Upstream Fuel Cycle Emission Approaches and Sensitivities: Methodologies and Results

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Eastern Research Group

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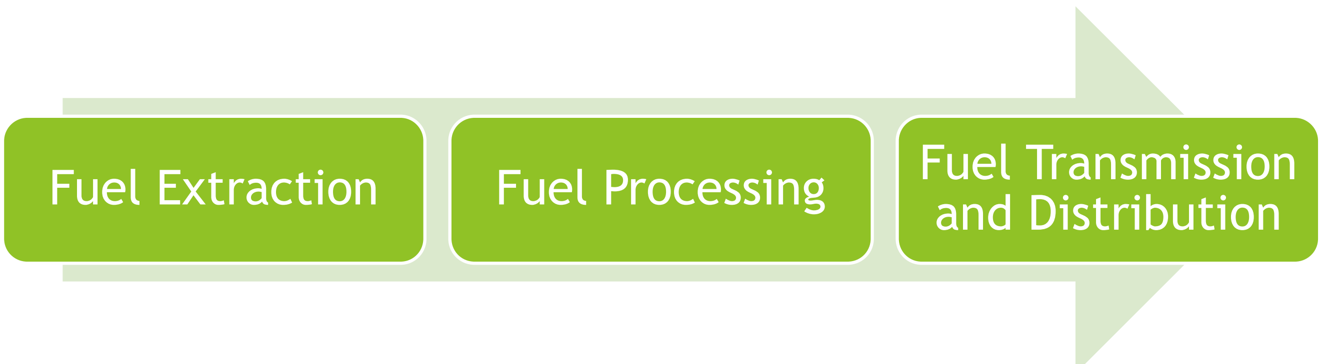
Outline

- Project Background
- Natural Gas Modeling (out-of-state & well-to-burner)
  - Sensitivities for natural gas modeling supported by recent research
- Coal Modeling
- Petroleum Modeling
- Summary of Upstream Fuel Cycle Emission Factors

Project Background

- New York State's 2019 Climate Leadership and Community Protection Act requires accounting of GHG emissions associated with the extraction and transmission of fossil fuels imported into the state using a 20-year time horizon
- This requirement necessitates using upstream fossil fuel cycle factor data that cover extraction, processing and transmission/distribution of natural gas, coal and petroleum into the state



Starting Point Natural Gas Approach

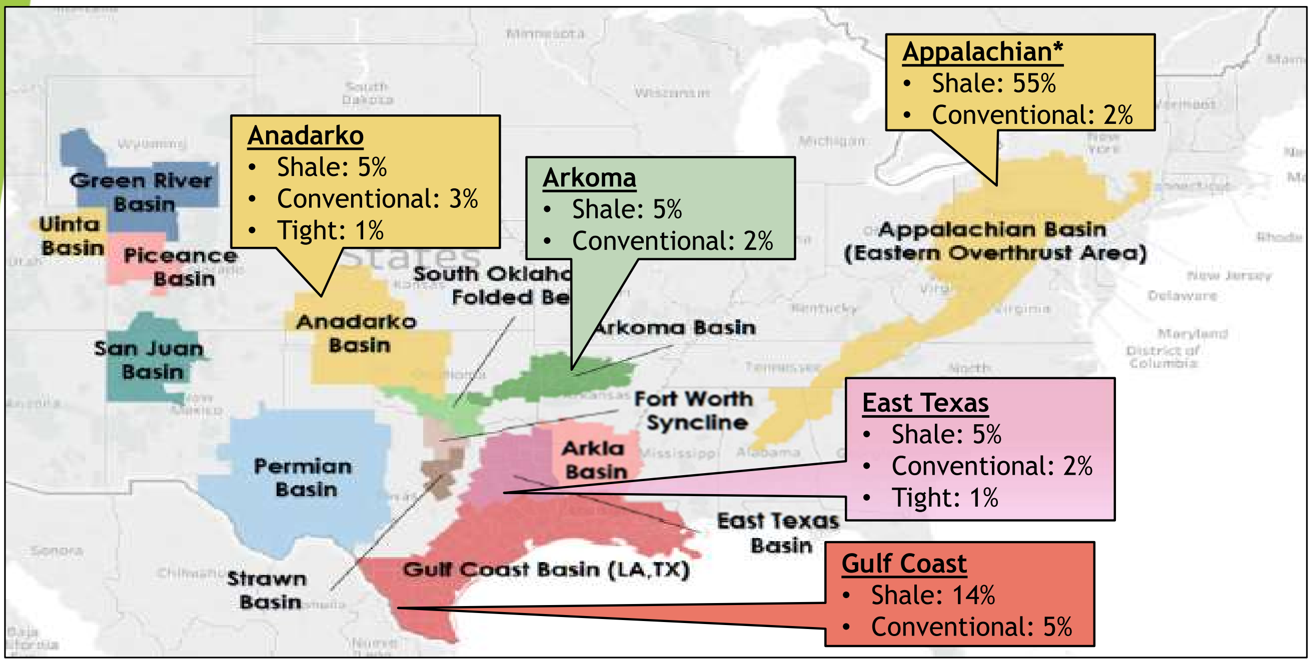
- Leverages National Energy Technology Laboratory (NETL) natural gas model (NETL, 2019b) and U.S. Greenhouse Gas Inventory (GHGI) emissions data:
  - Emission rates for natural gas basins are sourced from the NETL natural gas model, which reflects 2016 data
  - Emissions are adjusted throughout the time series using national scaling factors by stage based on reported emissions in the GHGI
- Natural gas consumed in New York is sourced from several U.S. production basins, with contributions from each basin modeled proportional to annual production (EIA, 2020d)
- Includes emissions from all relevant gas types: Conventional, Tight, Shale

EIA. (2020d). Natural Gas Gross Withdrawals and Production (1936-2019). U.S. Energy Information Administration (EIA).

NETL. (2019). Life Cycle Analysis of Natural Gas Extraction and Power Generation. Pittsburgh, PA: National Energy Technology Laboratory.

NYSERDA. (2019). *New York State Oil and Gas Sector Methane Emissions Inventory.* New York State Energy Research and Development Authority (NYSERDA).

Natural Gas Boundaries and Production-Weighted Contributions to Total Natural Gas Consumed in New York in 2018



*Excluding in-state New York production, which accounts for 1% of production.
Source: Exhibit 2-2 from the NETL Natural Gas report (NETL, 2019a)

Out-of-State Boundaries

Boundaries cover the following stages of the natural gas supply chain up to the New York State border:

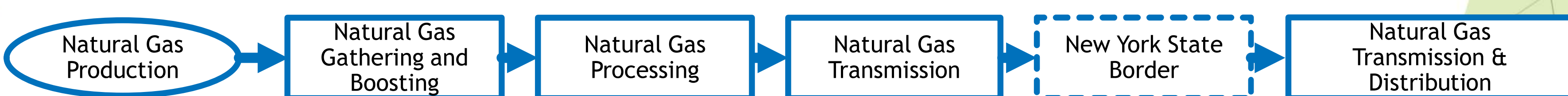
- Production
- Gathering & Boosting
- Processing
- Transmission

Well-to-Burner Boundaries

Well-to-burner includes out-of-state boundaries and incorporates stages included in NYSERDA's in-state inventory to develop a well-to-burner perspective.

- Production
- Gathering & Boosting
- Processing
- Transmission
- Distribution (includes past-the-meter to end-user)

NYSERDA. (2019). *New York State Oil and Gas Sector Methane Emissions Inventory*. New York State Energy Research and Development Authority (NYSERDA).



NETL. (2019a). *Life Cycle Analysis of Natural Gas Extraction and Power Generation, DOE/NETL-2019/2093*. National Energy Technology Laboratory (NETL).

Parameters for Evaluation – NG Modeling

The purpose of the sensitivities is to evaluate the effect of various parameters on the methane emissions rate for natural gas consumed in New York State.
The following parameters were analyzed:

1. Appalachian Emission Factors
   - Revisions to emission factors for production of Conventional and Shale gas in the Appalachian basin (Omara et al., 2016)

2. Stage-Level Emission Factor Adjustments
   - Revisions to emission factors for production in other basins and other natural gas stages (gathering and boosting and transmission) based on recent literature addressing discrepancies in methane emission estimates between inventory data and emissions monitoring (Alvarez et al., 2018)

- Use of these revised emission factors results in a higher methane emission rate for gas consumed in New York as compared to the starting point approach

Alvarez et al. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. Science 361, 186-188.

Omara et al. (2016). Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate. Environmental Science & Technology, 52(21), 12915-12925.

Parameter: Appalachian Emission Factors

NETL natural gas model does not include emissions data for the production of Appalachian conventional natural gas, so an alternate data source is used:

- Omara et al. (2016) provides *production* emissions estimates from PA and WV for both shale and conventional gas wells
- These Omara estimates are used in the New York In-State Oil & Gas Inventory (NYSERDA, 2019) to define a low (default), mid, and high emission rate for sensitivity:

Conventional Gas	Low EF	Mid EF
Low-Producing Wells	9.4%	25.4%
High-Producing Wells	4.1%	7.2%

Low: 25th percentile *Mid: Median*

- Omara-derived emission factors for Appalachian shale gas production (0.54%) are also applied in a sensitivity to assess the uncertainty in this data point based on empirically-derived emissions. These emission factors replace NETL model data.

NYSERDA. (2019). *New York State Oil and Gas Sector Methane Emissions Inventory.* New York State Energy Research and Development Authority (NYSERDA).

Omara et al. (2016). Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate. Environmental Science & Technology, 52(21), 12915-12925.

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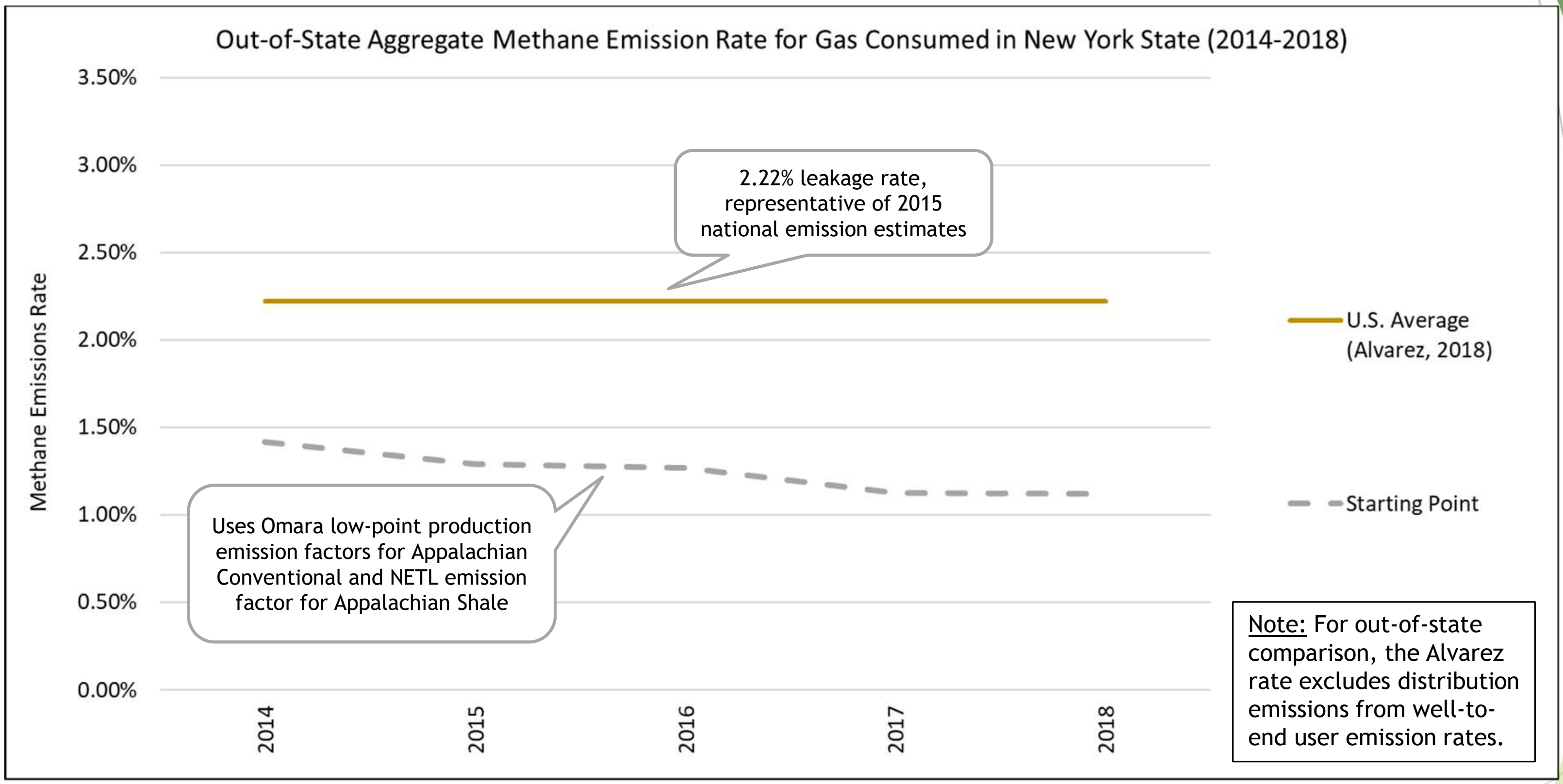
Parameter: Stage-Level Emission Factor Adjustments

- Alvarez et al. (2018) assesses national methane emissions from the U.S. natural gas supply chain using facility-level estimates and validates these estimates with aircraft observations (2015 data)
- Estimates national methane emissions to be ~60% higher than reported by U.S. GHGI, as the U.S. GHGI does not account for emissions released during abnormal operating conditions
- Enables stage-level emission factor adjustments to reconcile discrepancy between U.S. GHGI and the study's facility-level estimates
- These adjustments are applied in a sensitivity to mitigate the potential for under-accounting emissions
  - Adjustment for Production applied to non-Appalachian basins only
  - Adjustment for Gathering and Boosting, Processing, and Transmission and Storage applied to all basins

Alvarez et al. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. Science 361, 186-188.

Out-of-State Starting Point Approach Results



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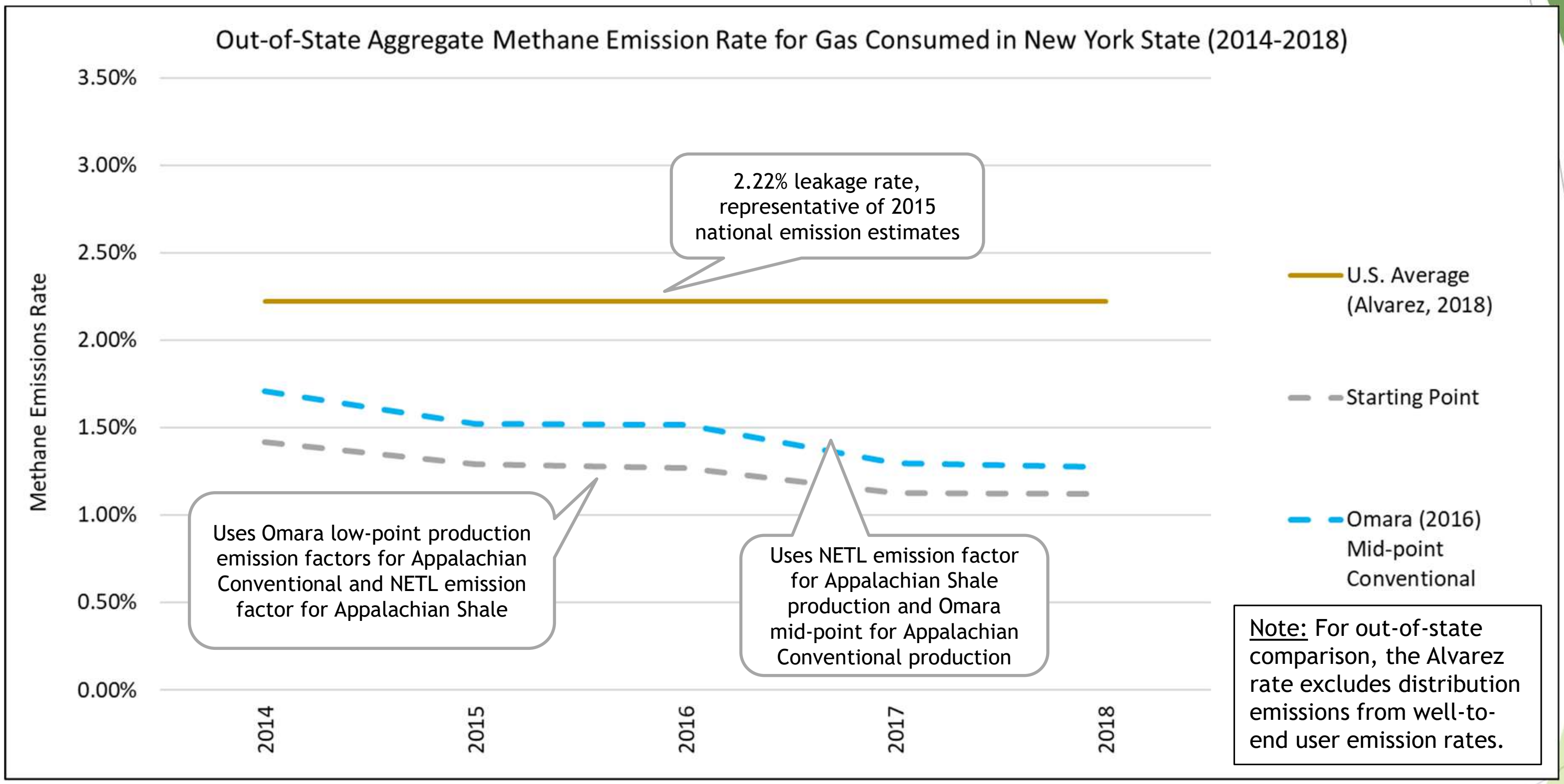
Appalachian Conventional Midpoint Emission Factors



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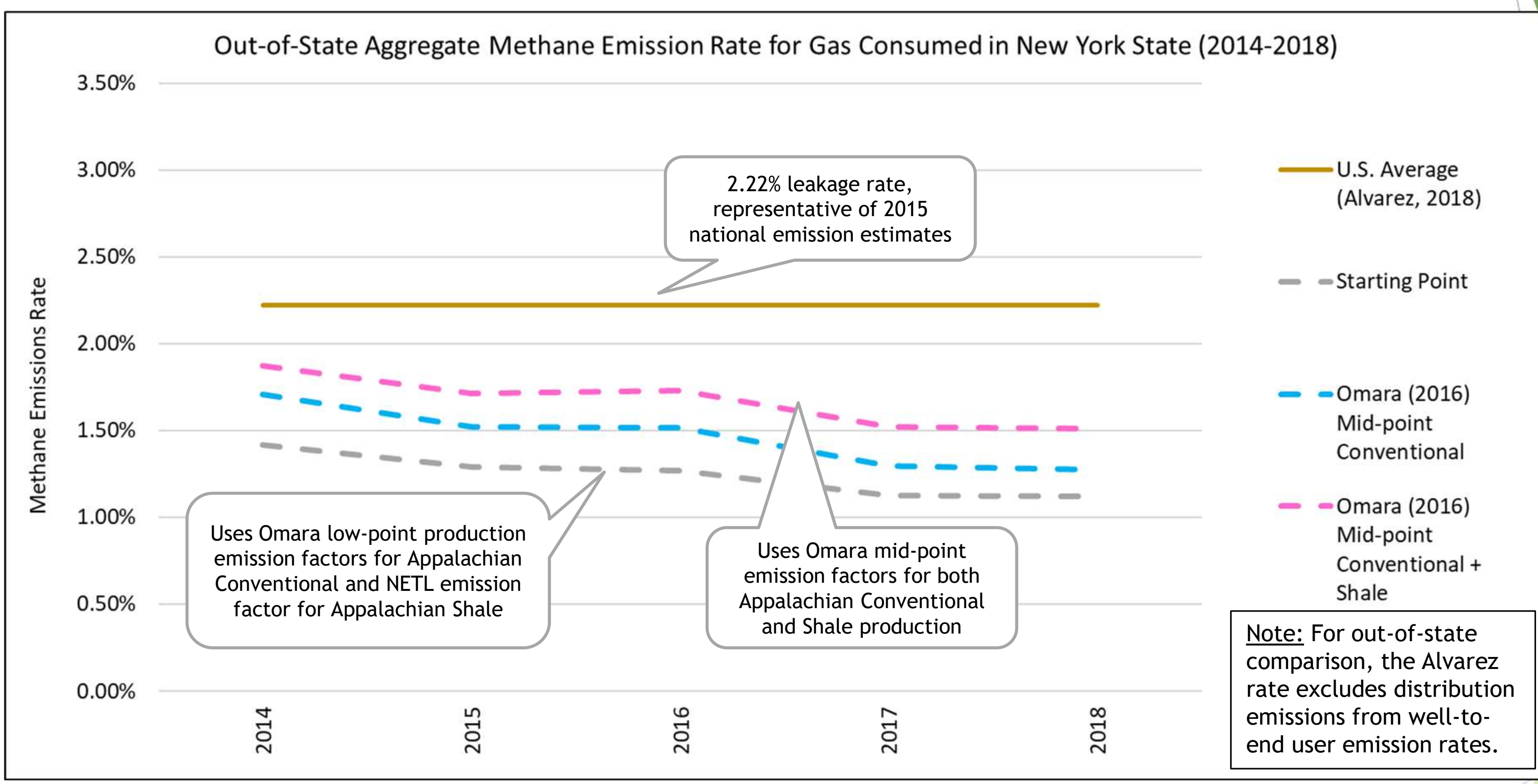
Appalachian Conventional & Shale Midpoint Emission Factors



Alvarez et al. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. Science 361, 186-188.

Omara et al. (2016). Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate. Environmental Science & Technology, 52(21), 12915-12925.

Out-of-State All-in Sensitivity

1. Emission factors for Appalachian Conventional & Shale production: Omara (2016) Mid-point
2. Adjustment applied to Production in other basins (Alvarez et al., 2018)
3. Adjustments applied to Gathering and Boosting, Processing, and Transmission and Storage (Alvarez et al., 2018)

Note: Adjustments are applied similarly to recommendation by Burnham (2019) used in GREET

Alvarez et al. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. Science 361, 186-188.

Burnham, A. (2019). *Updated Natural Gas Pathways in the GREET1_2019 Model*. Argonne National Laboratory.

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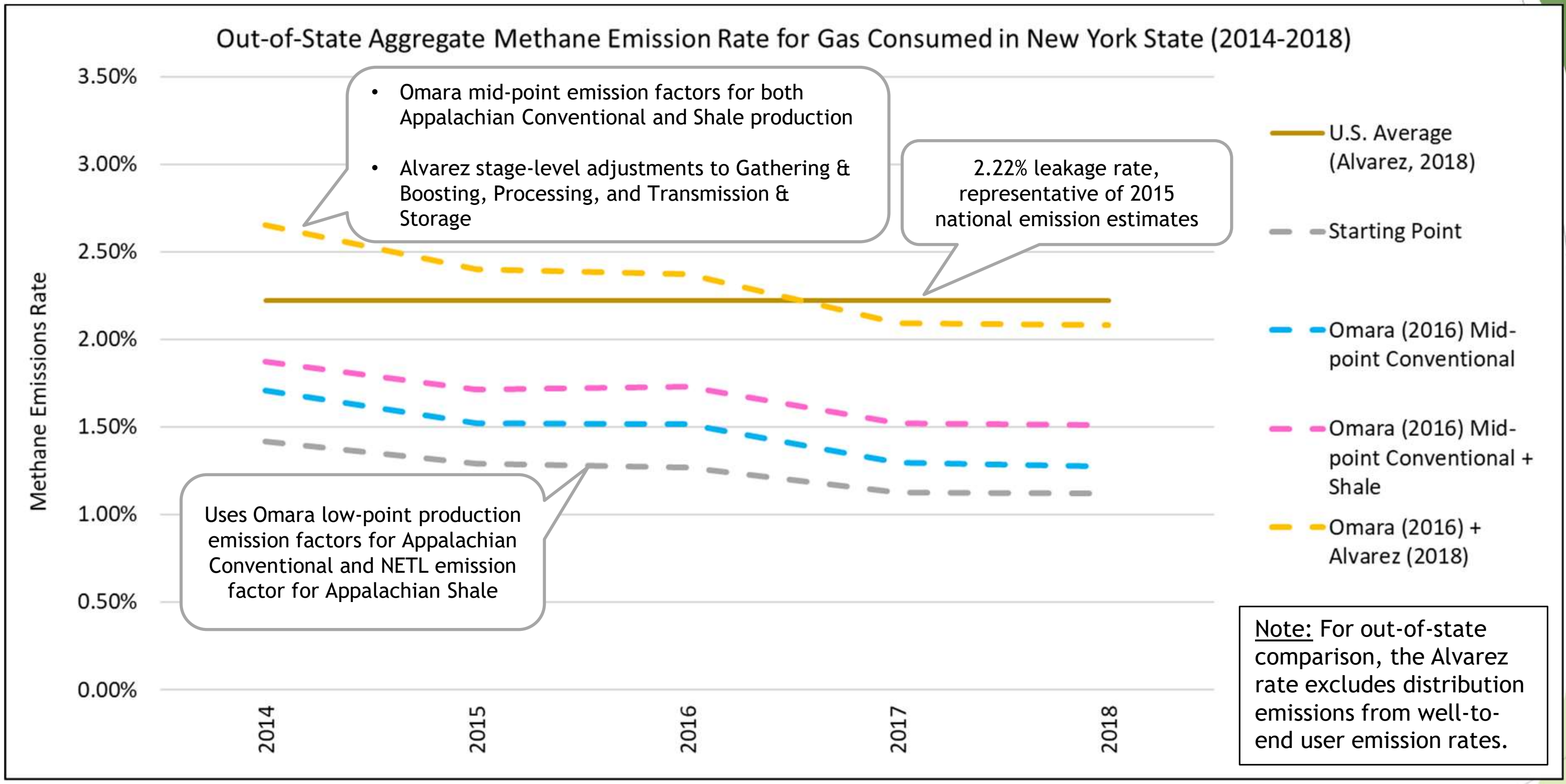

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Emission Rates Across Approaches & Sensitivities: Out-of-State Emission Rates for Natural Gas Consumed in New York State

Scenarios	2018
U.S. Average (Alvarez, 2018)	2.22%
Omara (2016) + Alvarez (2018)	2.08%
Omara (2016) Mid-point Conventional + Shale	1.51%
Omara (2016) Mid-point Conventional	1.28%
Starting Point	1.12%

*In descending order of 2018 emission rates

Uses Omara low-point production emission factors for Appalachian Conventional and NETL emission factor for Appalachian Shale

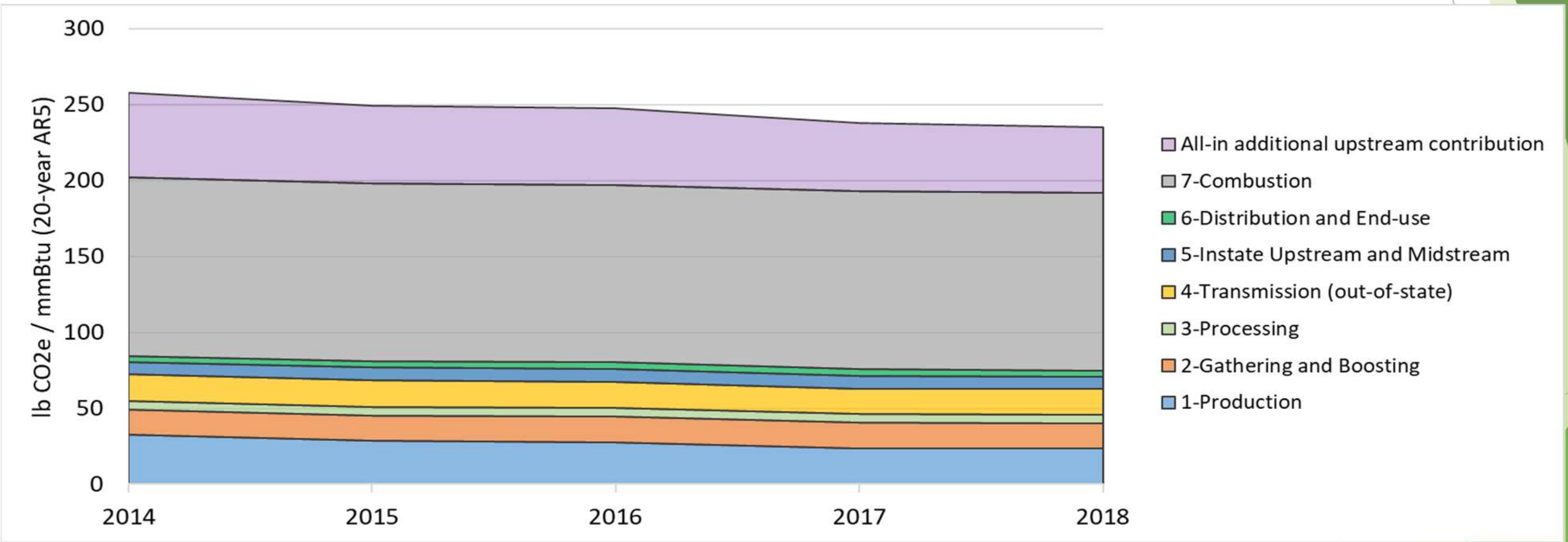
Alvarez et al. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. Science 361, 186-188.

Omara et al. (2016). Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate. Environmental Science & Technology, 52(21), 12915-12925.

Emissions by Stage by Fuel

Natural Gas Well-to-Combustion Emissions

- In-state production, gathering & boosting, processing, transmission, distribution, and end-use emissions are sourced from NYSERDA's Oil & Gas Methane Inventory (NYSERDA, 2019)



Top of natural gas range reflects the Omara (2016) + Alvarez (2018) sensitivity

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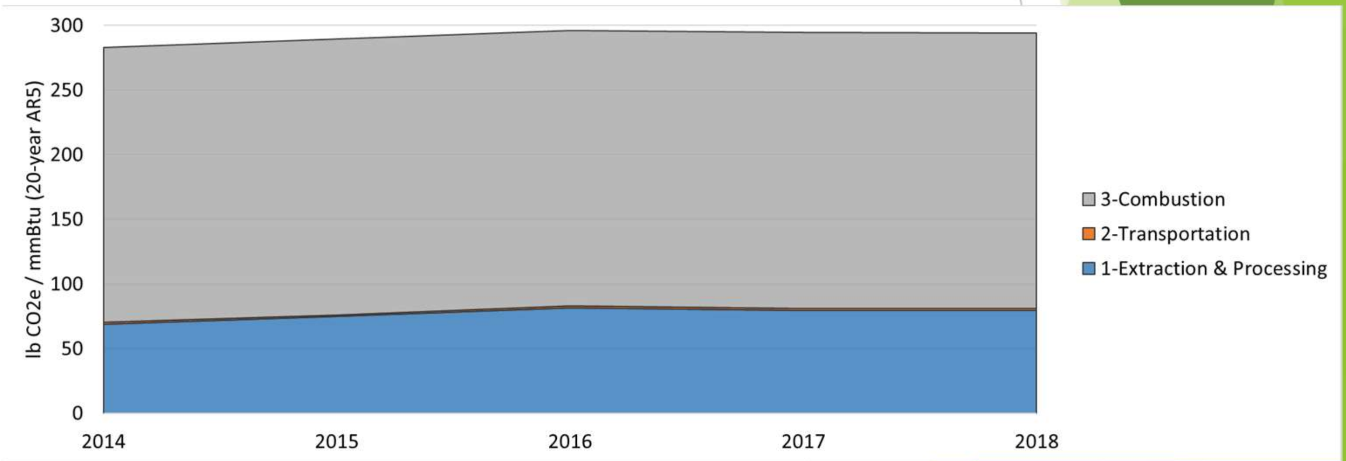
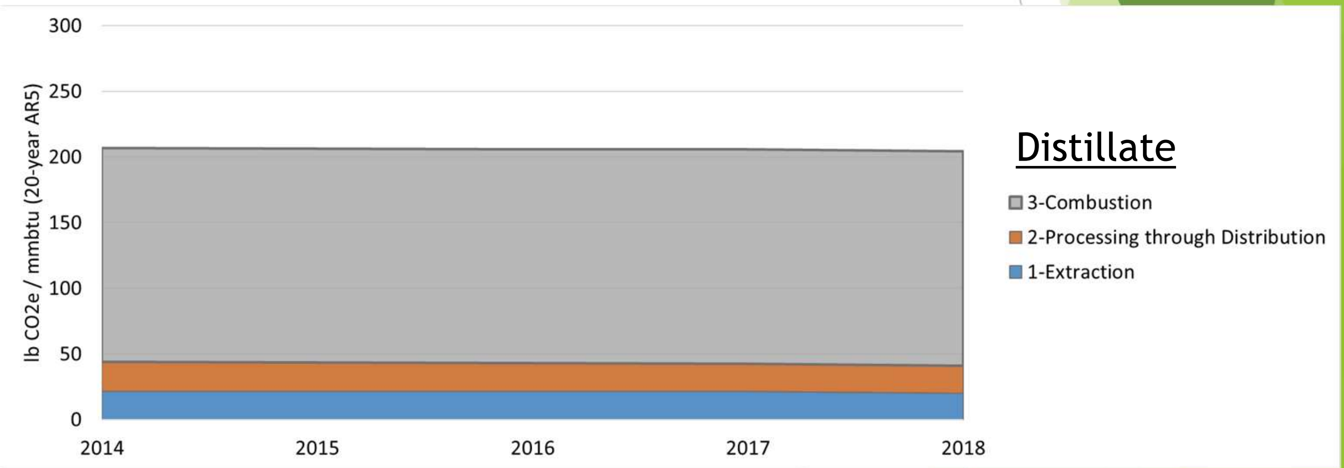
Coal Inventory Method

- Uses NETL Coal Model (NETL, 2020) to calculate basin- and mine-specific EFs
- Applies U.S. GHG Inventory data to develop historical scaling factors
- Applies FERC Form 423 and IEA Form 923 data to determine coal basins serving NYS by year (FERC, 2011; EIA, 2020a)
  - Quantity of coal received by NY plants, as well as coal source state and mine type
- Coal transport data (mode) taken from EIA's Annual Coal Distribution Report (EIA, 2019a)
- Coal transport emission factors sourced from NETL Transportation Unit Processes



Petroleum Inventory Method

- Based on GREET 2019 Model and uses GREET time series information (Argonne National Laboratory, 2019)
- The ethanol content of gasoline in New York is based on MOVES (EPA, 2020)
- Data on annual petroleum imports via tanker and Canadian pipeline are sourced from the EIA's company-level imports archives (EIA, 2020b; EIA, 2020c)
- Data on domestic, interstate petroleum movement are sourced from EIA's Movement by Pipeline and Refinery and Blender Net Production datasets (EIA, 2020b; EIA, 2020c)



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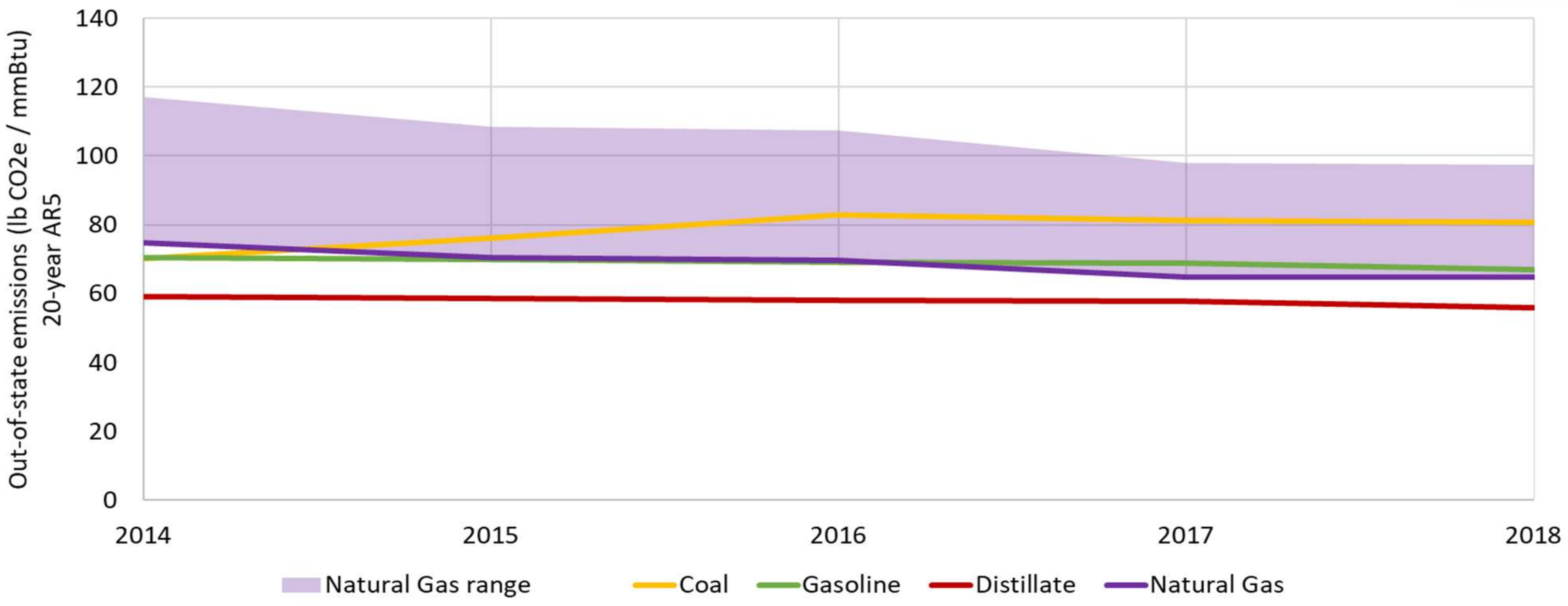
Summary of Fuel Cycle Emission Factors
Out-of-state emissions



- Data reflect extraction, processing, and transportation to the state border
- Top of natural gas range reflects the Omara + Alvarez sensitivity
- Gasoline and Distillate reflect unblended fossil-based streams
- GWP based on AR5, 20-year

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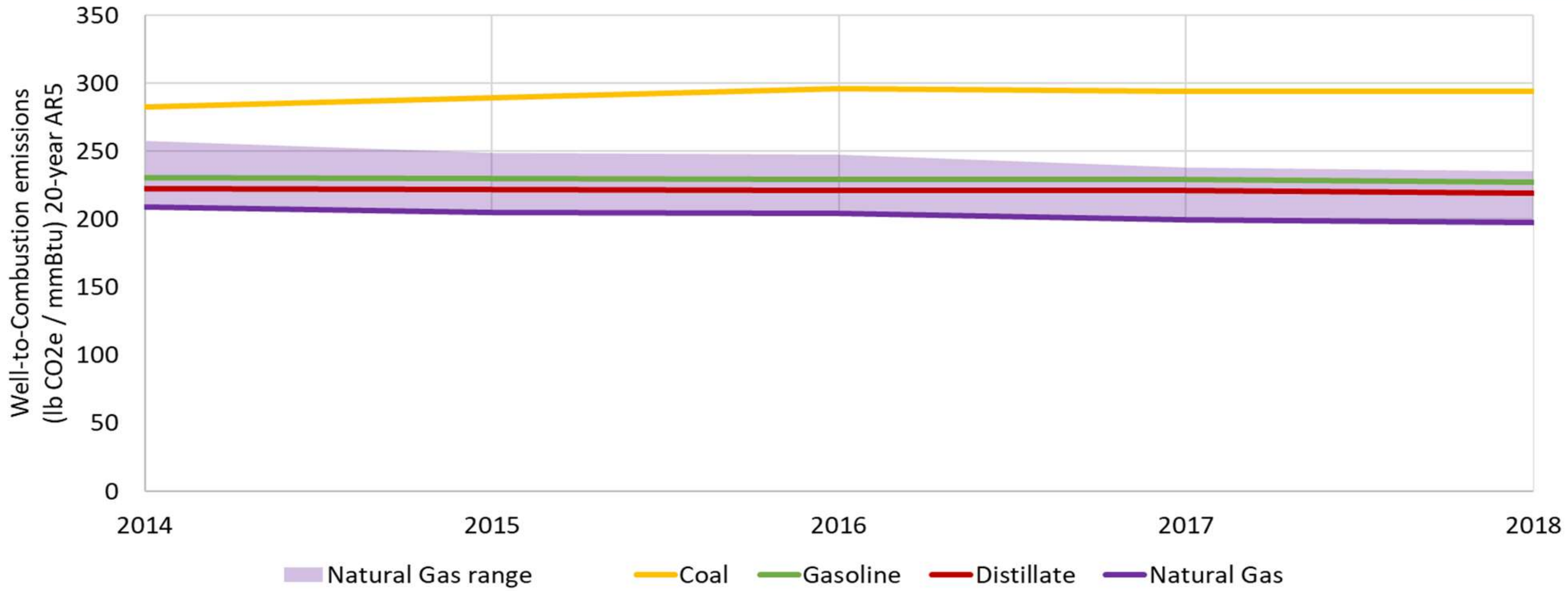
Summary of Fuel Cycle Emission Factors Well-to-combustion emissions



- Data reflect extraction, processing, and combustion emissions (i.e., well to combustion)
- Top of natural gas range reflects the Omara + Alvarez sensitivity
- Gasoline and Distillate reflect unblended fossil-based streams and use combustion emissions factors from EPA-EIA
- GWP based on AR5, 20-year

References

- Alvarez et al. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. Science 361, 186-188.
- Argonne National Laboratory. (2019). *The Greenhouse gases, Regulated Emissions, and Energy use in Transportation Model (GREET)*. Argonne, IL. Retrieved from https://greet.es.anl.gov/
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- EIA. (2019b). Natural Gas Annual (2018). U.S. Energy Information Administration (EIA). Retrieved from https://www.eia.gov/naturalgas/annual/archive/2018/.
- EIA. (2020a). Electricity: Form EIA-923 (2001-2020). U.S. Energy Information Administration (EIA).
- EIA. (2020b). *Movements by Pipeline between PAD Districts*. Washington, DC: U.S. Energy Information Administration. Retrieved from https://www.eia.gov/dnav/pet/pet_move_pipe_a_EPP0_LMV_mbbl_a.htm
- EIA. (2020c). *Movements by Tanker and Barge between PAD Districts*. Washington, DC: U.S. Energy Information Administration. Retrieved from https://www.eia.gov/dnav/pet/pet_move_tb_dc_R10-R30_mbbl_a.htm
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- NETL. (2019b). NETL OpenLCA Natural Gas Extraction Model. Easter Research Group (ERG).
- NETL. (2020). NETL OpenLCA Coal Extraction Model. Eastern Research Group (ERG).
- NYSERDA. (2019). *New York State Oil and Gas Sector Methane Emissions Inventory.* New York State Energy Research and Development Authority (NYSERDA). Retrieved from https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/NYS-oil-and-gas-sector-methane-emissions-inventory.pdf
- Omara et al. (2016). Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate. Environmental Science & Technology, 52(21), 12915-12925.

Thank You

Supporting Slides

- Out-of-state vs. in-state emissions calculation methodology
- Out-of-state vs. in-state transmission modeling methodology
- Well-to-burner natural gas sensitivity graphs
  - Starting approach
  - Appalachian conventional midpoint emission factors
  - Appalachian conventional & shale midpoint emission factors
  - All-In
- Comparative table of well-to-burner emission rates across approaches and sensitivities
- Summary table of fuel cycle emission factors

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Out-of-State vs. In-State Calculation Approach

- Out-of-State
  - Emissions from natural gas production, gathering & boosting, processing, and transmission are primarily sourced from emissions modeling developed by the National Energy Technology Laboratory (NETL)
  - The NETL model does not characterize emissions from Appalachian Conventional gas; instead, production emissions were sourced from Omara et al. (2016) data, which provides emissions measurements from natural gas producing sites in Southwestern Appalachia
- In-State
  - Production, gathering & boosting, processing, transmission, distribution, and end-use emissions are sourced from NYSERDA's Oil & Gas Methane Inventory

Omara et al. (2016). Methane emissions from natural gas production sites in the United States: Data synthesis and national estimate. Environmental Science & Technology, 52(21), 12915-12925.

Out-of-State vs. In-State Transmission

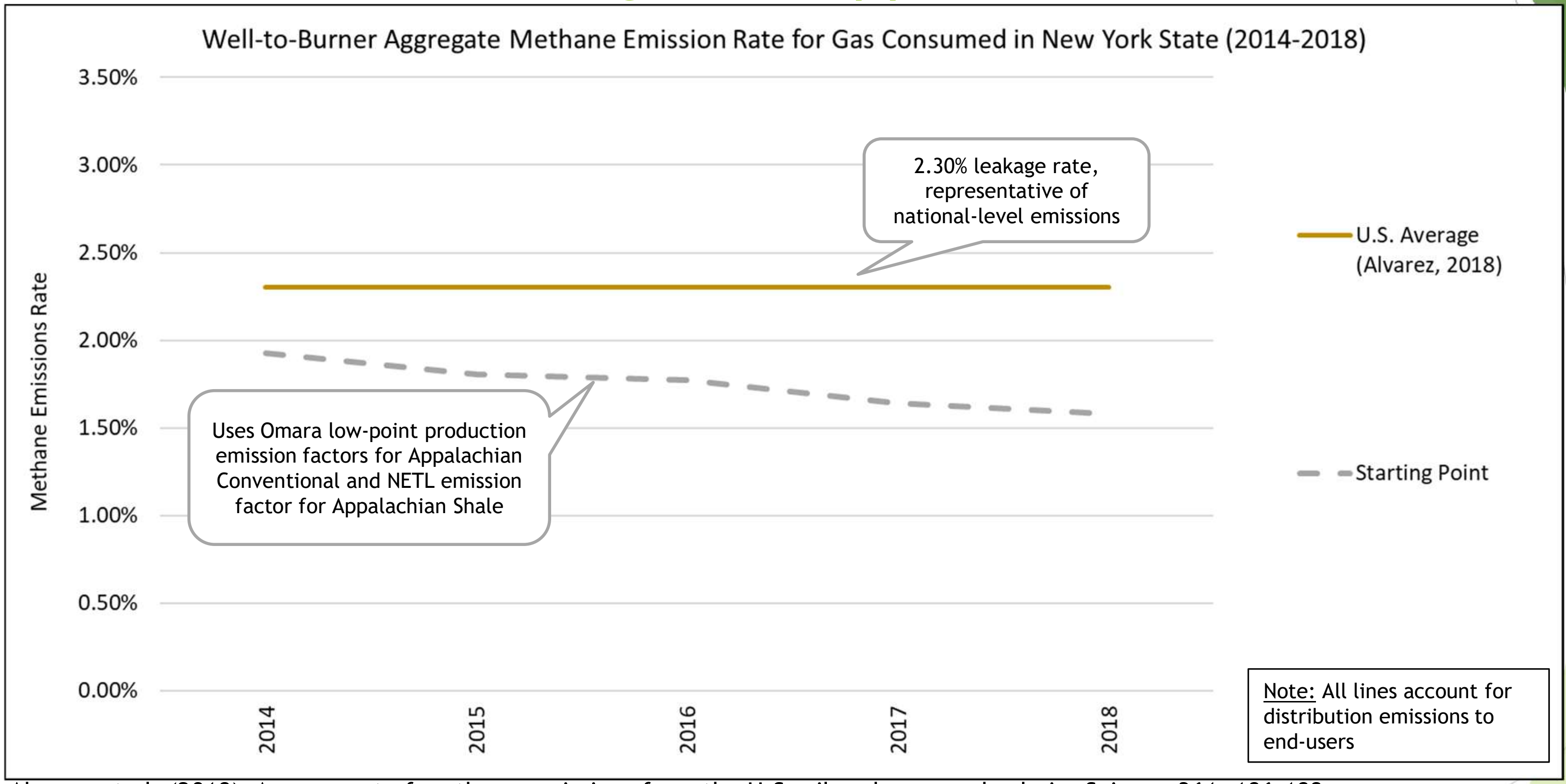
- Out-of-State
  - Transmission emissions sourced from NETL model
  - Adjustments were made to transmission in model to account for distance to New York State boundary
- In-State
  - Excludes emissions from gas that is passing through the state*
  - EIA data on receipts and deliveries (EIA, 2019b) were used to determine the percentage of gas received by New York that is consumed in-state (58%). This percentage is multiplied by the in-state transmission emissions rate provided in the NYSERDA Oil & Gas Methane Inventory.

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

*Emissions from gas passing through New York State to other jurisdictions are captured as part of statewide greenhouse gas emissions accounting

EIA. (2019b). Natural Gas Annual (2018). U.S. Energy Information Administration (EIA). Retrieved from https://www.eia.gov/naturalgas/annual/archive/2018/.

Well-to-Burner Starting Point Approach Results



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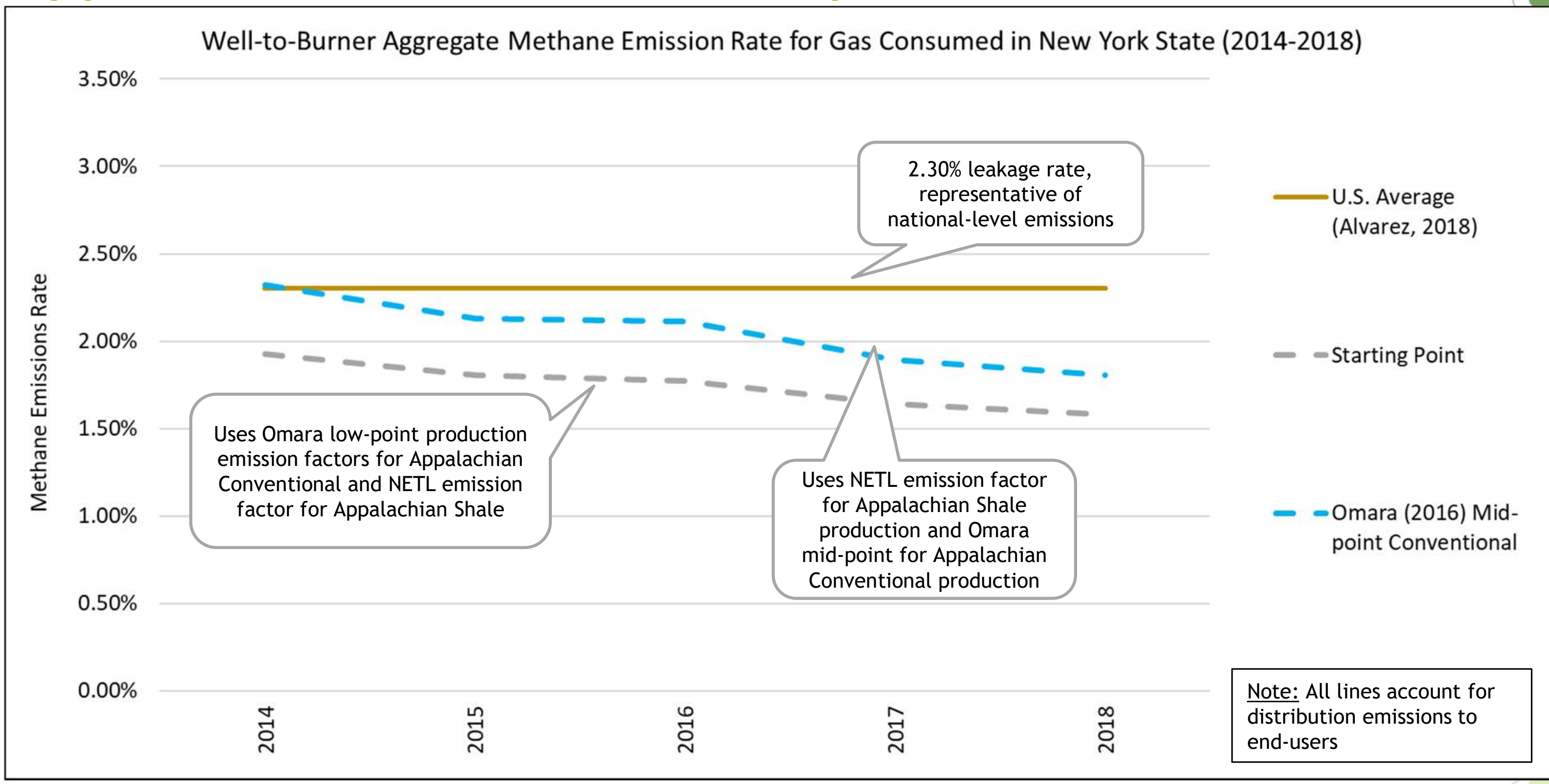
Appalachian Conventional Midpoint Emission Factors



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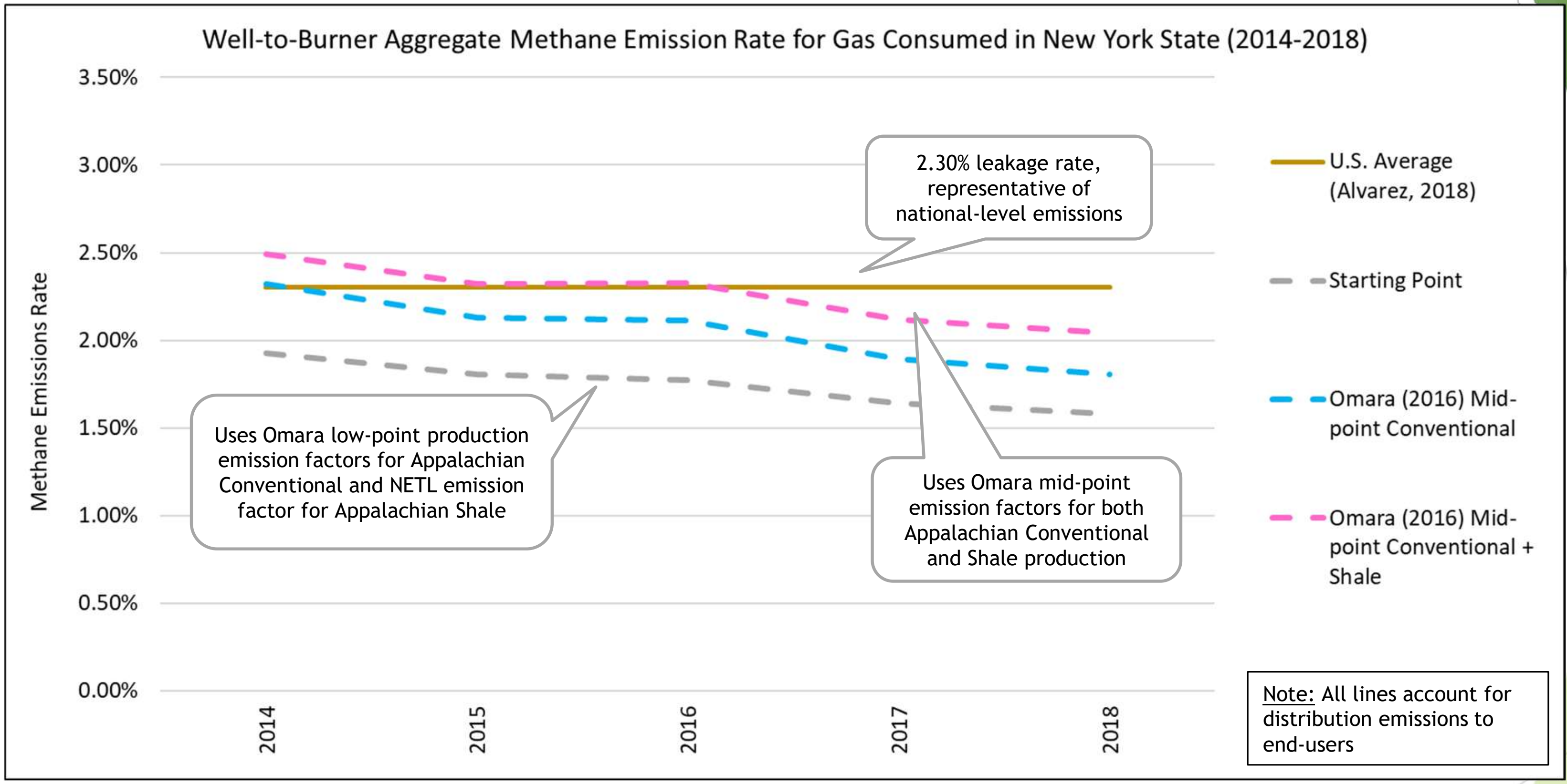
Appalachian Conventional & Shale Midpoint Emission Factors



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Well-to-Burner All-in Sensitivity

1. Emission factors for Appalachian Conventional & Shale production: Omara Mid-point (Omara et al., 2016)
2. Adjustment applied to Production in other basins (Alvarez et al., 2018)
3. Adjustments applied to Gathering and Boosting, Processing, and Transmission and Storage (Alvarez et al., 2018)
4. New York State upper bound Gathering and Boosting, Processing, In-State Transmission, Distribution, and End-Use loss rate (NYSERDA, 2019)

Note: Adjustments are applied similarly to recommendation by Burnham (2019) used in GREET

Alvarez et al. (2018). Assessment of methane emissions from the U.S. oil and gas supply chain. Science 361, 186-188.

Burnham, A. (2019). *Updated Natural Gas Pathways in the GREET1_2019 Model*. Argonne National Laboratory.

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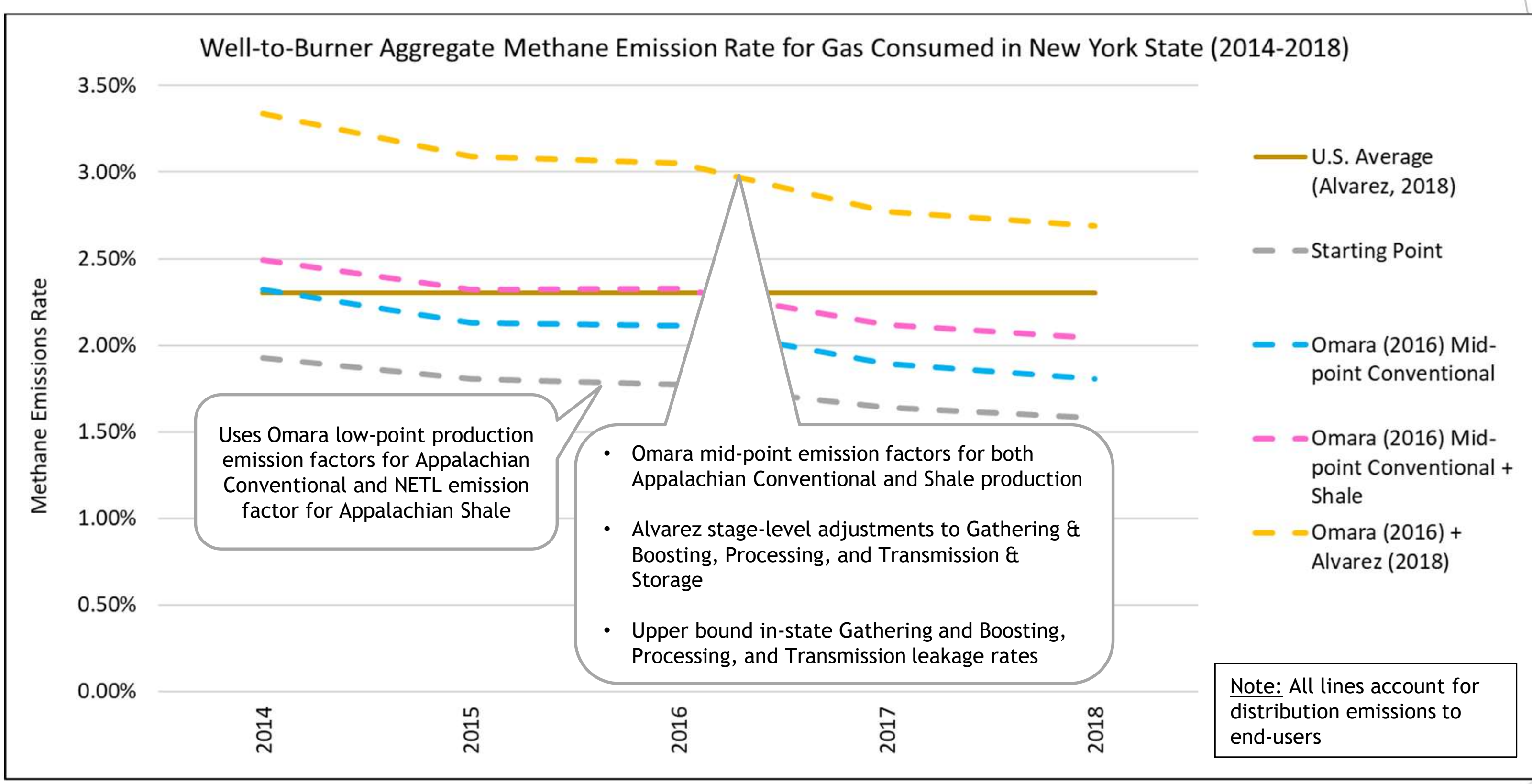
All-in Sensitivity



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Emission Rates Across Approaches & Sensitivities: Well-to-Burner Emission Rates for Natural Gas Consumed in New York State

Scenarios	2018
Omara (2016) + Alvarez (2018)	2.69%
U.S. Average (Alvarez, 2018)	2.30%
Omara (2016) Mid-point Conventional + Shale	2.04%
Omara (2016) Mid-point Conventional	1.81%
Starting Point	1.58%

*In descending order of 2018 emission rates

Uses Omara low-point production emission factors for Appalachian Conventional and NETL emission factor for Appalachian Shale

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Summary of Fuel Cycle Emission Factors

Stage	Pollutant	Coal	Distillate	Gasoline	A	B	C	D
					Natural gas			
Out of state	CO_2	7.23	33.4	43.2	26.2	26.2	26.2	26.2
	CH_4	73.5	22.4	23.6	38.4	43.7	51.7	71.2
	N_2O	0.06	0.15	0.19	0.08	0.08	0.08	0.08
In-state	CO_2				0.05	0.05	0.05	0.05
	CH_4				15.7	18.1	18.1	20.9
	N_2O				3.02E-5	3.02E-5	3.02E-5	3.02E-5
Combustion	CO_2	210.9	163.0	157.0	116.6	116.6	116.6	116.6
	CH_4	0.14	0.06	1.40	0.20	0.20	0.20	0.20
	N_2O	2.2	0.06	1.9	0.18	0.18	0.18	0.18
Total	CO_2e	294.0	219.1	227.3	197.5	205.2	213.2	235.4

Natural Gas Approaches
A - Starting Point

B - Omara Mid-point Conventional

C - Omara Mid-point Conventional + Shale

D - Omara (2016) + Alvarez (2018)

All values in lb CO_2e/mmBtu (AR5-20 yr)

- Data reflect extraction, processing, and combustion emissions (i.e., well-to-combustion)
- Out of state emissions reflect extraction, processing, and transportation to the state border
- In-state emissions for natural gas include all stages occurring within the state boundaries
- In-state emissions for coal and petroleum fuels are not explicitly included in this table due to modeling limitations but are not expected to contribute significantly to total; these emissions would be accounted for in the NY State GHG inventory in other sectors
- Gasoline and Distillate reflect unblended fossil-based streams and use combustion emissions factors from EPA-EIA
- GWP based on AR5, 20-year: CO_2-1, CH_4-84, N_2O-264

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