NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Office of Climate, Air, & Energy, Deputy Commissioner
625 Broadway, 14th Floor, Albany, New York 12233-1010
P: (518) 402-2794 | F: (518) 402-9016
www.dec.ny.gov

Request for Public Input: Emissions Associated with Imported Fossil Fuels

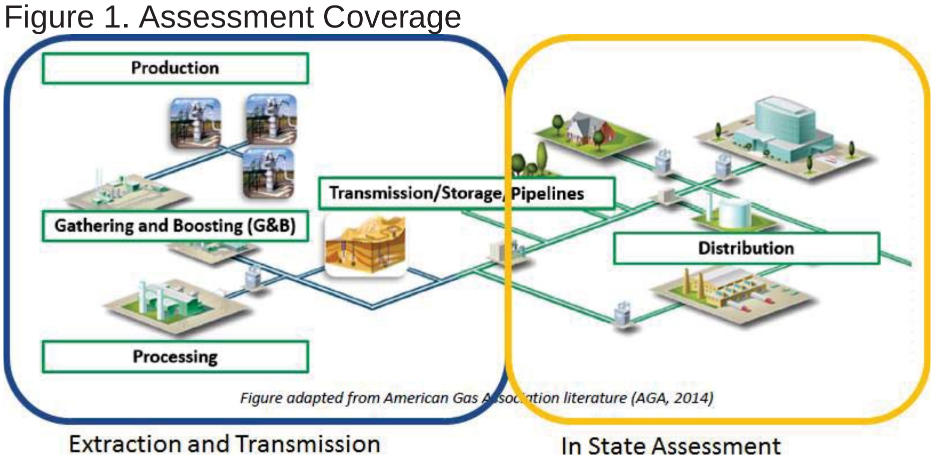
The New York State Climate Leadership and Community Protection Act (CLCPA) became effective in January 2020. One of the CLCPA requirements is the development of an annual greenhouse gas inventory.[1] This inventory requires the inclusion of greenhouse gas emissions that are associated with the out-of-state extraction and transmission of fossil fuels imported into the state. The emissions within New York State are analyzed by a separate assessment (Figure 1).[2]

The New York State Department of Environmental Conservation (the Department) is evaluating several analytical approaches to develop an estimate of extraction and transmission emissions that most closely characterize out-of-state emissions. The analytical methods consist of two primary types of estimation:

1. A bottom-up, component-based modeling
2. A national average, top-down validated emission leakage rate

The Department is seeking feedback from stakeholders on which estimation approach best represents emissions for the purposes of the annual GHG emissions report. Additional background information has been provided from Eastern Research Group (ERG) in the attached memo. Additionally, the Department is hosting a Technical Conference on March 26, 2021 to further discuss these options. Feedback received before May 01, 2021 will be most-easily integrated into the 2021 annual report, but comments are welcome at any time.

Figure 1. Assessment Coverage



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[1] ECL § 75-0105

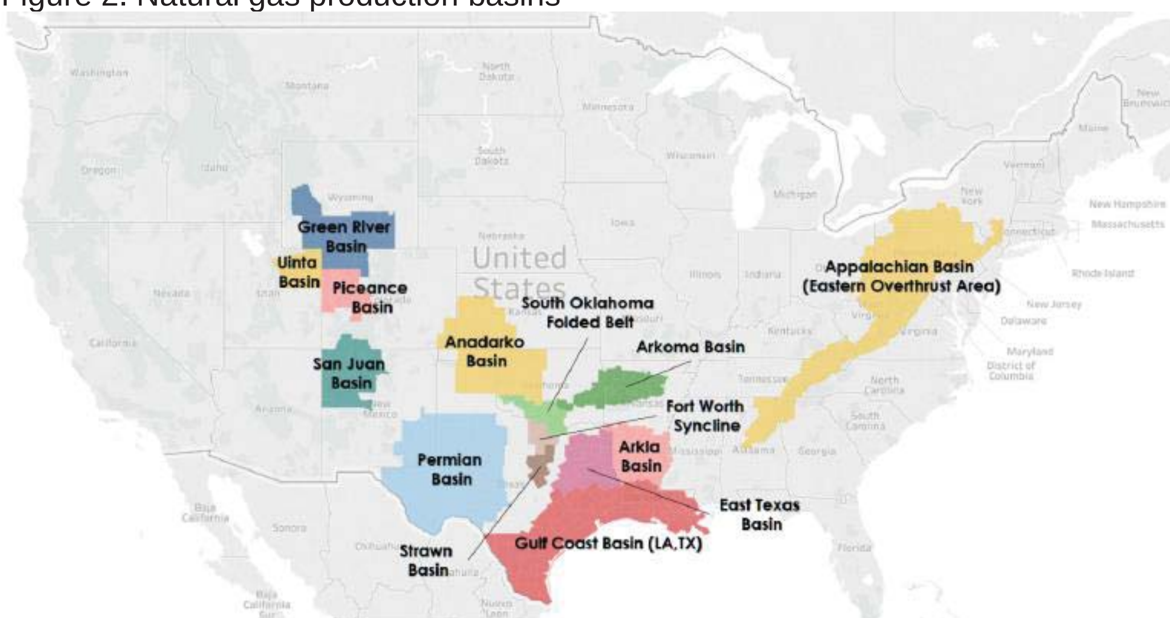
[2] NYSERDA and Abt (2019) Oil and Gas Methane Inventory. https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Greenhouse-Gas-Inventory

1. Bottom-up component-based model estimation

The bottom-up, component-based model is a modification of a lifecycle assessment model developed by the National Energy Technology Laboratory (NETL) (Life Cycle Analysis of Natural Gas Extraction and Power Generation, 2019). The Department is considering using this emissions model to assess emissions from the well to the New York state border.

The NETL model utilizes data submitted to the USEPA GHG reporting program and does not include emission factors for sources emitting less than 25,000 tons per year, in particular conventional natural gas production within the Appalachian Basin. The Department is considering how to best account for emissions from these sources in concert with the model output. Additionally, the Department is evaluating methods to apply emission factors from other data collection activities to the component/basin based NETL model.

Figure 2. Natural gas production basins



2. National average top-down leakage rate estimation

The national average emission factor method would rely on peer reviewed studies of emissions at natural gas facilities validated with top down methods. There is a growing body of scientific literature based on remote-sensing data that suggests that standard, bottom-up analyses of methane from oil and natural gas systems may be underestimating actual methane emissions. Most of this top-down data has been collected very recently and only in limited areas. This work extrapolates emission estimates from production basins such as those shown in Figure 2 to the national natural gas production, processing, and transmission system. The Department can apply this emission factor to the volume of natural gas imported into the state. The state emissions estimated utilizing this method are not dependent on basin level production data or transmission distance and would typically only be updated based on the evaluation of new published emissions information.

MEMORANDUM

TO: New York State Department of Environmental Conservation (NYSDEC)

FROM: Sarah Cashman, Danny Hage, Ben Young (ERG)

SUBJECT: **Upstream Fuel Cycle Approach for Natural Gas, Coal, and Petroleum**

DATE: March 15, 2021

1. Background

This memorandum summarizes ERG's implemented approach to develop upstream fuel cycle emission factors for natural gas, coal, and petroleum fuels consumed in New York State (NYS), which are a new requirement for NYS to incorporate in its greenhouse gas (GHG) inventory based on the 2019 Climate Leadership and Community Protection Act. For this inventory, "upstream fuel cycle" emissions are defined as emissions from the various stages of the fuel supply chain: extraction, processing, and transmission or transportation to the NYS boundary. The upstream fuel cycle does not include emissions associated with infrastructure construction and maintenance or manufacture of equipment.

2. Natural Gas

Emissions from natural gas extraction, processing, and transmission are primarily sourced from emissions modeling developed by the National Energy Technology Laboratory (NETL) for U.S. basins specific to one of three gas or extraction methods: conventional, tight, and shale (NETL, 2019b). The NETL Natural Gas Extraction Model draws on the U.S. EPA Greenhouse Gas Reporting Program's (GHGRP) emissions and activity data to account for emissions from the point of production to the point of distribution as well as from energy inputs into the supply chain. While the U.S. natural gas market draws from production basins throughout the country, all processed natural gas enters the same domestic transmission network; the production source, therefore, cannot be ascertained once natural gas arrives at the end user due to mixing in transmission lines. Five basins were therefore chosen to model the production of natural gas consumed by New York based on their proximity to New York and location of major transmission lines (Rosenberg, 2006), with each basin containing one or more gas types (Table 1).

To develop a New York production-weighted aggregate emission rate, the annual contribution of each basin and gas type to total gas consumed in New York was calculated (Table 2). State-level data on conventional and shale gas production (Table 3) (EIA, 2020b) were assigned to a basin using an estimate of the state's total natural gas-producing area covered by the basin (Table 4) (NETL, 2019a, Exhibit 2-2). Data on shale gas production were further divided to separate the portion estimated to be from tight gas plays (Table 5 and Table 6) (EIA, 2020c).

Emissions data sourced from the NETL natural gas model are representative of 2016 conditions. To account for changes in emission factors (EFs) over time for venting, flaring, and acid gas removal activity at relevant stages of the fuel cycle, scaling factors derived from the U.S. Greenhouse Gas Inventory (GHGI) (Table 7) (U.S. EPA, 2019) were applied to the NETL Natural Gas model (NETL, 2019) through the addition of stage-specific parameters. The scaling factors represent changes in annual emission rates (CH_4 per unit gas produced) as compared to 2016 rates (NETL model baseline year). A parameter was also added to adjust for transmission distance to the New York boundary. Conventional extraction of natural gas in the Appalachian basin is not characterized in the NETL model, as wells in that region often do not meet the GHGRP emissions reporting threshold of 25,000 tonnes CO2e per year per facility (100-yr IPCC AR4 GWP) (NETL, 2019a). Given the importance of the Appalachian basin to natural gas consumed in New York, our approach included a method to assess conventional gas production emissions from this basin. Production emissions for this basin were sourced from the NYSERDA Oil and Gas Methane Inventory (OGMI) (NYSERDA, 2019). The default EFs in the NYSERDA OGMI reflect the 25th percentile of measured site-level production emissions from conventional wells in Southwest Appalachia (Omara et al., 2016).

Our approach assessed two boundary conditions for the natural gas supply chain: out-of-state emissions only and well-to-burner emissions. Out-of-state emissions are representative of natural gas production, gathering and boosting (G&B), processing, and transmission outside of the state up to the NY border. Well-to-burner is inclusive of out-of-state emissions and also includes in-state natural gas production, G&B, processing, as well as in-state transmission, distribution, and post-meter leakage. In-state related emissions were sourced from the NYSERDA OGMI. EIA data on receipts and deliveries (EIA, 2019b) were used to determine the percentage of gas received by New York that is consumed in-state (Table 8 and Table 9) so as not to account for emissions of gas only passing through the state. This ratio was applied to the in-state transmission EF from the NYSERDA OGMI (Table 10). In-state emissions were also taken from the NYSERDA OGMI, which provides a range of EFs that are categorized into lower bound, midpoint, and upper bound for each fuel cycle stage. The OGMI also contains a default inventory which is informed by a mixture of underlying parameter EFs. In-state emissions are representative of in-state production (default inventory - EFs taken from 25th percentile of Omara data), G&B/processing (midpoint EFs), distribution (upper bound EFs), and end-use emissions (default inventory).

Three sensitivities were performed on the original starting point approach (Approach 1) to analyze the effect of various parameters on the overall emission rate (Table 11, Table 12). Several literature sources have highlighted the disproportionate emissions contribution from low-producing conventional wells, known as super-emitters (Alverez et al. 2018, Schneising et al. 2020, Zavala-Araiza et al. 2015). Approach 2 builds on Approach 1 by applying Omara-derived midpoint EFs (50th percentile of measured site-level production emissions from conventional wells in Southwest Appalachia) to Appalachian and in-state conventional gas production. All other parameters from Approach 1 remain unchanged. Approach 3 builds on Approach 2 by applying shale-specific EFs from Omara (2016) to Appalachian shale gas production. Approach 4 builds on Approach 3 by applying Alvarez et al. (2018) top-down scaling factors to other basins and stages (note top-down scaling factors were not applied to Appalachian conventional or shale because those already use adjusted EFs). For in-state emissions, the upper bound G&B/processing and transmission EFs were applied.

3. Coal

The NETL Coal Model (NETL, 2020), which profiles coal extraction through coal cleaning, is used to model coal production emissions. Underground coal mine methane emissions are closely linked with coal production (Kholod et al., 2020), so changes in emissions would be expected as coal production activity varies over time. To account for annual changes in emissions, GHGI-derived basin level scaling factors were applied to the model (Table 13) (U.S. EPA, 2019). The scaling factors represent changes in annual emission rates (CH_4 emitted per unit coal produced) as compared to the baseline 2016 rates, which are representative of NETL model conditions. All other mining emissions are assumed unchanged. Data on coal source basins and production amounts destined for NY power plants were sourced from EIA Form 923 (EIA, 2020a) (Table 14) and were used to calculate an annual production-weighted contribution to coal consumed in NY from each basin.

Coal transport was modeled using EIA's Annual Coal Distribution Reports (EIA, 2019a), which specify the amount of coal delivered to NY via a particular transport mode. These data were used to calculate a yearly contribution by transport mode that was then applied to the production data from EIA Form 923. Emission factors for different transport modes were sourced from transportation unit processes from NETL**.**

4. Petroleum

Petroleum fuel cycle emission factors and data on the domestic and international share of crude oil (Table 15) are sourced from Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) Model 2019 (ANL, 2019). Emissions associated with crude extraction and transport in GREET are allocated to petroleum products on an energy basis, while emissions from petroleum refining use default GREET parameters. GREET 2019 does not provide data for waxes and lubricants; research by Sun et al. (2019) to characterize emission for refinery products at U.S. refineries was used to scale refining emissions for waxes and lubricants from GREET residual oil data.

Transportation emissions are modeled in GREET, with modification of parameters to reflect transport distances to the NY boundary. The source of petroleum products to NY is estimated based on data from EIA reflecting international imports and shipments between Petroleum Administration for Defense Districts (PADDs) (Table 16).

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Upstream Fuel Cycle Approach for Natural Gas, Coal, and Petroleum – Tabular Data

Natural Gas Tables (1-12)

Table 1. Natural Gas Basins, Gas Types and Transmission Distances

Basin	Gas Type	Transmission Distance to NY Boundary (mi)
Anadarko	Conventional Shale Tight	1,320
Appalachian	Conventional Shale	315
Arkoma	Conventional Shale	1,170
East Texas	Conventional Shale Tight	1,420
Gulf	Conventional Shale Tight	1,420

Table 2. 2018 Production-Weighted Contribution to Total Natural Gas Consumed in New York

Technobasin	Contribution (%)
Anadarko Conventional	3%
Anadarko Shale	5%
Anadarko Tight	1%
Appalachian Conventional	2%
Appalachian Shale	55%
Arkoma Conventional	2%
Arkoma Shale	5%
East Texas Conventional	2%
East Texas Shale	5%
East Texas Tight	1%
Gulf Conventional	5%
Gulf Shale	14%
Gulf Tight	0%
New York In-State	1%

*Values do not add up to 100% due to rounding

Table 3. 2018 EIA Raw Natural Gas Production Data

State	Conventional (MMCF)	Shale/Tight (MMCF)
Texas	2,272,680	6,533,829
Oklahoma	1,259,491	2,063,870
Arkansas	82,904	505,306
Ohio	48,582	2,340,757
Pennsylvania	157,683	6,077,554
West Virginia	101,496	1,588,444
Virginia	17,149	284

Source: EIA Natural Gas Gross Withdrawals and Production

Table 4. Percent of State Natural Gas Production Area by Basin

State	Anadarko Basin	Appalachian Basin	Arkoma Basin	East Texas Basin	Gulf Basin
Texas	0%	0%	0%	15%	40%
Oklahoma	50%	0%	25%	0%	0%
Arkansas	0%	0%	65%	0%	0%
Ohio	0%	100%	0%	0%	0%
Pennsylvania	0%	100%	0%	0%	0%
West Virginia	0%	100%	0%	0%	0%
Virginia	0%	100%	0%	0%	0%

*Percentages were estimated using Exhibit 2-2 from the NETL Natural Gas report (2019)

Exhibit 2-2. Basins that Account for Majority of U.S. Natural Gas Production

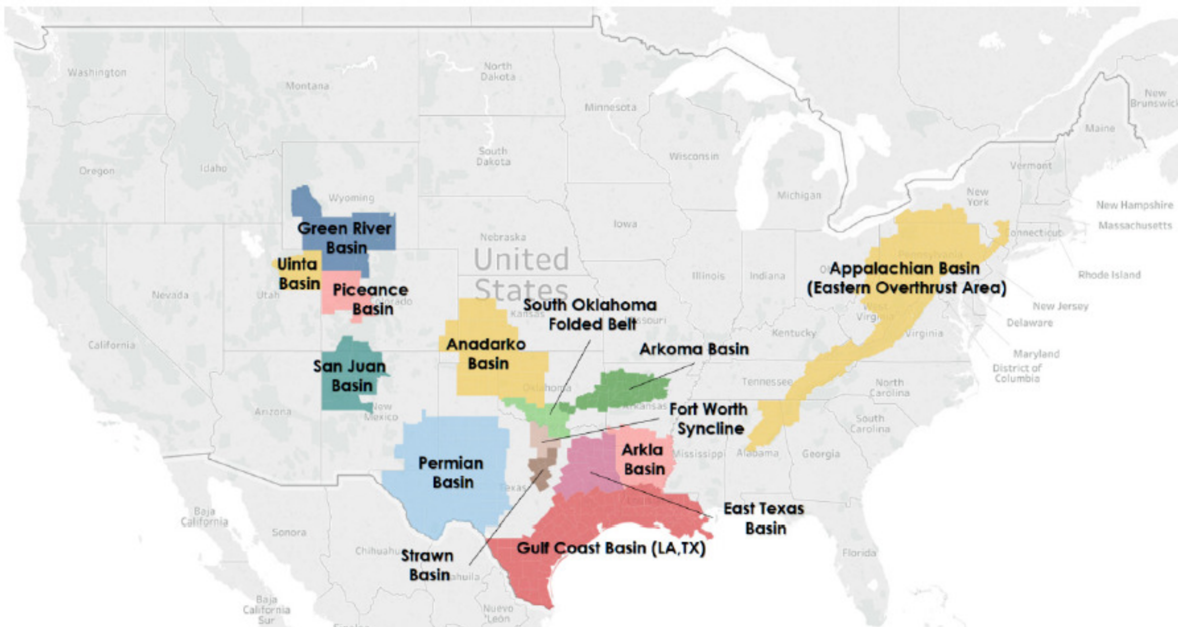

Table 5. 2018 Shale/Tight Gas National Split

Gas Type	Contribution (%)
Shale	85%
Tight	15%

Source: EIA Annual Energy Outlook 2020

Table 6. 2018 EIA Raw Natural Gas Production Data (expansion of Table 4 using Table 5 data)

State	Conventional (MMCF)	Shale (MMCF)	Tight (MMCF)
Texas	2,272,680	5,584,246	949,583
Oklahoma	1,259,491	1,763,921	299,949
Arkansas	82,904	431,868	73,438
Ohio	48,582	2,000,567	340,190
Pennsylvania	157,683	5,194,283	883,271
West Virginia	101,496	1,357,590	230,854
Virginia	17,149	243	41

Table 7. 2017[+] Natural Gas Scaling Factor Example Calculation - Gathering & Boosting

	2017	2016	2017 Scaling Factor
G&B Net Emissions (kt CH_4)[^]	2,380	2,295	
U.S. Gas Production (MMCF)[*]	33,292,113	32,591,578	
kt CH_4/MMCF	**7.15E-05**	**7.04E-05**	**1.02**

Scaling Factor Calculation: 7.15E-05 / 7.04E-05 = 1.02

[+]2017 calculations shown because at time of inventory development, GHGI 2018 data was unavailable and 2018 data points were extrapolated by ERG

[^]Emissions taken from GHGI Annex 3.6

[*]Production data taken from https://www.eia.gov/dnav/ng/hist/n9010us2a.htm

Table 8. 2018 NY Natural Gas Production, Receipts, & Deliveries

	Amount (MMCF)
In-State Production	9,985
Receipts	2,869,577
Deliveries	1,222,400
Net (Receipts-Deliveries)	**1,647,177**

Source: EIA Natural Gas Annual Reports

Table 9. 2018 Allocation of Natural Gas Passing through NY

	Amount (MMCF)
Net + In-State Production	1,657,162
Receipts + In-State Production	2,879,562
% Allocated to NY	**58%**

Table 10. 2018 Calculation of In-State Transmission Rate

	Percentage
In-State Transmission Rate (kg CH_4/kg nat gas)	0.27%
% Gas allocated to NY	58%
Adjusted Transmission Rate (kg CH_4/kg nat gas)	**0.16%**

Calculation: 58% x 0.27% = 0.16%

Table 11. Calculated Emission Rates by Basin

Basin	Out of State Emissions Rate (2018)				Well-to-Burner Emissions Rate (2018)			
	Starting Point	Omara Mid-point Conventional	Omara Mid-point Conventional + Shale	All-in	Starting Point	Omara Mid-point Conventional	Omara Mid-point Conventional + Shale	All-in
Anadarko Conventional	1.75%	1.75%	1.75%	3.16%	2.15%	2.15%	2.15%	3.64%
Anadarko Shale	0.98%	0.98%	0.98%	1.50%	1.39%	1.39%	1.39%	1.99%
Anadarko Tight	1.40%	1.40%	1.40%	2.41%	1.80%	1.80%	1.80%	2.89%
Appalachian Conventional	6.93%	15.59%	15.59%	15.74%	7.33%	15.99%	15.99%	16.23%
Appalachian Shale	0.67%	0.67%	1.09%	1.25%	1.07%	1.07%	1.50%	1.74%
Arkoma Conventional	2.81%	2.81%	2.81%	5.41%	3.21%	3.21%	3.21%	5.89%
Arkoma Shale	1.25%	1.25%	1.25%	2.02%	1.65%	1.65%	1.65%	2.51%
East Texas Conventional	0.98%	0.98%	0.98%	1.49%	1.38%	1.38%	1.38%	1.98%
East Texas Shale	1.09%	1.09%	1.09%	1.74%	1.49%	1.49%	1.49%	2.22%
East Texas Tight	1.28%	1.28%	1.28%	2.15%	1.68%	1.68%	1.68%	2.63%
Gulf Conventional	1.62%	1.62%	1.62%	2.95%	2.02%	2.02%	2.02%	3.43%
Gulf Shale	1.68%	1.68%	1.68%	3.07%	2.08%	2.08%	2.08%	3.56%
Gulf Tight	0.87%	0.87%	0.87%	1.32%	1.28%	1.28%	1.28%	1.81%
New York In-State	-	-	-	-	8.06%	17.47%	17.47%	17.57%
New York Aggregate	1.12%	1.28%	1.51%	2.08%	1.58%	1.81%	2.04%	2.69%

Table 12. Summary Table of Nat Gas Approaches and Parameters

	Parameters	2018 Scenarios: Starting Point (Approach 1)	Omara Mid-point Conventional (Approach 2)	Omara Mid-point Conventional + Shale	All-in (Approach 4)	Parameter Notes	Data Source
	NETL NG Model; emissions by technobasin	x	x	x	x	Gas Types: Conventional, Shale, Tight	NETL. (2018), EIA. (2020).
	Addition of App Conv production emission rate [Low][1]	x				Prod. emission rate: 6.4% [4.1% - 9.4%]	Omara et al. (2016).
	Addition of App Conv production emission rate [Mid]		x	x	x	Prod. emission rate: 15.0% [7.2% - 25.4%]	Omara et al. (2016).
	NETL NG App Shale production emission rate	x	x			Prod. emission rate: 0.12%	NETL. (2018).
	Revision to App Shale production emission rate			x	x	Prod. emission rate: 0.54%	Omara et al. (2016).
	Top-down scaling factor				x	Top-down scaling factors [Production: 2.17 (+117%); Gathering & Boosting: 1.13 (+13%); Processing: 1.16 (+16%); out-of-state Transmission: 1.38 (+ 38%)][2]	Alvarez et al. (2018).
Out-of-State	**NY Aggregate Out-of-State Emission Rate (%)**	**1.12%**	**1.28%**	**1.51%**	**2.08%**	Representative of production, gathering & boosting, processing, and out-of-state transmission	
Out-of-State	**Emission Factor (lbs CH4/mmBtu)**	**0.46**	**0.52**	**0.62**	**0.85**		
Out-of-State	**Emission Factor (lbs CO2/mmBtu)**	**26.2**	**26.2**	**26.2**	**26.2**		
Out-of-State	**Emission Factor (lbs N2O/mmBtu)**	**3.00E-04**	**3.00E-04**	**3.00E-04**	**3.00E-04**		
Out-of-State	**Emission Factor (lbs CO2e/mmBtu)**	**64.7**	**70.0**	**78.0**	**97.5**	AR5-20yr	
	In-state production emissions [Low]	x				Prod. emission rate 7.1% [4.1% - 9.4%][3]	Omara et al. (2016) within NYSERDA (2021).
	In-state production emissions [Mid]		x	x	x	Prod. emission rate: 16.5% [7.2% - 25.4%]	Omara et al. (2016) within NYSERDA (2021).
	In-state gathering and boosting emissions [Mid]	x	x	x		Prod. emission rate: 0.60%	NYSERDA. (2021).
	In-state gathering and boosting emissions [High]				x	Prod. emission rate: 0.63%	NYSERDA. (2021).
	In-state transmission emissions [Mid]	x	x	x		Emission rate: 0.16% [4]	NYSERDA. (2021).
	In-state transmission emissions [High]				x	Emission rate: 0.24% [4]	NYSERDA. (2021).
	In-state distribution emissions	x	x	x	x	Emission rate: 0.25% (includes end-use emissions)	NYSERDA. (2021).
In-state	**Emission Factor (lbs CH4/mmBtu)**						
In-state	*Upstream*	**0.02**	**0.05**	**0.05**	**0.05**		
In-state	*Midstream*	**0.06**	**0.06**	**0.06**	**0.10**		
In-state	*Distribution*	**0.10**	**0.10**	**0.10**	**0.10**		
In-state	**Emission Factor (lbs CO2/mmBtu)**	**0.05**	**0.05**	**0.05**	**0.05**		
In-state	**Emission Factor (lbs N2O/mmBtu)**	**1.15E-07**	**1.15E-07**	**1.15E-07**	**1.15E-07**		
Well-to-Burner	**NY Aggregate Well-to-Burner Emission Rate (%)**	**1.58%**	**1.81%**	**2.04%**	**2.69%**	Representative of out-of-state emissions, in-state transmission, distribution, and end-use	
Well-to-Burner	**Emission Factor (lbs CH4/mmBtu)**	**0.64**	**0.74**	**0.83**	**1.10**		
Well-to-Burner	**Emission Factor (lbs CO2/mmBtu)**	**26.2**	**26.2**	**26.2**	**26.2**		
Well-to-Burner	**Emission Factor (lbs N2O/mmBtu)**	**3.00E-04**	**3.00E-04**	**3.00E-04**	**3.00E-04**		
Well-to-Burner	**Emission Factor (lbs CO2e/mmBtu)**	**80.5**	**88.2**	**96.2**	**118.4**	AR5-20yr	

Emission Factors and Emission Rates are on the basis natural gas consumed in NY, unless identified as a production emission rate

Notes:

1. Use of 'Low', 'Mid', and 'High' reflect selection of emission factors consistent with those used in the NYS Oil and Gas Sector Methane Emissions Inventory
2. Top-down scaling factors applied from production through out-of-state transmission for all basins and stages except Appalachian production
   Example calculation: If original production emission rate is 1.34%, the top-down adjusted rate is 1.34% * 2.17 = **2.91%.** This is representative of an increase of 117% compared to the original rate.
3. The underlying production emissions rates for conventional gas in Appalachia and New York state are the same (reflecting Omara et al. 2016), but account for differences in high- vs. low-producing conventional gas wells.
4. In-state transmission emissions are allocated between gas consumed in state and gas transmitted through the state based on pipeline receipts. The emissions rate shown here reflects only the emissions for gas consumed in state.

Sources

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Coal Tables (13-14)

Table 13. 2017 Underground Coal Mine Methane Scaling Factors

Basin	CH4 Emissions (ktons)		Coal Extracted (thousand short		2017/2016
	2017	2016	2017	2016	Scaling Factor
Central Appalachia	304	254	46,052	39,800	1.03
Illinois	259	334	80,855	76,577	0.73
Northern Appalachia	760	757	97,742	94,685	0.97
Western Interior	60	20	343	421	3.68
Black Warrior	193	192	10,491	7,434	0.71
Western	51	71	37,647	33,189	0.63
National	1,368	1,629	273,130	252,106	

Source: GHGI (2019), Table A-128, A-129, A-130

Table 14. 2018 Coal Consumption and Transport Modes by Basin

Basin and Mine Type	Short tons	Truck	Rail	River	Great Lakes	Ocean
Northern Appalachia, Surface	13,888	8%	92%	0%	0%	0%
Northern Appalachia, Underground	26,662	8%	92%	0%	0%	0%
Central Appalachia, Underground	152,222	1%	99%	0%	0%	0%
Northern Appalachia, Underground	163,361	1%	99%	0%	0%	0%

Source: EIA 923; EIA Coal Distribution Report

Petroleum Tables (15-16)

Table 15. Source of Crude at U.S. Refineries (GREET)

Year	2018
U.S. Domestic	64.4%
Canada (Oil Sands)	8.0%
Canada (Conv. Crude)	9.0%
Mexico	3.1%
Middle East	6.8%
Latin America	5.2%
Africa	2.2%
Others	1.4%

Table 16. Share and Distance for Transportation of Petroleum Products to New York State in 2018

Origin	Mode	Distance (mi)	Amount (MMbls)	Source
PADD 3	Barge	2200	1,260	a
PADD 3	Pipeline	1410	198,020	b
PADD 1	Pipeline	40	283,780	b
Africa, Middle East, Eur	Tanker	4920	86,797	c
Caribbean, South Amer	Tanker	2125	27,059	c
Canada	Pipeline	2000	22,063	c

Sources

a) PADD 1B Receipts by Tanker and Barge from PADD 3 of Total Petroleum Products, allocated to NY based on data reported in NYSERDA, Petroleum Infrastructure Study, 2006

b) Pipeline capacity to NY, split between PADDs based on Movement between PADDs (EIA)

c) EIA Company Level Imports by month, https://www.eia.gov/petroleum/imports/companylevel/archive/