Emissions Guidebook

Part 5: Commodity Carbon Intensities

Section 4: Methanol Carbon Intensity Quantification Methodology

United States

Version 1.0

Center of Emissions Excellence

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About the Emissions Guidebook

Purpose

Greenhouse gas (GHG) emissions have emerged as a critical metric for governments and investors given an ever-growing focus on establishing transparent frameworks for measuring, reporting, quantifying and ultimately reducing GHG emissions globally. It is of utmost importance that methodologies used by different entities are transparent and clear so different studies and emission estimates can be compared on a like-for-like basis. Without this transparency, emissions estimates have limited utility in the marketplace. The Emissions Guidebook is an evergreen document that provides the market with unparalleled transparency into S&P Global Commodity Insights' approach, methodology and key assumptions behind our emissions work. We hope this document can contribute to advancing consistency in GHG emissions accounting.

Context

The Emissions Guidebook is a product of the S&P Global Commodity Insights Center of Emissions Excellence. The "Center" is a dedicated team of carbon accounting specialists focused on ensuring consistency, transparency and credibility of emissions data across any emissions offerings.

About S&P Global Commodity Insights

At S&P Global Commodity Insights, our complete view of global energy and commodity markets enables our customers to make decisions with conviction and create long-term, sustainable value.

We're a trusted connector that brings together thought leaders, market participants, governments and regulators, and we create solutions that lead to progress. Vital to navigating commodity markets, our coverage includes oil and gas, power, chemicals, metals, agriculture, shipping and energy transition. Platts® products and services, including the most significant benchmark price assessments in the physical commodity markets, are offered through S&P Global Commodity Insights. S&P Global Commodity Insights is a division of S&P Global (NYSE: SPGI).

S&P Global is the world's foremost provider of credit ratings, benchmarks, analytics and workflow solutions in the global capital, commodity and automotive markets. With every one of our offerings, we help many of the world's leading organizations navigate the economic landscape so they can plan for tomorrow, today.

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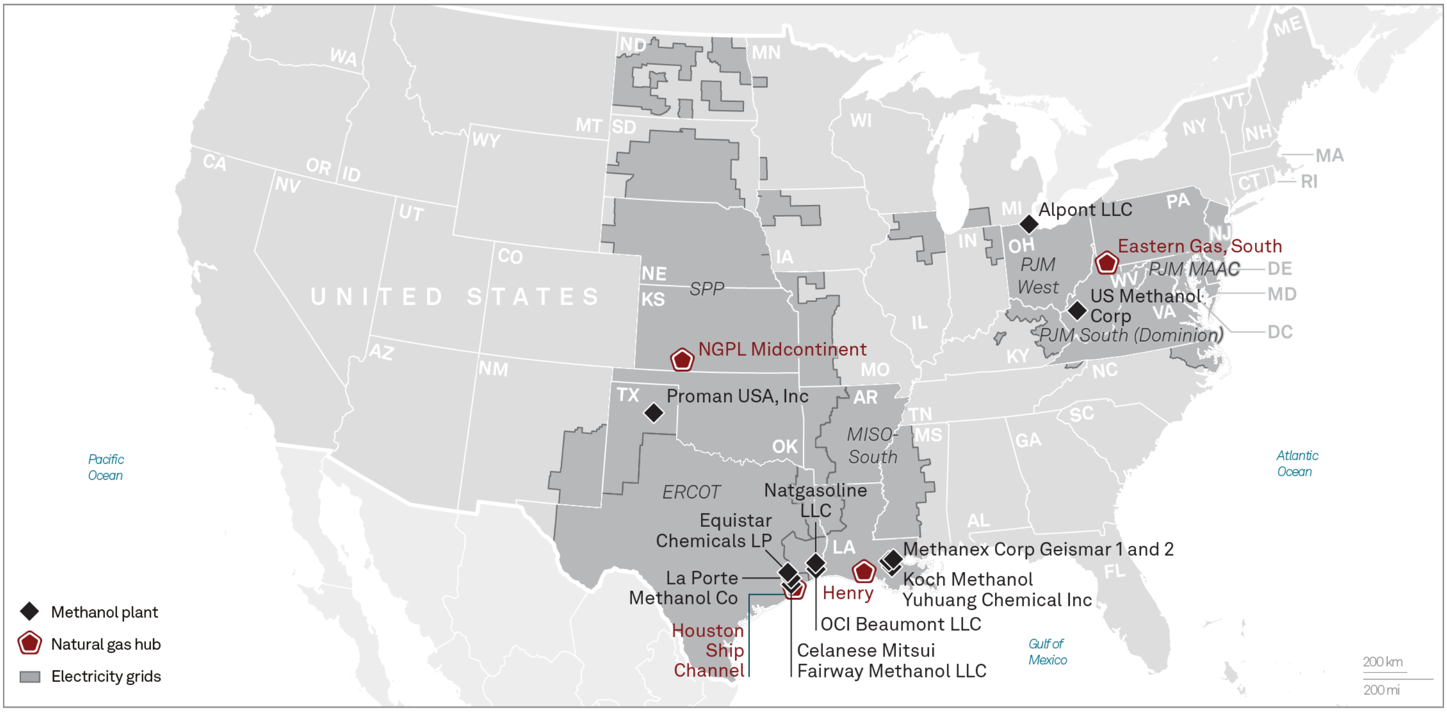
Approach

Overview

This document outlines the detailed methodology and formulae used to calculate methanol supply chain carbon intensities (CI) produced in methanol plants in the United States from natural gas as feedstock. Emissions from the natural gas supply chain, methanol produced via natural gas conversion processes at chemical plants and methanol end-use combustion are included. In total, 11 such natural gas-fed methanol plants were identified in the US as shown in Figure 1.

Figure 1

Key US natural gas-fed methanol plants, electricity grids and natural gas supply hubs



Data compiled Feb. 7, 2025.
Credit: CI Content Design.
Source: RAPID: 250340-01.

Key purpose and expected application

S&P Global Commodity Insights seeks to provide an independent source of US natural gas-fed methanol production weighted average carbon intensity that could be used as a US benchmark. The carbon intensities estimated are the weighted averages of numerous sources and pathways. Any individual supply chain may differ materially from the average. Therefore, it is important to point out that this work does not attempt to quantify any individual bespoke supply chain. Our objective is to serve as an independent resource for industry, investors and buyers to look to and compare their own operations, supply chains and investments against. The benchmark carbon intensity, which is based on natural gas feedstock, provides a reference to compare lower-carbon methanol production as more green and blue methanol production starts to come online in the coming years. The use case considered in this analysis is for methanol as a marine bunkering fuel.

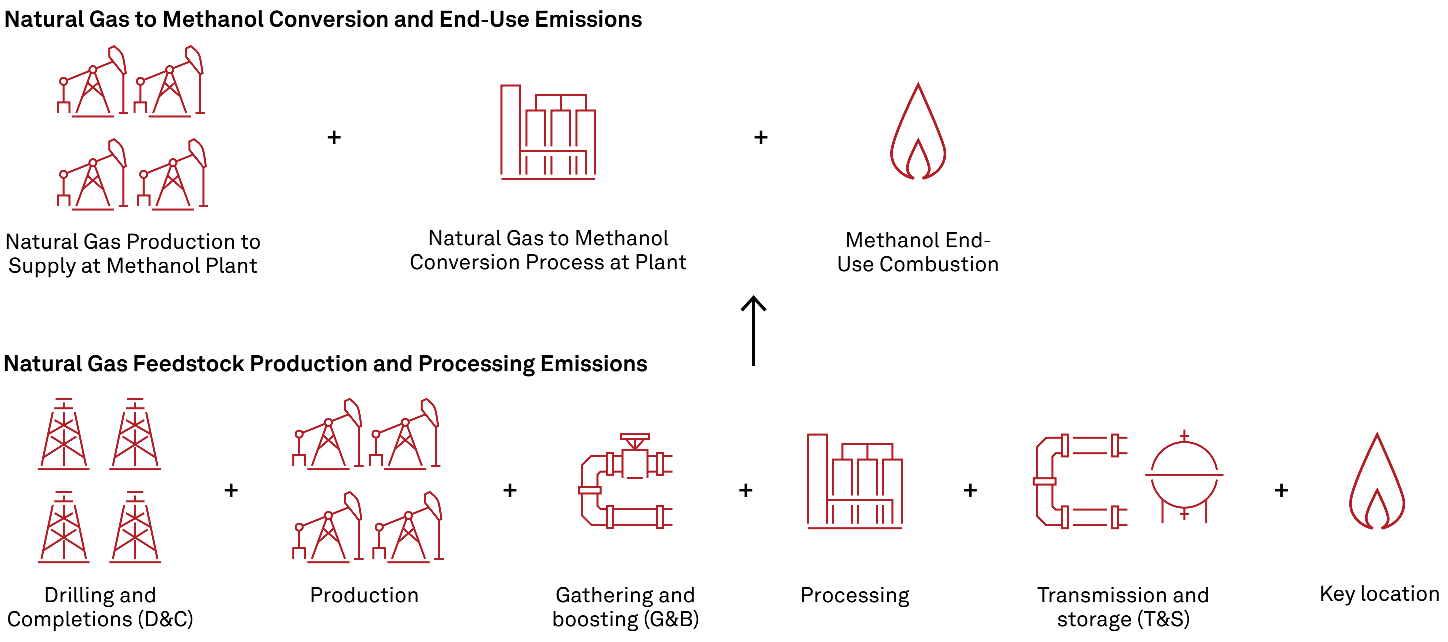
Methanol supply chain emissions accounting

Methanol supply chain system boundary

The boundary used for the estimation of US benchmark methanol carbon intensity considers the supply chain emissions of natural gas produced and processed as feedstock from well to methanol facility gate, conversion of natural gas to methanol in the plant and combustion of methanol at end use. Emissions from transport of methanol to end user via shipping exports is not considered in this assessment because the end use of methanol is considered to be its use as a marine bunkering fuel delivered at US ports. Emissions from natural gas feedstock drilling and completions, production, gathering, boosting, processing, transmission and storage, and delivery to North American hubs or key locations are estimated and details are given in another section of the Emissions Guidebook (*Emissions Guidebook Part 5: Commodity Carbon Intensities Section 1: Natural Gas Carbon Intensity Quantification Methodology*). Figure 2 shows the system boundary used for the emissions accounting from natural gas production to methanol end-use combustion.

Figure 2

Natural Gas-Fed Methanol Supply Chain System Boundary



Source: S&P Global Commodity Insights.

Units

Functional unit

A functional unit must be chosen before an assessment is undertaken and it must be kept consistent throughout the evaluation of each segment of a supply chain. This functional unit is the denominator basis for a greenhouse gas (GHG) intensity calculation. The units of grams of carbon dioxide equivalent per megajoule (gCO_2e/MJ)

are the units of choice for this study. The basis for the energy must also be specified to be on a lower heating value (net calorific value) or higher heating value (gross calorific value) basis. This basis must be specified and kept consistent for each segment of a supply chain. For this study, a lower heating value (LHV) basis was used.

Reporting unit

The final carbon intensity of the weighted US methanol production is converted from gCO_2e/MJ to metric tons of carbon dioxide equivalent per metric ton of methanol ($mtCO_2e/mt$ methanol) and reported out monthly.

Global warming potential

GHGs emitted into the atmosphere trap heat from the sun and contribute to a rise in global temperatures. Once in the atmosphere, various GHGs can interact with the environment differently and contribute to varying degrees of global warming. This concept is known as global warming potential (GWP). GHG emissions are often expressed in units of mass of carbon dioxide equivalent (CO_2e), with GWPs being used to convert different gases into this comparative basis.

The United Nations Framework Convention on Climate Change (UNFCCC) Intergovernmental Panel on Climate Change (IPCC) publishes Assessment Reports (ARs) of GWP. These are typically referenced as AR4, AR5 or AR6. For each GHG, the warming potential of each gas differs by the time horizon that is looked at because each gas has a different lifespan in the atmosphere and a different ability to absorb energy. The UNFCCC publishes two different time horizons to show short- and long-term effects of GHGs on global warming: 20-year and 100-year horizons. For this work, AR4 100-year GWPs were used to convert emissions to a CO_2e basis, given in Table 1.

Table 1

100-year AR4 Global Warming Potentials of CH_4 and N_2O

Gas	GWP AR4 100-yr
CO_2	1
CH_4	25
N_2O	298

CH_4= methane; N_2O = nitrous oxide.
Source: IPCC Fourth Assessment Report (AR4).

Natural gas feedstock supply carbon intensity

Well production, gas processing and supply to methanol plants

The Emissions Guidebook Part 5: Commodity Carbon Intensities, Section 1: Natural Gas Carbon Intensity Quantification Methodology details the methodology used to estimate production weighted average carbon intensity (CI) of natural gas produced from basins/fields, processed and supplied to 13 North American hubs. The natural gas hubs closest to the methanol plants in the United States were identified and used to estimate emissions associated with upstream natural gas feedstock.

The quantity of natural gas feedstock required for methanol production in each US plant is determined by assuming average feedstock consumption of processes from from S&P Global Commodity Insights' Process Economics Program (PEP) reports. Methanol production quantity for each plant is reported in S&P's Competitive Cost and Margin Analytics Model (CCMA).

Having estimated the quantity of natural gas required in each US methanol plant, the production weighted natural gas supply chain carbon intensity is estimated for a given hub as per the following formulae:

$$CI_{Upstream} = \frac{CI_{NG\ Feed} \times NG_{Feed}}{Prod_{Methanol}}$$

Where,

$CI_{Upstream}$ = is the natural gas feedstock upstream carbon intensity supply to a specific US methanol facility in $\left[\frac{gCO_2e}{MJ\ LHV\ Methanol}\right]$

$CI_{NG\ Feed}$ = is the natural gas hub carbon intensity of hub closest to a methanol facility in $\left[\frac{gCO_2e}{MJ\ LHV\ Natural\ gas}\right]$

NG_{Feed} is the natural gas consumed for annual methanol production at a given facility in [*MJ LHV Natural gas*]

$Prod_{Methanol}$ is the annual methanol production at a given facility [*MJ LHV Methanol*]

$$CI_{Upstream\ PWA} = \sum_{i=1\ to\ n}\left(CI_{Upstream\ i} \times \frac{Prod_{Methanol\ i}}{\sum_{i=1\ to\ n} Prod_{Methanol\ i}}\right)$$

Where,

$CI_{Upstream\ PWA}$ is the production weighted average upstream carbon intensity

i is a specific methanol plant in the US and *n* is the total number of methanol plants considered in the US.

Methanol plant carbon intensity

Natural gas-to-methanol conversion emissions

Processes used to convert natural gas to methanol in methanol-producing plants produce emissions from gas combustion that drive utilities, process reactions and electricity consumption. Methanol plants in the US report their combustion and process reaction emissions to the US Environmental Protection Agency (EPA) Greenhouse Gas Reporting Program (GHGRP). The plant-level emissions reported for each plant are divided by the methanol production to get the carbon intensity. Production weighted average carbon intensity is further obtained as shown in the following formulae:

$$CI_{Methanol\,Facility\,Scope\,1} = \frac{RE_{Methanol\,Facility}}{Prod_{Methanol}}$$

Where,

$CI_{Methanol\,Facility\,Scope\,1}$ is the Scope 1 methanol production carbon intensity within a methanol facility in $\left[\frac{gCO_2e}{MJ\ LHV\ Methanol}\right]$

$RE_{Menthanol\,Facility}$ is the *US EPA GHGRP* reported emissions for combustion and process emissions by a specific methanol facility in [gCO_2e]

$Prod_{Methanol}$ is the annual methanol production at a given facility [*MJ LHV Methanol*]

$$CI_{Methanol\,Facility\,Scope\,1\,PWA} = \sum_{i=1\,to\,n}\left(CI_{Methanol\,Facility\,Scope\,1_i} \times \frac{Prod_{Methanol\,i}}{\sum_{i=1\,to\,n} Prod_{Methanol\,i}}\right)$$

Where,

$CI_{Methanol\,Facility\,Scope\,1\,PWA}$ is the production weighted average Scope 1 methanol facility emissions

Scope 2 emissions due to imported electricity are estimated by multiplying the electricity consumption per methanol conversion process with the local electricity grid factor. S&P Global Commodity Insights' Process Economics Program (PEP) reports have theoretical estimates of electricity consumption per methanol conversion process. For our estimation, the electricity consumption is assumed to be for the Casale process. The electricity grid emission factors were obtained from our North American Power Analytics data, which includes annual historical and forecast grid emissions for the major US grids.

Having obtained each plant's electricity intensities, the production weighted average carbon intensity was obtained from the following equations:

$$CI_{Methanol\,Facility\,Scope\,2} = \frac{Electricity_{Methanol\,Facility} \times GE}{Prod_{Methanol}}$$

Where,

$CI_{Methanol\ Facility\ Scope\ 2}$ is the Scope 2 methanol production carbon intensity within a methanol facility in $\left[\frac{gCO_2e}{MJ\ LHV\ Methanol}\right]$

$Electricity_{Menthol\ Facility}$ is electricity consumption by a specific methanol facility in [MWh]

GE is the electricity grid emission factor of the grid catering to a given methanol facility in $\left[\frac{gCO_2e}{MWh}\right]$

$Prod_{Methanol}$ is the annual methanol production at a given facility [$MJ\ LHV\ Methanol$]

$$CI_{Methanol\ Facility\ Scope\ 2\ PWA} = \sum_{i\,=\,1\ to\ n}\left(CI_{Methanol\ Facility\ Scope\ 2\ i} \times \frac{Prod_{Methanol\ i}}{\sum_{i\,=\,1\ to\ n} Prod_{Methanol\ i}}\right)$$

Where,

$CI_{Methanol\ Facility\ Scope\ 2\ PWA}$ is the production weighted average Scope 2 methanol facility emissions.

Methanol end-of-life carbon intensity

End-use methanol combustion emissions

The end-use combustion emissions of methanol are added to complete the US methanol benchmark analysis. This equals a CI of 69 gCO_2e/MJ LHV Methanol. This means the largest part of the life-cycle emission cannot be avoided when natural gas is the feedstock.

$$CI_{End\ Use\ Combustion} = 69 \left[\frac{gCO_2e}{MJ\ LHV\ Methanol} \right]$$

US methanol benchmark carbon intensity

The benchmark carbon intensity of US methanol marine bunkering fuel for natural gas feedstock-based methanol production is estimated by the following production weighted averages as follows:

$$CI_{Menthanol\ Benchmark} = CI_{Upstream_{PWA}} + CI_{Methanol\ Facility\ Scope\ 1_{PWA}} + CI_{Methanol\ Facility\ Scope\ 2_{PWA}} + CI_{End\ Use\ Combustion}$$

Appendix A: Overview of S&P Global products and models

Competitive Cost & Margin Analytics Model (CCMA)™

CCMA provides a comprehensive analysis of the major methanol producing facilities worldwide in an effort to determine the relative competitiveness of the world's various producing facilities. All methanol producing units exist worldwide, all of which were individually studied. Additional methanol production units that are expected to be on-stream by 2030 are also included in the scope of this study. Important factors such as plant size, technology, and estimated and feedstock valuations, are incorporated into the analysis to provide a determination of the competitive nature of each facility. From this, a view of which suppliers can economically best participate in a given market is available. The overall objective of the Competitive Cost & Margin Analytics – Methanol is to provide clients with a general view of methanol cash cost competitiveness for each producing facility, country and region worldwide. It is important to note that the study is not based on a particularly rigorous survey of individual plant operating data and cost structures. Rather, this study analyzes the key parameters in each plant that have the most significant impact on cost competitiveness, such as raw material feedstock costs, process technology, and other variable and fixed costs. This study is intended to provide a more universal view of the competitive issues facing regional methanol production now as well as in the future, rather than a rigorous benchmarking tool for comparing individual plants. The primary objectives of this study are to:

- Establish methanol industry production cash cost curves on both a global and regional basis, benchmarking industry conditions for historical years from 2015 to 2024 and forecast years 2025 and 2030.
- Show the regional differences in feedstock costs and production capacities and assess their impact on relative competitiveness of the major methanol producing regions.
- Identify the lowest-cost and highest-cost regions and primary sources of competitive advantage or disadvantage.
- Present the potential impact of new capacity on the global methanol industry.

Process Economics Program

The Process Economics Program (PEP) provides in-depth, independent technical and economic evaluation of both commercial and emerging technologies for the chemical, biochemical and refining industries. PEP analyzes the impact of changes in processes, feedstocks, energy prices and government regulations on chemical and fuel production economics for our clients. The PEP Yearbook is the world's largest online process economics database. Updated quarterly starting in 2014, it provides current production economic data for more than 1,400 processes used to manufacture over 600 chemical, polymer, refining and biotech products. The database estimates raw material and utility requirements and demonstrates capital and production costs for three plant capacity levels, while an online application tool enables users to customize plant capacity for quick scaling analysis.

North American Power Analytics

North American Power Analytics data contains historical and forecast power grid emission factors for all major regional grids within the United States and Canada.

Appendix B: Constants, conversion factors and additional data

Conversion factors

Table B-1

Mass conversion

Source unit	Equals or denotes
1 kilogram (kg)	2.205 pounds
1 metric ton (t)	1,000 kg
1,000 grams	1 kg
1 Mt	1 mega metric ton
1 kt	1 kilo metric ton

Table B-2

Volume conversion

Source Unit	Equals or denotes
1 m^3	35.31 ft^3
1 Mcf	1,000 ft^3
1 MMcf	1,000,000 ft^3
1 gallon (gal)	3.785 L
1 barrel (bbl)	42 gal
1 m^3	6.2898 bbl

Table B-3

Energy conversion

Source unit	Equals or denotes
1 Megajoule (MJ)	1 million J
1 MMBtu	1 million Btu
1 MJ	1,055 MMBtu
1 MWh	3,600 MJ
1 gigajoule (GJ)	1,000 MJ

Source: S&P Global Commodity Insights.

Heating value of methanol

Higher heating values or gross heating values are obtained by assuming that all water in the combustion products is in liquid form, therefore resulting in more energy availability in the fuel (as the energy to condense the water vapor is included as available energy). In reality, most combustion processes do not condense the water vapor in the exhaust. The lower heating value or net heating value assumes that the water remains vapor in the exhaust. In the work that the Center of Emissions Excellence does for supply chain emission accounting, lower heating values are used to represent carbon intensities of energy commodities. The lower heating value of methanol is 19.9 MJ/kg.

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