility companies to consider the SCC in their operations.

Cap-and-Trade

Cap-and-trade is an environmental policy tool that applies a mandatory cap on emissions while providing emission sources (e.g. power plants) flexibility in how they comply. Cap-and-trade, in essence, is a market-based approach to reduce emissions, and is comprised of two key components—a limit or cap on carbon emissions and tradable allowances.

Carbon tax and cap-and-trade systems attempt to achieve the same basic goal—reduce emissions that affect climate change. A carbon tax sets a price on emissions which is expected to reduce emissions. Cap-and-trade sets the level of emissions which helps to set emissions

pricing. Successful cap-and-trade programs reward innovation, efficiency, and early action without reducing economic growth.

Prior cap-and-trade success story. The Clean Air Act Amendments of 1990 set a goal of significantly reducing annual SO₂ emissions in the US. The SO₂ emission reductions were achieved through a market-based system based on capping and trading—the centerpiece of EPA’s Acid Rain Program. The allowance trading system created low-cost rules of exchange that minimized government intrusion and made allowance trading a viable compliance strategy for reducing SO₂. The SO₂ emission reductions achieved the goal of massive reductions and at a cost less than expected.

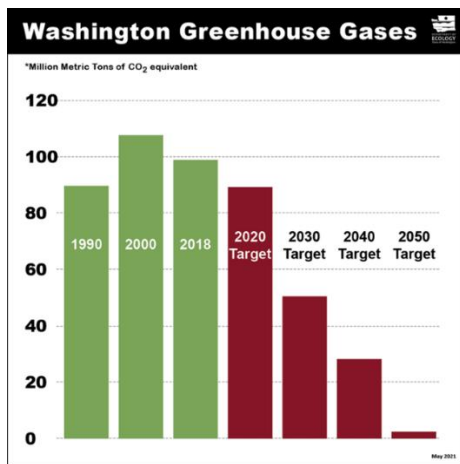
California and cap-and-trade. The goal for California is to reduce GHG emissions to 1990 levels by 2020 and ultimately a 80% reduction by 2050. The emission allowances are sold in terms of \$/tonne of CO₂e. The California program started earlier than most in January 2012. Additionally, California is working with British Columbia, Quebec, Nova Scotia, and Washington State through the Western Climate Initiative to coordinate their cap-and-trade programs.

Recent (August 2024) carbon auctions in California resulted in pricing of about \$30/tonne of CO₂e with auctions conducted by the California Air Resources Board.

Cap and Invest (Washington State)

The cap and invest program works in conjunction with past Washington State legislation which sets reductions for GHG emissions (through the Climate Commitment Act). By previously setting GHG emissions reduction goals, Washington State now, with a cap-and-trade system, has a process to achieve the reduction goals. The cap-and-invest process was underway by January 2023 (11 years after California). If curious, the largest emitter in Washington State for 2024 was Marathon Petroleum with 2.4 million allowances (with each allowance representing 1 tonne of CO₂e). [Seattle Times (2024)]

GHG reduction goals. Washington State legislation set the goal of GHG emission reductions of 95% reduction below 1990 levels by 2050, and interim goals of GHG emissions by of 45% by 2030 and 70% by 2040 (again, with 1990 as the starting point) shown in the figure below.



Washington GHG Targets

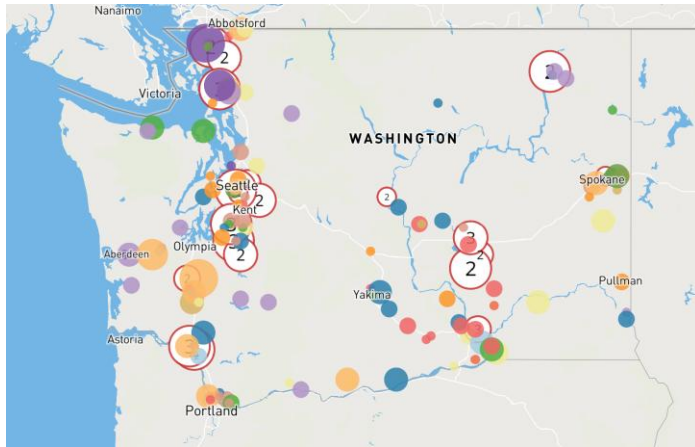
- 2020: Reduce to 1990 levels.
- 2030: Reduce to 45% below 1990 levels.
- 2040: Reduce to 70% below 1990 levels.
- 2050: Reduce to 95% below 1990 levels and achieve net zero emissions.

Source: WA Dept of Ecology, “Greenhouse Gases,” <https://ecology.wa.gov/air-climate/reducing-greenhouse-gas-emissions/tracking-greenhouse-gases>

Who participates? Under the Climate Commitment Act, most Washington state facilities or businesses that produce more than 25,000 tonnes of CO₂e emissions a year are required to obtain emissions allowances. Some of these allowances are sold in auctions, while others are awarded at no cost. Participation in the cap-and-invest program is compulsory for about 150 companies, public utilities and other organizations. This includes public institutions such as UW and WSU since they both exceed the 25,000-tonne threshold. These organizations buy “allowances” through quarterly auctions hosted by the Washington State Department of Ecology which are reduced over time. Smaller organizations are allowed to participate voluntarily. Participant options include (1) buying allowances via state-sponsored auctions, (2) trading allowances, or (3) receiving allowances at no cost, in some cases.

Major exceptions for buying allowances are granted to **Emissions Intensive Trade Exposed industries (EITEs)**. EITEs are still required to reduce their emissions and help achieve net zero by 2050, but they have a longer lead time than other businesses. These companies are important, local, and mostly manufacturing facilities. They typically use high levels of energy and release substantial GHG emissions while also facing significant national or global competition for their products. About 40 facilities in Washington qualify. These facilities produce a variety of products, including paper, food, beverages, steel, aluminum, glass, cement, building materials, airplanes, semiconductors, fertilizer, and transportation fuels. Five examples are Weyerhaeuser (pulp and paper), Nucor Steel, Ash Grove Cement, BP Cherry Point Refinery, and REC Silicon [after DOE, “Emissions Intensive Trade Exposed industries”]

The cap and invest program will cover about 75% of statewide emissions. The remaining 25% — which includes smaller emitters as well as most of the agriculture, aviation and maritime sectors — will be exempt due to existing laws that already regulate energy use in those industries.



Map of Washington which shows locations of GHG emissions for 2022. For example, clicking on the UW shows that the University emits almost 92,000 tonnes/year of CO₂e.

Source: <https://data.wa.gov/Natural-Resources-Environment/GHG-Reporting-Program-Map/gtyb-56w7>

University of Washington Seattle Campus - Seattle	
Sector	Government
Subsector	Education
Total Emissions (MTCO ₂ e)	91,798
Biogenic Carbon Dioxide (MTCO ₂ e)	0
Notes	(No value)

Auctions. The first auction of Washington’s GHG allowances occurred during February/March 2023 and generated a price of \$48.50/tonne CO₂e. Given that 6.2 million allowances were made available, the sale generated \$300 million. The starting price was initially set to \$22.20/tonne. The May/June 2023 auction generated \$550 million with prices ranging between \$31 to \$56/tonne CO₂e. The September 2023 auction resulted in a price of \$63/tonne CO₂e. For all of 2023, 41 million allowances (tonnes) generated \$1.8 billion in revenue from 58 bidders or \$44/tonne CO₂e. The auction results for June 2024 was \$30/tonne CO₂e. **As of the end of 2024**, a total of \$2.7 billion has been raised through the auctions with the highest price per allowance \$63/tonne CO₂e and the lowest price was \$26/tonne CO₂e over the last eight quarters. The auctions started Q1 2023 and have continued through Q4 2024.

Who gets the money ... or not? It depends. The EITEs largely fall into a middle category. These organizations are given **no-cost allowances** by the State until at least 2034. Other states have similar arrangements. The EITEs can either purchase additional allowances from the State to meet future emission caps or sell these allowances to other EITEs if they have extra ones. In the latter case, those EITEs that have a total of both allowances and reduced emissions below their cap can get money from the sale of their extra allowances.

The remaining organizations mentioned earlier that meet the auction participation trigger (25,000 tonnes of CO₂e per year) buy needed allowances from the State of Washington at auction. In this case, **the State gets the money**. Revenue raised by the State of Washington from the auctions is allocated into accounts such as: transit, transportation, climate, environmental justice, and ecological programs and projects.

An initiative to reverse the Washington cap and invest program was on the ballot in November 2024 but failed to pass.

Voluntary Carbon Markets

Voluntary carbon credits and associated market mechanisms are another approach to account for and reduce carbon emissions; however, there are issues. This limited content will offer a definition and describe a primary issue associated with carbon credits as well as results from COP29 in Baku, Azerbaijan. As we start, a quote from Lloyds Banking Group helps: “The world must reduce emissions to near zero and invest in carbon removal solutions to address what cannot be reduced. The Voluntary Carbon Market (VCM) offers a practical way for organizations to take immediate action now and complement their abatement activity.” [Lloyds Banking Group (2025)]

A basic definition for a carbon credit is “... a certificate representing a one-ton drop in greenhouse gas emissions tied to projects such as a wind farm or a tree-planting scheme. They’re bought by companies to compensate for the pollution they produce somewhere else in the world.” [Bloomberg (2024)] The issue is there are limited laws and regulations that underpin potential carbon markets. Thus, banks and investors are unlikely to allocate billions of dollars to support the buying and selling of carbon credits in questionable markets. We should not forget that markets set values and standards for assets with an example being crude oil. Crude oil can be classed as a commodity asset since it can be traded globally. So, are carbon credits some type of asset? Unfortunately, many view this question as unanswered. It is best to not forget the past issues with digital currencies such as Bitcoin...which is typically classified as a digital asset but with some similar issues.

The November 2024 **COP29** meeting in Baku, Azerbaijan with 200 nations attending addressed what will become an **international voluntary carbon market**. This new carbon market will be governed under **Article 6 of the Paris Agreement** (drafted during **COP21**, 2015 and approved in 2016). There are two primary clauses you will be reading about if you follow how this market evolves---**Article 6.2** which covers country-to-country emissions trading approaches. The current text describes how to prevent double counting of emissions reductions. Additionally, **Article 6.4** was created which governs international carbon markets (in essence, a rulebook for carbon markets). [Forbes (2024)] Two key standards outline the current market process [UNCC (2024)].

- **Standard on methodology requirements:** Requirements for developing and assessing projects under the Paris Agreement Crediting Mechanism.
- **Standard on activities involving removals:** Requirements for projects that remove greenhouse gases from the atmosphere.

Presumably additional clarity and structure of voluntary carbon markets and potential for reducing carbon emissions will be forthcoming during the remainder of this decade. However, know that today a wide range of entities currently enable voluntary carbon markets to exist and function. They fall into categories such as trading organizations, verification organizations and far more. [for specific examples see Environmental Finance (2025)].

Summary

To start, a quote from the World Bank Group is appropriate: “Carbon pricing seeks to align the costs of consuming carbon-intensive fuels or using carbon-intensive processes with the social costs of doing so. If well designed, and sufficiently ambitious, carbon pricing can create strong economic incentives for the changes needed in investment, production, and consumption patterns, and to induce technological advancements, reducing the extent of additional public investment needed.”

We covered three types of carbon pricing (along with a brief mention of voluntary carbon markets): carbon taxes, cap-and-trade with variations, and finally the social cost of carbon. At this point you might ask ... how effective are these pricing systems? To address the question, we will use a bit of insight provided by the World Bank. The Bank data shows the following: [World Bank, “State and Trends of Carbon Pricing Dashboard”]

- **Number of ETS and carbon tax systems.** The global total is 75 implemented carbon trading or tax systems (ETS = 36 and carbon tax = 39, e.g., California would count as 1 ETS system).
- **Percent of global emissions covered.** 24% of global CO₂e emissions are covered by countries that apply ETS or carbon tax systems. Recall the total CO₂e global emissions were estimated for 2023 at 59 billion tonnes.
- **Share of emissions** varies significantly based on country groupings based on income. The percentages represent the amount emissions covered by ETS or carbon tax systems that are generated by each of the groupings: 31% for high-income countries, 22% middle-income countries, and 0% by low-income countries.
- **Price of emissions** varies within a very wide range (based on CO₂e/tonne): \$0.46 up to \$167/tonne (the SCC price noted for the US in this brief is not in an ETS or a tax system). Additional perspective is required about prices: (source World Bank, “State and Trends of Carbon Pricing—2024”)
 - The IPCC estimates costs for emissions to limit warming to 1.5°C by 2030 should fall within a range of \$226 to \$385/tonne CO₂e (in 2024 US dollars).
 - Similarly, to limit warming to 2°C the estimated range is \$63 to \$127/tonne CO₂e (also estimated for 2030).
 - World Bank conclusion on pricing: Only a few countries with ETS or carbon tax systems covering 1% of global emissions have emission price levels that meet or exceed \$63/tonne CO₂e. Thus, the implementation to date suggests limited impact as to temperature targets set by the IPCC.
- **Revenue from ETS and carbon taxes.** Global government revenue for 2023 totaled \$104 billion (with \$75 billion from ETS systems and \$29 billion from carbon tax systems).

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