Emissions Guidebook

Part 5: Commodity Carbon Intensities

Section 1: Natural Gas Carbon Intensity Quantification Methodology

North America

Version 2.0

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.

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Approach

Overview

This document outlines the detailed methodology and formulae used to calculate natural gas supply chain carbon intensities at key North American locations. Emissions from drilling and completions, production, gathering and boosting, gas processing and transmission to key location are included. In total, carbon intensities are quantified at 13 key locations, as shown in Figure 1 below.

Figure 1

Natural gas carbon intensity assessment locations: Key locations for carbon intensity estimation

Data compiled Jan. 22, 2025.
Source: S&P Global Commodity Insights: 250271-01.

Key Purpose and Expected Application

S&P Global Commodity Insights seeks to provide an independent source of North American natural gas average carbon intensity at various key locations that can be used as benchmarks. The key location carbon intensities are the weighted average 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.
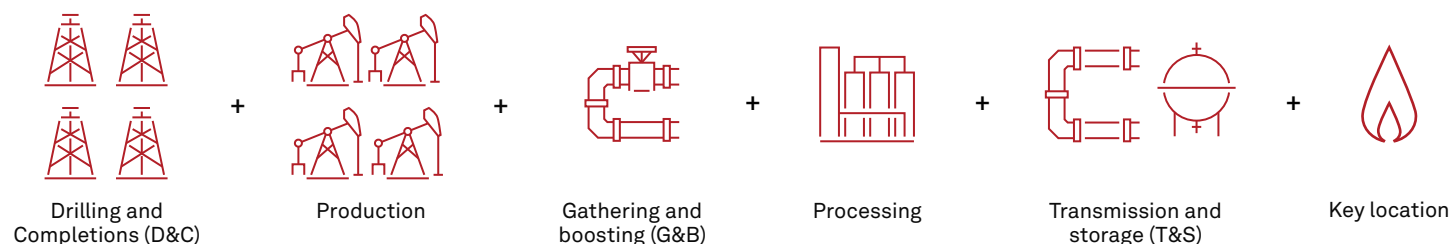
Supply Chain Emissions Accounting

Natural Gas Supply Chain System Boundary

Emissions are added over a supply chain of natural gas from well to key location. First natural gas and oil are drilled for and co-produced. Then rich gas often containing natural gas liquids is gathered and boosted and sent to a gas processing plant gate. Rich gas is processed to separate liquids from gas and also to purify the gas to pipeline quality specification by removing H_2S and CO_2 entrained within the produced gas. Transmission pipelines with various storage facilities are included in the final segment of the supply chain which ultimately delivers the gas to the key location of interest. Figure 2 shows the system boundary used for the emissions accounting from well head to key natural gas trading location.

Figure 2

Natural gas supply chain system boundary

| Drilling and Completions (D&C) | Production | Gathering and boosting (G&B) | Processing | Transmission and storage (T&S) | Key location |

Source: S&P Global Commodity Insights.
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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 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

While the functional unit chosen for this work is gCO_2e/MJ (LHV basis), following supply chain quantification, units may be converted to a unit that is commonly understood in the marketplace. For this work, final carbon intensities are reported units of metric tons of carbon dioxide equivalent per million British thermal units of energy on a lower heating value basis, $tCO_2e/MMBtu$ (LHV basis).

Treatment of Co-Products

Oil and gas are typically co-produced at the well head. Additionally, there is variability in the liquids content of all gas streams produced. Some have a large amount of natural gas liquids (ethane, propane, butane) and higher carbon content liquids often characterized as condensates. When we are accounting for a final dry marketable natural gas carbon intensity, we want to apportion to just the natural gas supply chain. This is done by applying an energy ratio to the emissions at each segment of the supply chain.

The energy ratio is defined as

$$ER = \frac{MJ_{Natural\ Gas}}{MJ_{Natural\ Gas} + MJ_{Oil + NGLs + Condensates}}$$

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 (AR) 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 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. For this work, AR4 100-year GWPs were used to convert emissions to a carbon dioxide equivalent 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

Source: IPCC Fourth Assessment Report (AR4).
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Methane Emissions Estimation

Satellite methane observation data from Sentinel 5P is currently being gathered and processed for 19 basin-state main oil and gas producing regions within the United States. In house data experts ingest the raw data and apply algorithms to quantify mass emissions rates for all areas. The 19 locations that this work is done for are given in Table 2.

Table 2

19 Locations for Methane Assessment

1	Haynesville - LA	8	Eagle Ford	14	Anadarko
2	Haynesville - TX	9	Delaware	15	Piceance
3	Appalachian - OH	10	Midland	16	Arkoma
4	Appalachian - PA	11	Scoop-Stack	17	San Juan
5	Appalachian - WV	12	D-J	18	Green River
6	Fort Worth	13	Powder River	19	Uinta
7	Bakken				

SCOOP = South Central Oklahoma Oil Province; STACK = Sooner Trend Anadarko Canadian Kingfisher.
Source: S&P Global Commodity Insights.
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Methane emissions are estimated for onshore basins in the United States and Australia with observed data from the European Space Agency's Copernicus Sentinel-5 Precursor satellite equipped with the TROPOspheric Monitoring Instrument (TROPOMI). Methane data is summarized monthly per basin and also by province or state if applicable. Basin polygons have been set to encapsulate primarily oil- and gas-producing areas while excluding sources that are not oil and gas related such as feedlots or coal mines.

Owing to the fact that observed methane emissions could be attributed to multiple segments along the natural gas supply chain, an attribution methodology was developed to assign a portion of the observed methane emissions within a basin to upstream oil and gas production, natural gas gathering, natural gas processing, natural gas transmission and storage, and distribution. For the US, this attribution was based upon the proportion of US Environmental Protection Agency (EPA) reported[1] methane emissions for each of the segments over the same polygon areas as observed methane is analyzed. The result is a unique set of attribution percentages for each basin. For areas where gridded EPA Greenhouse Gas Inventory (GHGI) data was unavailable, attribution was assumed to follow an average of 58% production, 20% gathering, 8% processing, 10% transmission and storage and 4% other.

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[1] Based upon gridded emissions reported in the 2018 GHGI using the GHGI Version 2 hyperlink https://pubs.acs.org/oi/10.1021/acs.est.3c05138, "A Gridded Inventory of Annual 2012–2018 U.S. Anthropogenic Methane Emissions," Maasakkers, et al., Oct. 19, 2023.

Field/Basin Level Carbon Intensity

Drilling and Completions and Production

GHG emissions associated with the development of each well (occurring prior to production) including venting associated with mud degassing, flaring during well testing, and diesel, natural gas or electrical power consumption for drilling and completing each well is estimated.

Drilling diesel consumption is estimated based on the number of drill days and daily diesel consumption for drilling estimates. Completions include fuel combustion for hydraulic fracturing, which includes diesel consumption by the frac fleet and by the frac pumps and delivery of sand to well sites. Well testing emissions are estimated using an assumed duration of three hours and the gas-to-oil ratio (GOR) for the well to estimate the volume of gas flared.

Production-stage GHG emissions are estimated based on the monthly production profile of each well over its production life. Production emissions include fuel use or electricity consumption for lifting, flaring, venting, and well test (once per year). It is assumed that wells begin their life on natural lift for the first six months, then switch to gas lift for two months, and then rely on electric submersible pumps (ESPs) for the remainder of the well life. Energy for each lift mechanism is based on the production levels of oil, gas, and water; water disposal; oil gathering; and gas gathering systems. The energy-use calculation is based on monthly production levels of oil, gas, and water; power consumption for the various lift mechanisms; water disposal; oil gathering; and gas gathering levels on a well basis. Using the total estimated energy consumption, emissions are estimated based on the diesel combustion emissions factors and regional grid intensities.

Emissions from gas flared are estimated based on state or provincial averages (percent of produced gas volumes) generated by regulatory data.

Total pre-production and production emissions are estimated for each field or basin for each state at the play level and summed to production weighted average intensities per field. Total volumes of oil and gas produced in the same field are summed, coupled with estimated energy content of each field and included in the ER correction factor.

$$gCO_2e_{Field, D\&C + Prod} = \left\{ \sum_{1}^{\# Plays} (gCO_2e_{D\&C + Production} \times ER_{Prod}) \right\}$$

Gathering and Boosting

Gathering and boosting emissions are predominately taken from emissions data reported to federal regulatory bodies in Canada and the United States. This reported emissions data is augmented additional emissions supported by reasonable assumptions regarding electricity imports, comprehensiveness of the dataset, and methane satellite emissions quantified for various basins. Total production volumes from each field coupled with the estimated energy content of each field are used in the ER correction factor.

$$gCO_2e_{Field, G\&B} = \left\{ \sum_{1}^{\# Plays} (gCO_2e_{G\&B} \times ER_{G\&B}) \right\}$$

Gas Processing

Gas processing emissions are predominately taken from emissions data reported to federal regulatory bodies in Canada and the United States. This reported emissions data is augmented additional emissions supported by reasonable assumptions regarding electricity imports, comprehensiveness of the dataset, and methane satellite emissions quantified for various basins. Total throughput volumes into each processing plant coupled with the estimated energy content of each throughput are used in the ER correction factor.

$$gCO_2e_{Field,\,Processing} = \left\{ \sum_{1}^{\#\,Plays} (gCO_2e_{Processing} \times ER_{Processing}) \right\}$$

Transmission and Storage

Transmission and storage emissions are estimated by using an emission factor derived primarily from reported emissions data for all US pipelines and storage areas with methane emissions overlayed from the US average methane emission rate for the T&S segment according to the apportionment methodology described in the section on methane emissions. The applied emission rate is in $gCO_2e/(MJ\text{-}km)$.

$$gCO_2e_{Field,\,T\&S} = \left\{ \sum_{1}^{\#\,Plays} (EF\,CO_2e_{T\&S} \times Transport\,Distance \times MJ_{Transported}) \right\}$$

Full Supply Chain

To add up the natural gas supply chain carbon intensity, each segment of the supply chain must be considered separately and accurately accounting for changes in product flows through each segment. The total GHG intensity may be added up using the following equation:

$$CI_{Field\,/\,Basin} = \frac{gCO_2e_{Field,\,D\&C+Prod}}{MJ_{MarketableGas}} + \frac{gCO_2e_{Field,\,G\&B}}{MJ_{MarketableGas}} + \frac{gCO_2e_{Field,\,Processing}}{MJ_{MarketableGas}} + \frac{gCO_2e_{Field,\,T\&S}}{MJ_{MarketableGas}}$$

Emissions per segment should be calculated as per the sections in the preceding sections of this methodology document. Energy ratio (ER) changes throughout the value chain. In the beginning, co-products of natural gas, natural gas liquids and oil are produced so all of the products must be accounted for in the energy content of the stream. After production, oil is separated from the rich gas and the rich gas is gathered and subsequently processed. After processing, dry gas is collected, stored and transported to the key locations of interest. For the T&S segment of the supply chain, no emissions allocation to co-products is needed as all emissions are associated with marketable natural gas.

Key Location Carbon Intensities

Flows are summarized on a monthly basis for each pipeline feeding into each key location one month in arrears compared to the current assessment i.e., November 15 release is based upon October total gas flow data. Flow data are based upon Commodity Insights Analytics flows into each key location from each pipeline feed, with this supply broken down by the origination fields/basins. Flows are not from a specific supplier or operator and are not based upon spot contracts rather the average of the actual physical flows into each key location. The portion of flow from one particular basin fed into a key location varies by the month and therefore the overall intensity at the key location will also vary monthly. Specifications for each key location are determined by the [S&P Global US and Canada methodology and specifications guide](#).

$$CI_{Key\ Location} = \sum_{1}^{\#\ of\ fields} (CI_{Field} \times MJ_{Field})$$

Where,

CI_{Field} is the carbon intensity from well to key location from one specific supply field

MJ_{Field} is the monthly flow for one specific supply field into the key location in $m^3 \times LHV\ (MJ/m^3)$

# of fields is the number of individual specific supply fields the feed into the key location

Appendix A: Overview of S&P Global Products and Models

Energy Studio IMPACT™

Impact is a comprehensive data-enabled experience for advanced analytics focused on the North American upstream oil and gas supply chain. Energy Studio IMPACT integrates the North America Onshore Upstream model to present dashboard analytics for various parameters of interest including production, GHG emissions, and GHG emissions intensity. Results can be presented by basin, operator, and play.

It contains GHG emissions estimates for every month — from drilling and completions through operations for every well to the projected end of life and ultimately abandonment — for every well in the onshore since 1920. The emissions estimates are built on top of S&P Global Commodity Insights' extensive upstream data, which are principally sourced from publicly available government and regulatory data. It currently includes over 6 million wells with over 70 distinct variables running over 250 calculations per well to derive an independent estimate of monthly emissions and emissions intensity of drilling and completions and operational emissions by fuel and gas. This tool provides comprehensive estimates of all the activity within a play or basin to understand the full range, distribution, and medium and weighted average of activity.

The model uses detailed well data to estimate the GHG emissions. GHG emissions estimates are based on the estimated energy required during the drilling and completions of a well followed by production of oil throughout the life of each well. Based on the energy requirements, GHG emissions factors for the appropriate fuels and energy sources are applied for each stage of the process.

S&P Vantage™

Vantage is an upstream analytical solution that provides economic valuation of both conventional and unconventional global assets (non-North American onshore) with forward-looking production, including detailed capital cost information for over 20,000 global upstream oil and gas assets. Vantage uses the offshore and onshore international models as input as well as data reported to various regulatory jurisdictions. Vantage includes detailed production, emissions and cost metrics.

International upstream oil and gas emissions are estimated at the project level and then rolled up to the asset level. An asset is defined as an entity with defined ownership structure, associated commercial hydrocarbon resource, and planned or existing investment. An asset can include one or more oil and gas fields or can represent an acreage position with one or multiple planned or existing projects (or phases). Each project within an asset has an independent hydrocarbon production stream and corresponding investment schedule. In some cases, a single asset may include multiple projects, with each project representing a phase or area of development that can be considered as a separate entity or investment decision (such as a program of infield drilling late in the life of a field or an enhanced recovery project). Each project has an independent production and investment stream.

Emissions estimates are inclusive of direct emissions resulting from production, processing, maintenance, flaring, venting, and fugitive releases. For offshore assets, emissions are estimated for fuel consumption, flaring, venting and fugitive emissions.

Emissions from these sources are calculated from the volumes or masses combusted (in the case of fuel consumption and flaring) or released to air (in the case of venting and fugitives) using S&P Global standard conversion factors, emissions factors, and data on fluid/gas properties.

EDIN™

EDIN is an interface into our E&P, Basin and global Midstream datasets. It is a web browser solution that provides customers with the most complete industry datasets available. EDIN supports core industry workflows such as country and basin screening, portfolio optimization, prospect evaluation, peer group analysis and country entry strategy. EDIN emission data is primarily sourced from publicly reported data from regulatory reporting in different jurisdictions.

Commodity Insights Analytics

Commodity Insights Analytics, provides up-to-the-minute expert analytics of the North American natural gas market. The service offers comprehensive natural gas pipeline flows for every interstate natural gas pipeline in the United States and Canada. From these pipeline flows, detailed and accurate production volumes, supply and demand analytics, regional reports, and forecasts are offered via a dynamic visual interface.

By recording and capturing metered pipeline volumes, the following can be estimated:

– throughput volumes between states and regions;

– volumes at storage facilities;

– volumes delivered from gas processing facilities; and

– gas delivered to industrial facilities.

Statistics can be delivered daily, with data updated four times per day.

Appendix B: Reference Definitions and Data

Glossary of Key Terms

Glossary of Key Terms

Term	Definition
AR4	IPCC 4th Assessment Report – referred to for GWPs
AR5	IPCC 5th Assessment Report – referred to for GWPs
AR6	IPCC 6th Assessment Report – referred to for GWPs
CH_4	Methane
CI	Carbon Intensity
D&C	Drilling and Completions
ER	Energy Ratio
G&B	Gathering and Boosting
GHG	Greenhouse Gas
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
Fuel	Gas or diesel that is combusted at a site
Flare	Volumes of hydrocarbons that are flared at a site
Fugitives	Unintentional methane releases due to leaks
GWP	Global Warming Potential
GOR	Gas to Oil Ratio
N_2O	Nitrous Oxide
NGL	Natural Gas Liquids: volumes of higher carbon content hydrocarbons entrained within produced natural gas
T&S	Transmission and Storage
Vent	Volumes of hydrocarbons that are intentionally vented via pneumatic devices, pneumatic pumps, tanks, compressor seals, dehydrators, blowdowns etc.

Source: S&P Global Commodity Insights.
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Conversion Factors

Mass conversion

Source unit	Equals or denotes
1 kg	2.205 lb
1 metric ton (t)	1,000 kg
1,000 g	1 kg
1 Mt	1 mega metric ton
1 kt	1 kilo metric ton

Source: S&P Global Commodity Insights.
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Volume conversion

Source Unit	Equals or denotes
1 m³	35.31 ft³
1 Mcf	1,000 ft³
1 MMcf	1,000,000 ft³
1 gal	3.785 L
1 bbl	42 gal
1 m³	6.2898 bbl

Table B-4

Energy conversion

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

Source: S&P Global Commodity Insights.
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Heating Values

Higher and Lower Heating Value Definitions

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 vapour is included as available energy). In reality, most combustion processes do not condense the water vapour in the exhaust. The lower heating value or net heating value assumes that the water remains vapour 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 such as natural gas, crude oil, and natural gas liquids.

Natural Gas Heating Values

Table B-5 lists the lower heating values for various plays or basins within Canada and the United States that were used for this work. Gas composition data were obtained from reported sources and averaged over the basins/plays/subplays. It is expected that heating values will vary within each play and over time. If no information was available for a given play/subplay, a default LHV of 40 MJ/m³ was assumed.

Assumed Lower Heating Values for Various US and Canadian Plays

Play-Basin	LHV (MJ/m³)
Anadarko Pennsylvanian	38.9
Bakken Shale	47.2
Barnett Shale	37.4
Bone Spring	39.4
Eagleford Shale - Gassy Edge	39.9
Eagleford Shale	44.3
Haynesville Shale	33.7
Marcellus Shale -NE noncore	33.9
Marcellus Shale - Liquids Rich	37.2
Marcellus Shale -Periphery	34.4
Marcellus Shale - Supercore	33.9
Marcellus Shale - SW Core	34.5
Niobrara Fracture Play - DJ	41.1
Powder River Basin - Deep	46.7
Powder River Basin - Shallow	50.8
Scoop	40.9
Stack	38.4
Uinta	40.4
Utica Shale - Dry	34.5
Utica Shale - Wet	37.4
Wattenberg	41.1
Wolfcamp Delaware	38.2
Wolfcamp Midland - NE	43.0
Wolfcamp Midland -SW	39.8
Woodbine	38.1
Woodford - Arkoma	33.8
Woodford - Cana	38.4
AB Montney	39.5
BC Montney	41.0
Duvernay	45.1
Cardium	40.8
Spirit River	37.7

Source: S&P Global Commodity Insights.
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Crude Oil Heating Values

A correlation between heating values and API gravity of crude oil can be made and data extracted from the Fuel Oil Manual is presented in Table B-6. The assumptions are for representative crude oil compositions, discrepancies might surface if using this table for evaluating crudes with much different composition than what would be typical of a fossil crude.

Lower Heating Values for Various US and Canadian Plays

Crude density		LHV		Crude density		LHV	
Deg API	SG	MMBtu/bbl	MJ/bbl	Deg API	SG	MMBtu/bbl	MJ/bbl
4	1.044	6.18	6525	37	0.840	5.34	5635
5	1.037	6.17	6508	38	0.835	5.32	5609
6	1.029	6.15	6485	39	0.830	5.29	5582
7	1.022	6.12	6460	40	0.825	5.27	5556
8	1.014	6.10	6437	41	0.820	5.24	5530
9	1.007	6.08	6412	42	0.816	5.22	5508
10	1.000	6.05	6381	43	0.811	5.20	5482
11	0.993	6.02	6355	44	0.806	5.17	5456
12	0.986	5.99	6324	45	0.802	5.15	5430
13	0.979	5.97	6294	46	0.785	5.11	5389
14	0.973	5.94	6268	47	0.779	5.08	5362
15	0.966	5.91	6237	48	0.773	5.06	5335
16	0.959	5.89	6211	49	0.768	5.03	5307
17	0.953	5.86	6180	50	0.762	5.00	5280
18	0.946	5.83	6150	51	0.756	4.98	5253
19	0.940	5.80	6124	52	0.750	4.95	5225
20	0.934	5.78	6093	53	0.744	4.93	5198
21	0.928	5.75	6067	54	0.738	4.90	5171
22	0.922	5.72	6037	55	0.732	4.87	5143
23	0.916	5.70	6011	56	0.726	4.85	5116
24	0.910	5.67	5984	57	0.720	4.82	5089
25	0.904	5.64	5953	58	0.714	4.80	5062
26	0.898	5.62	5927	59	0.709	4.77	5034
27	0.893	5.59	5901	60	0.703	4.74	5007
28	0.887	5.57	5875	62	0.691	4.69	4952
29	0.882	5.54	5844	63	0.685	4.67	4925
30	0.876	5.51	5818	64	0.679	4.64	4898
31	0.871	5.49	5792	65	0.673	4.61	4870
32	0.865	5.47	5766	66	0.667	4.59	4843
33	0.860	5.44	5740	67	0.661	4.56	4816
34	0.855	5.42	5714	68	0.655	4.54	4788
35	0.850	5.39	5687	69	0.650	4.51	4761
36	0.845	5.36	5652				

Source: Schmidt, Paul F., Fuel Oil Manual, Fourth edition (1985).
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