Economic Drivers of Emissions from Upstream Oil and Gas

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Salata Methane Retreat
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Upstream oil and gas emissions are an economic outcome

- Unlike most pollutants, methane emissions impose a **private cost** as well as a social one
  - Methane is the primary component of natural gas
  - Emissions represent unsold product — billions of dollars in lost revenue
- Oil and gas producers make emissions decisions in response to economic variables:
  - Value of gas
  - Cost of gas transport
  - Emissions abatement costs
- Effectively regulating emissions from this sector requires understanding producer incentives

Incentives to Emit in Upstream Oil and Gas

with Toren Fronsdal

Incentives to Emit in Upstream Oil and Gas

Goal: Understand how market incentives, constraints shape emissions from upstream oil and gas

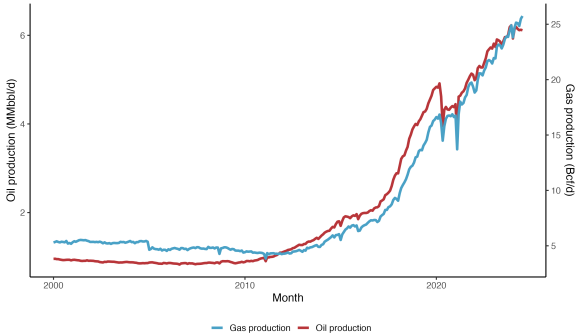
Context: Permian Basin. Largest oil/gas basin in U.S., source of $\approx$ 4 Tg of methane emissions per year

Our approach:

- Leverage weekly methane emissions estimates from Varon et al. (2026)
- Focus on two decision margins:
  1. How many wells to drill
  2. What share of gas production to sell vs. vent or flare
- Build a model of producer emissions decisions, incorporating key institutional features
- Estimate the impact of counterfactuals including a methane tax, pipeline congestion alleviation

Fact 1: In the Permian, gas is a byproduct of oil

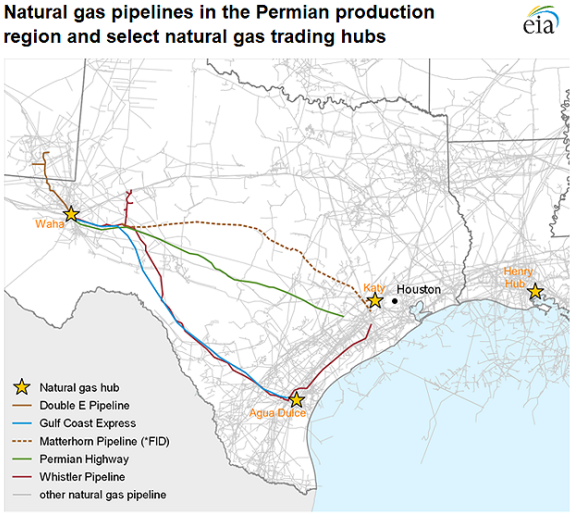
- Shale revolution → large increases in gas and oil production since 2010
- Permian wells produce both gas and oil; gas-to-oil ratios vary by subbasin
- Across subbasins, oil is the dominant economic driver
- Even the basin's top gas producers earn 70–95% of revenues from oil



Permian oil and gas production

Fact 2: Takeaway constraints create incentives to flare

- Gas can only reach market via pipeline
- Rapid production growth has strained pipeline capacity
- Waha basis (Henry−Waha spread) captures transport costs
- Pipeline congestion → higher transport costs → flaring becomes more attractive



Gas spot prices

Model overview

Firms make **two main decisions** that lead to methane emissions:

1. **How much gas to market vs. flare/vent**
   - Unmarketed gas is flared/vented $\Rightarrow$ methane emissions
   - Marketing gas is more profitable when gas prices are high, transport costs are low
   - Emissions from flaring/venting should **decrease** in gas prices and **increase** in transport costs

2. **Whether to drill new wells**
   - More wells $\Longrightarrow$ more emissions: drilling and normal well operations both generate methane
   - Producers drill more when value of new well's expected production increases (gas, oil prices $\uparrow$)
   - Emissions from drilling should **increase** in gas and oil prices

Total emissions should **increase** in transport costs and **increase** in oil prices.

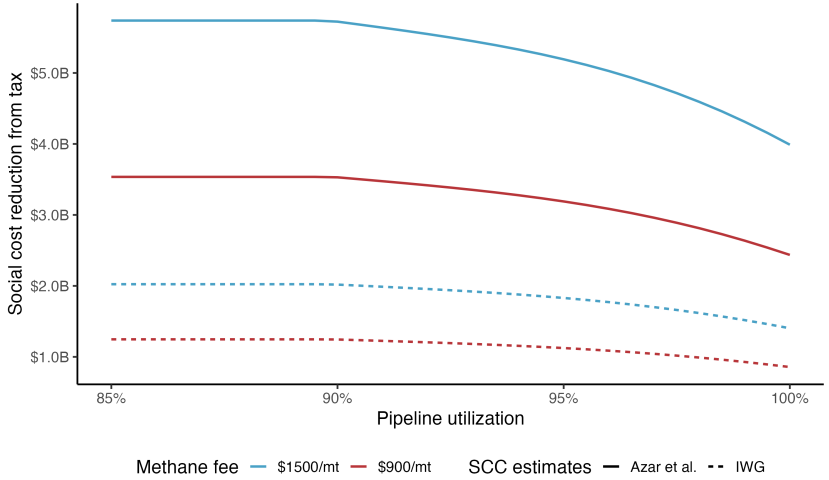
The relationship between total emissions and gas prices is theoretically ambiguous!

Methane emissions respond to Waha basis, gas and oil prices

	Dependent variable:		
	log(Emissions)		
	All	Midland	Delaware
	(1)	(2)	(3)
Henry Hub Price	−0.021*	−0.010	−0.053***
	(0.011)	(0.014)	(0.012)
Waha Basis	0.082***	0.107***	0.093***
	(0.019)	(0.025)	(0.020)
Cushing Spot Oil Price	0.003***	0.004**	0.006***
	(0.001)	(0.002)	(0.001)
Heating Degree Days (TX)	0.016***	0.014***	0.013***
	(0.002)	(0.003)	(0.002)
Year (2018 = 0)	0.013	0.022	−0.026*
	(0.013)	(0.017)	(0.014)
Constant	1.008***	−0.166**	0.122*
	(0.066)	(0.084)	(0.070)
Observations	258	258	258
R^2	0.249	0.185	0.256
Adjusted R^2	0.234	0.169	0.241
Residual Std. Error (df = 252)	0.226	0.289	0.239
F Statistic (df = 5; 252)	16.678***	11.468***	17.310***

Specification

Policy: Methane fee



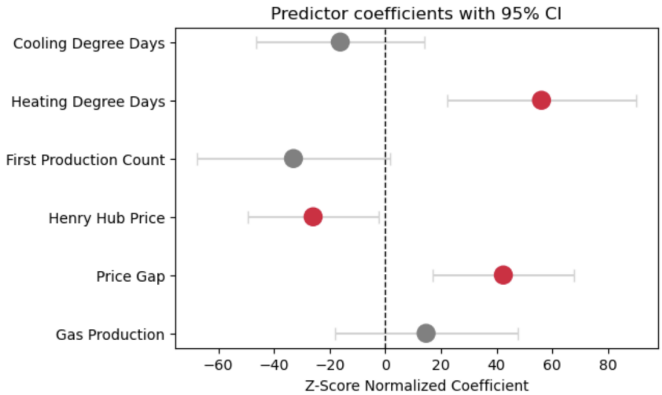
Full results | Pipeline expansion

Near Real-Time Emissions Monitoring in the Appalachian Basin with the Integrated Methane Inversion

with Lucas Estrada, Kaia Thomas, Daniel Jacob, et al.

Results suggest pipeline congestion matters in the Appalachian

3 Month Rolling Mean Emissions Jan 2022-Dec 2025



Environmental Regulation with Cross-Border Spillovers

with Toren Fronsdal

Environmental Regulation with Cross-Border Spillovers

Goal: Understand how state methane regulations affect emissions both in- and out-of-state

Context: Delaware sub-basin of the Permian Basin (crosses NM/TX state border)

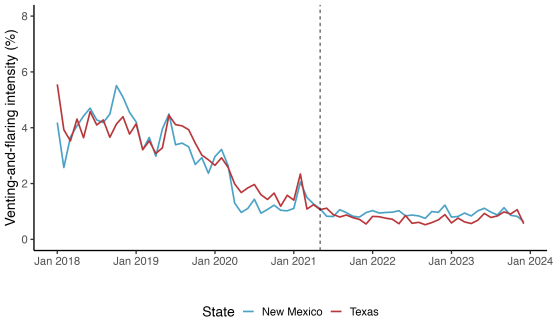
Our approach:

- Focus on the period before and after a policy change in New Mexico
- Examine flaring trends for firms split by policy exposure and geographic footprint

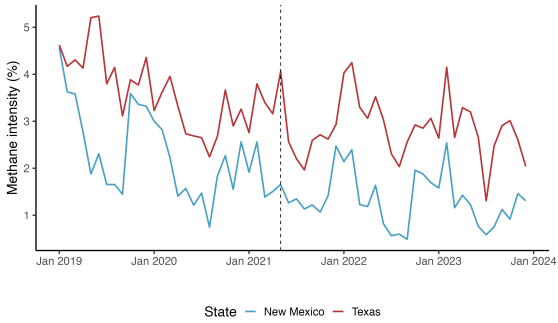
New Mexico's policy

- Tightened restrictions on routine venting and flaring
- Imposed more stringent reporting and monitoring requirements
- Phased in a 98% gas-capture target
- Went into effect May 2021, with staged implementation
  - October 2021: New vent/flare reporting requirement in effect
  - April 2022: Venting and flaring reductions begin
  - February 2023: Deadline for first certification of compliance with gas capture schedule
  - End of 2026: 98% capture target deadline

Delaware Basin flaring and methane emissions intensity by state

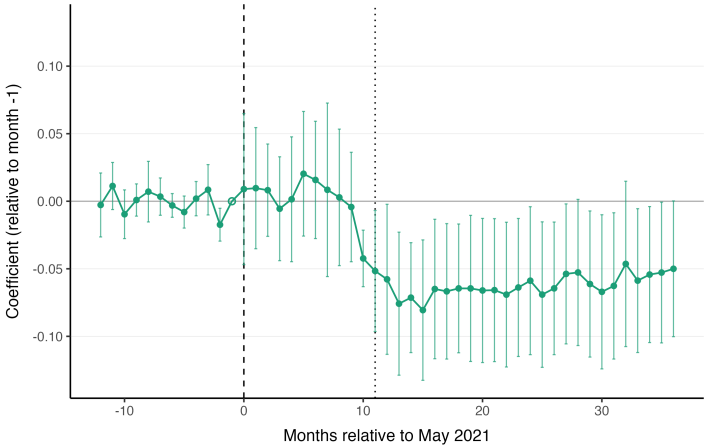


Operator-reported venting-and-flaring intensity



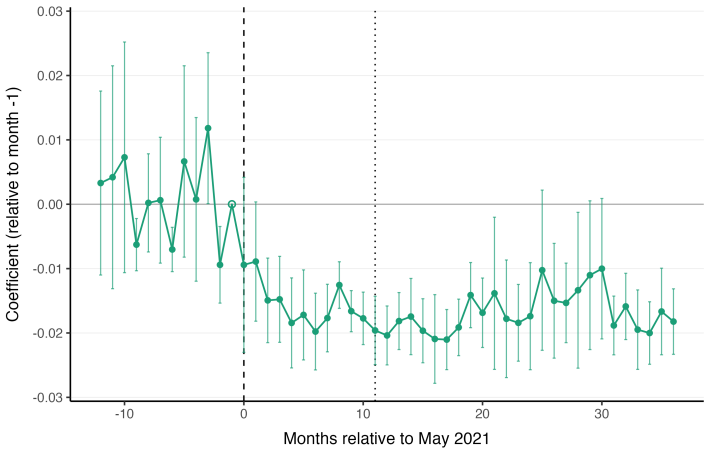
Remote-sensed methane emissions intensity

One-state operators: venting-and-flaring intensity



NM operators above 2% pre-policy intensity vs. TX operators

Spillovers: Texas venting-and-flaring intensity



TX wells of above-threshold two-state operators vs. TX-only operators

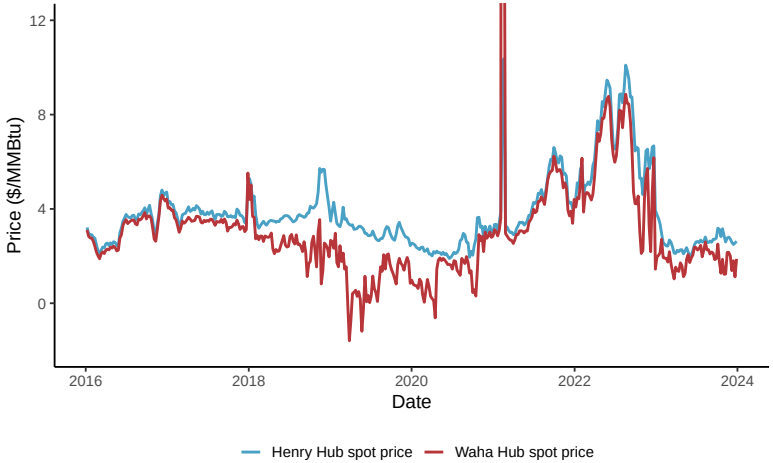
Future work

Future work

- **Behind-the-meter gas for data centers:**
  - Does building BTM data centers near oil and gas production sites decrease flaring?
  - How do data center developers choose between BTM gas and other, less emitting options?
- **Investments in pipeline leak prevention:**
  - How do pipeline operators decide whether to invest in pipeline maintenance?
  - What is the relationship between pipeline maintenance and pipeline leaks?

Appendix

Local and benchmark natural gas spot prices



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Emissions regression specification

We estimate basin-week regressions of methane emissions on prices:

$$\log(\text{Emissions}_{bt}) = \alpha_b^{(3)} + \beta_{1b}^{(3)} p_t^o + \beta_{2b}^{(3)} p_t^g + \beta_{3b}^{(3)} r_t + \mathbf{X}_t' \theta_b^{(3)} + \varepsilon_{bt}^{(3)}$$

- p_t^o, p_t^g: Cushing WTI oil and Henry Hub gas prices at time t
- r_t: Waha basis (transmission cost proxy)
- $\mathbf{X}_t$: heating degree days (Texas), linear time trend
- Dependent variable: log methane emissions (Tg/a) from Varon et al. (2026)
- Sample: January 2019–December 2023, weekly

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Methane fee: full results

	Methane fee, $900/mt				Methane fee, $1500/mt			
	98% flaring efficacy		91% flaring efficacy		98% flaring efficacy		91% flaring efficacy	
	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
% change in flaring	-1.39%	-2.11%	-6.01%	-6.75%	-2.30%	-3.50%	-9.81%	-10.99%
% change in CH_4 emissions	-0.72%	-1.45%	-3.11%	-3.87%	-1.19%	-2.41%	-5.08%	-6.32%
Value of abated gas	$83.7M	$123.3M	$363.1M	$403.0M	$138.8M	$204.2M	$592.1M	$656.0M
IWG social costs (SCC $67/mt; SCM $2,024/mt)								
Carbon cost reduction	$75.1M	$114.5M	$325.8M	$365.7M	$124.5M	$189.6M	$531.7M	$595.4M
Methane cost reduction	$51.8M	$104.9M	$224.7M	$279.7M	$85.9M	$174.1M	$366.7M	$456.5M
Social cost reduction	$210.5M	$342.7M	$913.6M	$1.05B	$349.2M	$567.8M	$1.49B	$1.71B
Azar et al. social costs (SCC $293/mt; SCM $6,880/mt)								
Carbon cost reduction	$328.6M	$501.0M	$1.43B	$1.60B	$544.9M	$829.8M	$2.33B	$2.61B
Methane cost reduction	$176.0M	$356.7M	$763.8M	$950.8M	$291.9M	$591.6M	$1.25B	$1.55B
Social cost reduction	$588.2M	$981.0M	$2.55B	$2.95B	$975.6M	$1.63B	$4.17B	$4.81B

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Pipeline expansion

Eliminating congestion entirely:

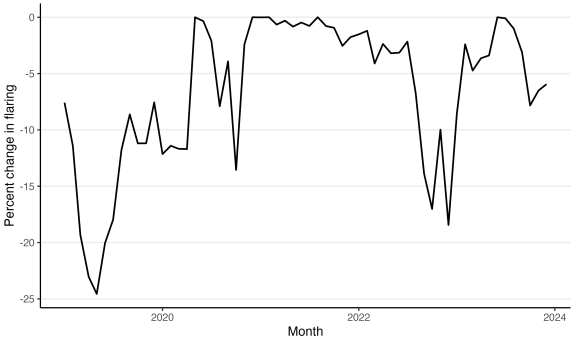
- 4.7% average flaring reduction
- Up to 20–25% during peak congestion

Adding a single large pipeline:

- 2,000 MMcf/d $\Rightarrow$ 4.3% flaring reduction
- Achieves most of full congestion relief

Cost-benefit:

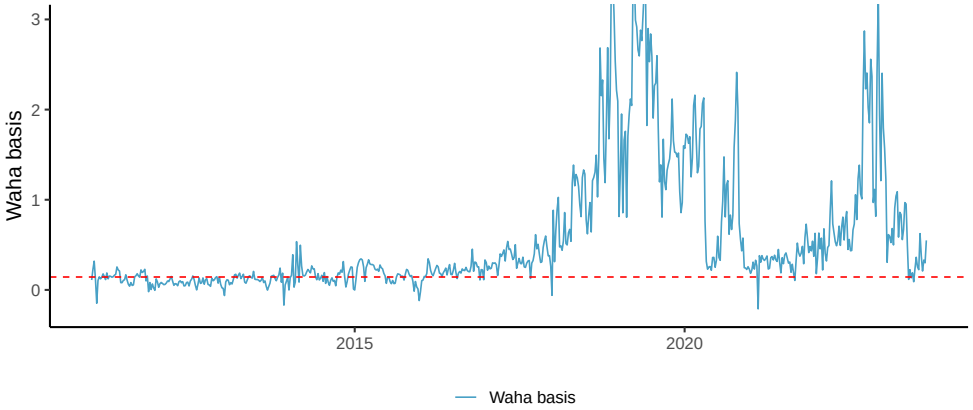
- 500-mile pipeline of this size costs $\approx$\$1.9B
- Social benefits: \$523M–\$1.8B/yr
- Pays for itself in a few years



Change in flared gas from relieving pipeline congestion

Back Waha basis history

Waha basis



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