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Methane Emissions Management, Abatement, and Utilization



WEDNESDAY, 2 SEPTEMBER
1100 CDT (UTC-5)



MODERATOR

CLAYTON NASH
TEGRE CORPORATION



SPEAKER

MARUTHI DEVARAKONDA
BAKER HUGHES



SPEAKER

JESSICA SHUMLICH
HIGHWOOD EMISSIONS
MANAGEMENT



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Methane Emissions Management, Abatement, and Utilization

Maruthi Devarakonda and Jessica Shumlich
September 2, 2026

Reducing Global Carbon Footprint from Energy Sector Through Methane Abatement and Utilization Technologies

Maruthi Devarakonda, Ph.D., F.ASME
September 2, 2026

Acknowledgements – A. Cruz, A. Mansouri, D. Sachdeva

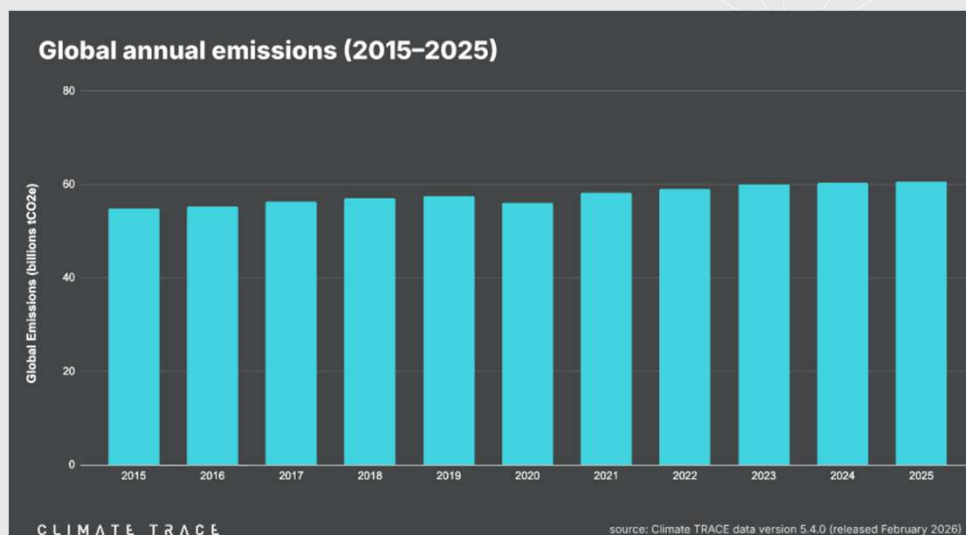
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Methane Emissions Overview

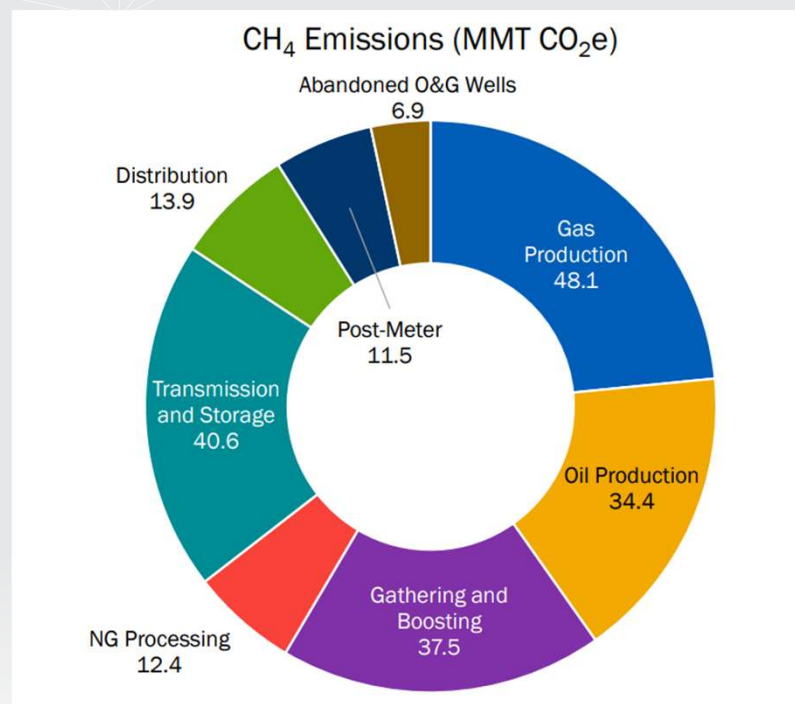
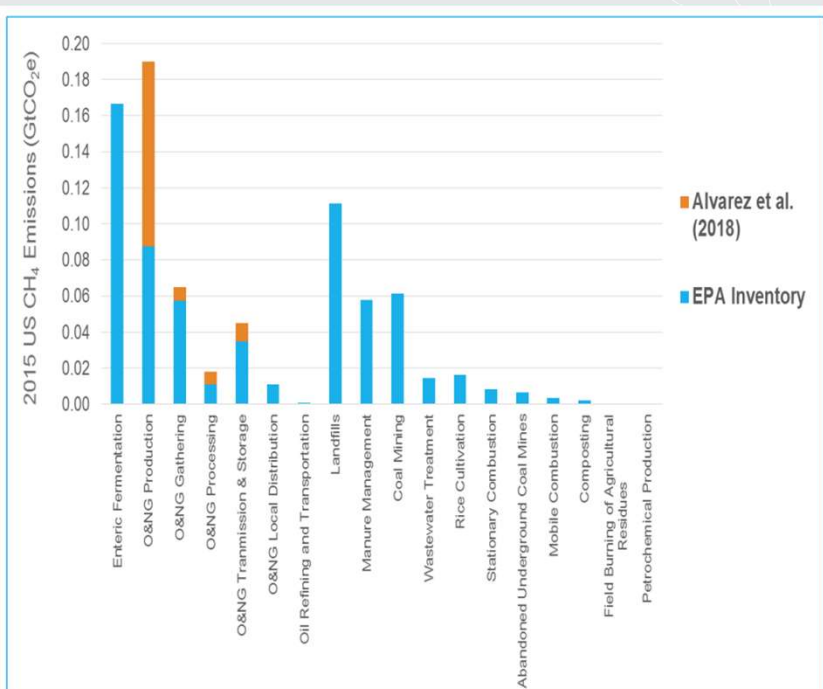
Global methane emissions increased by 1% in 2025 to a total of 413 MMt!



Top 10 Countries by Total 2025 GHG Emissions			
Country	Total GHG Emissions	Absolute Change vs. 2024	Percentage Change vs. 2024
1. China	17.4 Bt	48.8 Mt	0.28%
2. United States	7.0 Bt	16.2 Mt	0.23%
3. India	4.22 Bt	-27.5 Mt	-0.65%
4. Russia	3.2 Bt	51.6 Mt	1.64%
5. Indonesia	1.55 Bt	13.2 Mt	0.86%
6. Brazil	1.38 Bt	19.5 Mt	1.43%
7. Iran	1.28 Bt	-1.1 Mt	-0.09%
8. Japan	1.28 Bt	-5.3 Mt	-0.41%
9. Saudi Arabia	1.05 Bt	22 Mt	2.14%
10. Canada	0.95 Bt	0.34 Mt	0.04%

Key Methane Emission Sources in the US

Upstream activities accounted for 80% of methane emissions from O&G in 2025



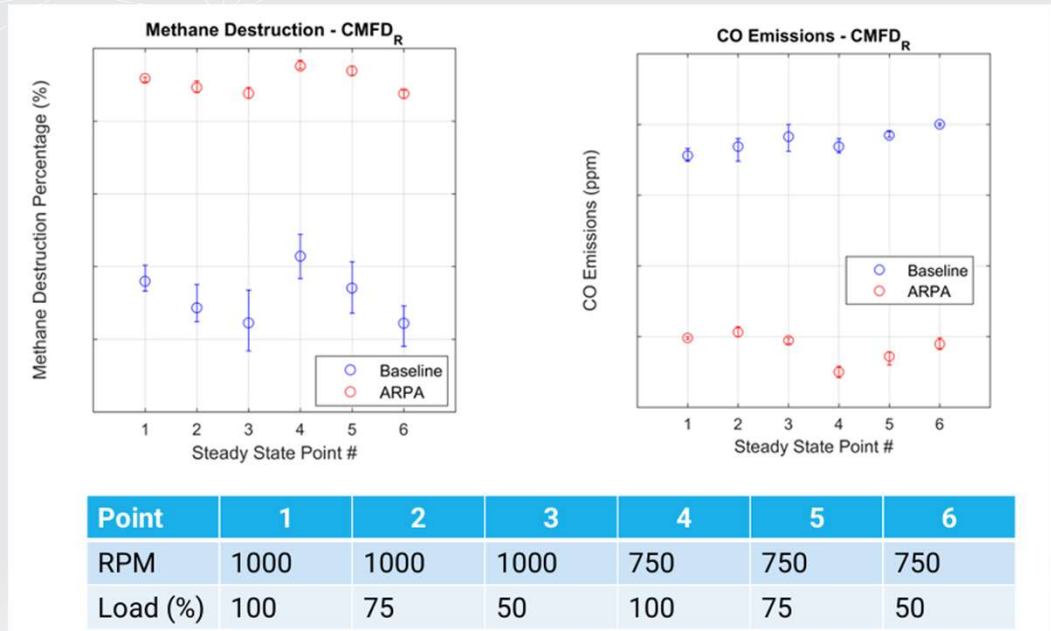
Methane Abatement Technologies



Broadly classified into mechanical, chemistry and bio-based technologies!

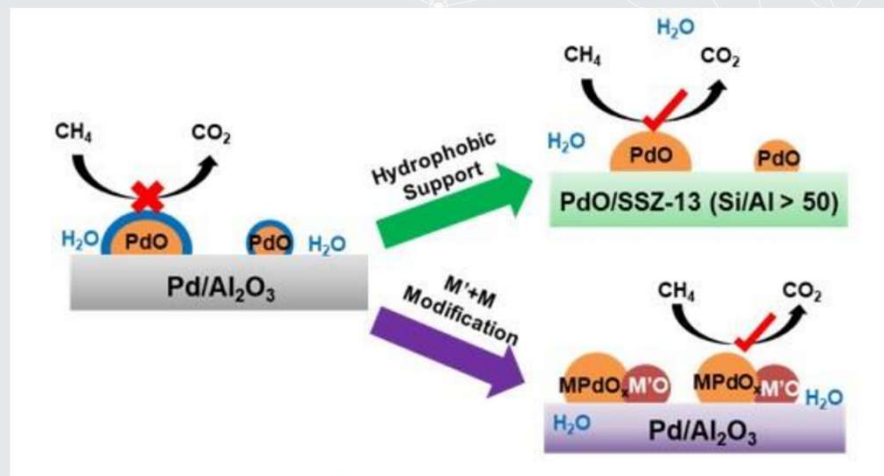


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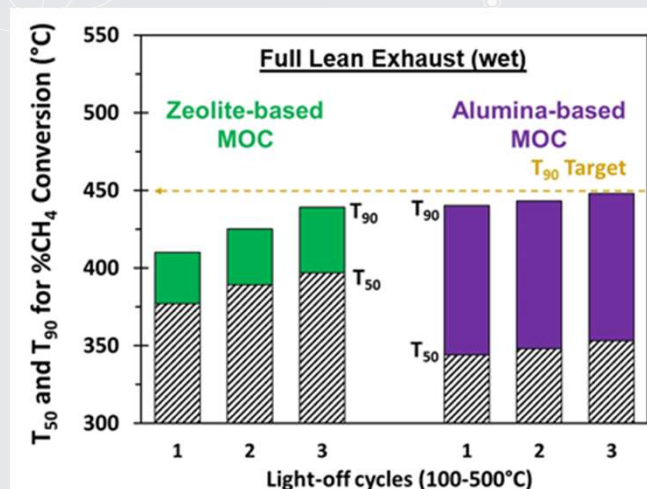


Chemistry/Catalysis Based Solutions

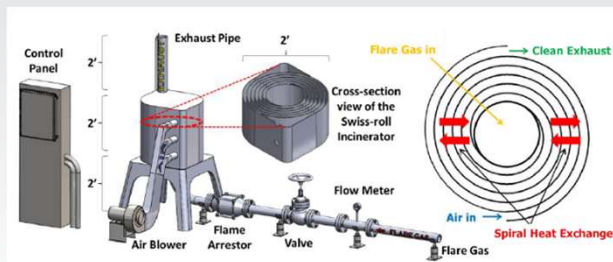
Solutions are effective in reducing methane emissions from engines, flares and ventilated coal mines



https://arpa-e.energy.gov/sites/default/files/2023-06/17_MAHLE-2023%20Annual%20Meeting_MPT_rev1vf.pdf



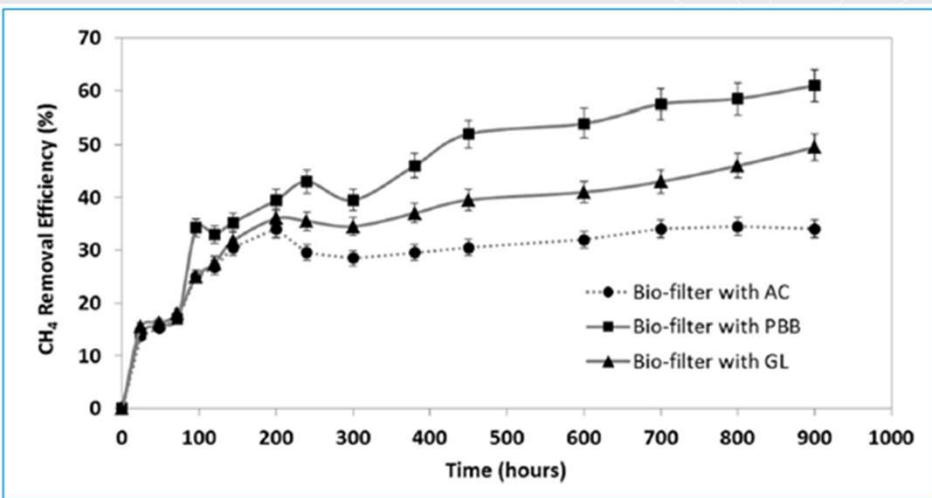
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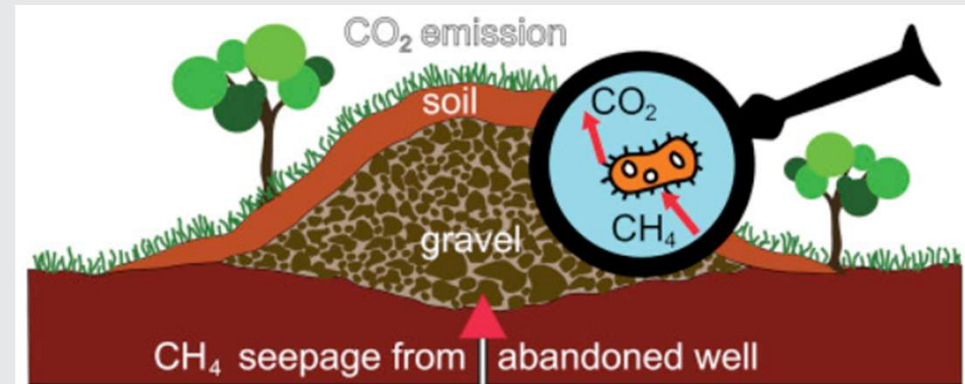
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Bio-based Abatement

Methanotrophs are effective in reducing methane emissions from landfills¹, abandoned oil and gas well and coal bed methane.



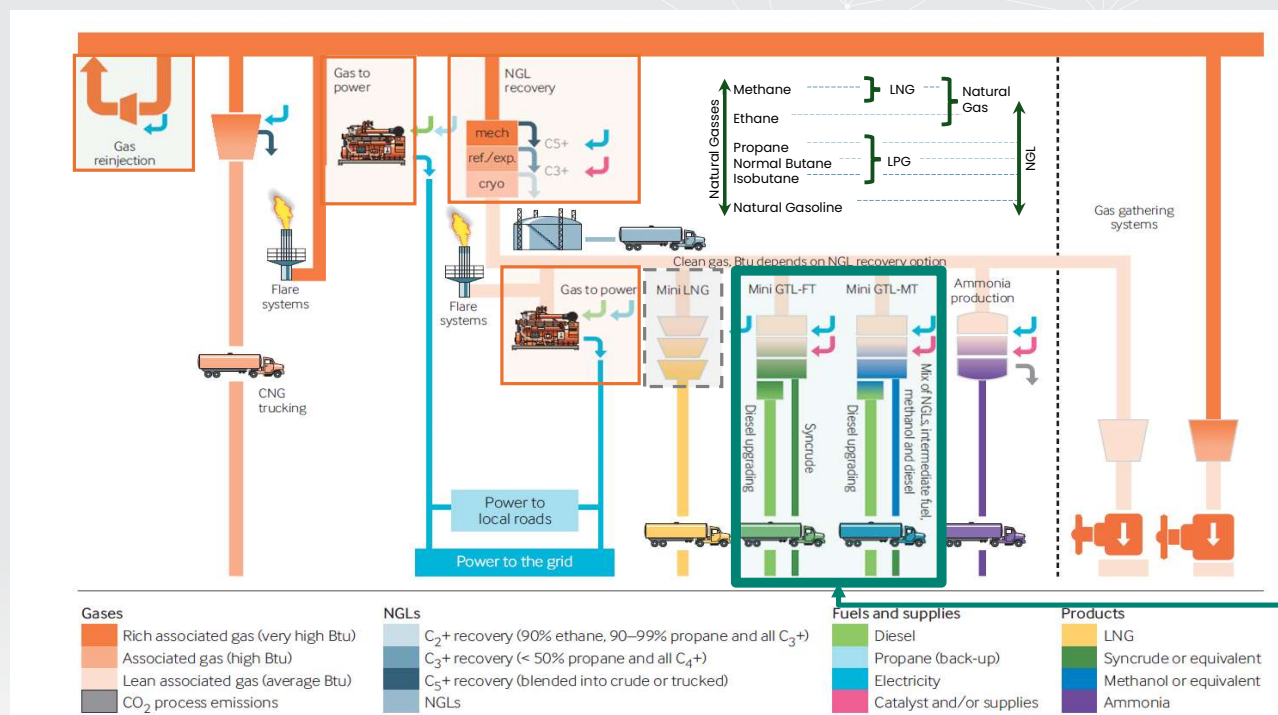
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<https://www.sciencedirect.com/science/article/abs/pii/S0301479721002760>



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An Approach to Flare Gas Utilization

Dependent on Economic Feasibility, Environmental Regulations, Integration Potential!



Key Flare recovery technology segments include:

- **Flare to Power:** Generate captive or grid power plus CO₂
- **Flare Pipeline:** Compression and clustering to central location
- **NGL recovery:** Extracting liquids and high value LPG/propane
- **Flare to Liquids:** Increase energy density by chemically converting flare gas to high value products: Methanol, synthetic fuels etc.

Flare-to-X



Innovative Solutions for hard to abate flares where standard solutions are unavailable, multiple utilization options available to monetize associated gas by chemical conversion to a valuable end product.

Multiple options to monetize flared gas

Cluster of technologies in an emerging area of transformation of off gas (or CO₂, syngas) to fuels

FLARE TO LIQUIDS

- Chemical conversion of associated gas into energy dense liquids
- Variety of possible liquids from syn-crude, Diesel, Jet Fuel, methanol, gasoline
- Lower carbon intensity of these fuels may lend to carbon incentives
- High CAPEX projects will benefit from modular design and delivery for small/medium flares

BITCOIN

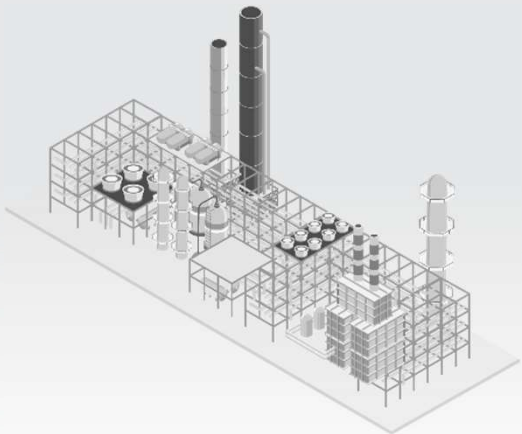
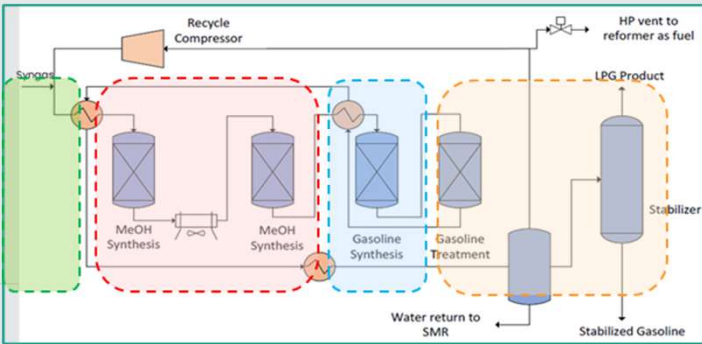
- Increasing bitcoin pricing and needs for clean energy pushing bitcoin miners to leverage flare gases for power generation
- Mobile Gas to Power combined with bitcoin mining rig can be power tool to monetize flare gas
- Innovative commercial models and partnerships can unlock projects

DATA CENTERS

- Clean power demand for data centers and AI growth increasing interest from flare to power
- Data centers need to be located close to source of gas and long-term gas availability
- Potential carbon credits with Gas to Power solution can drive investment from data center companies in Flare to power

FLARE TO LNG

- Large flares and clustered flares can be converted to LNG



Flare-to-Liquids

Turning Waste Gas into High-Value Liquid Fuels!

Why Flare Matters?

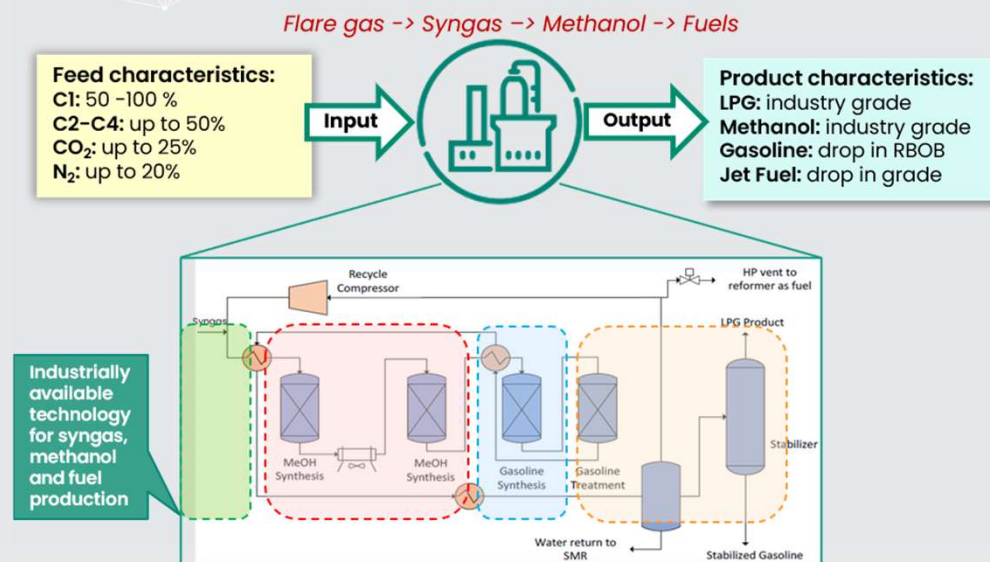
- Over 150 bcm of off-gas are flared globally each year.
- This equals annual 400 Mt CO₂-eq. in lost emissions.
- Traditional flaring = wasteful and polluting

What Is Flare Gas?

- By-product of refining, chemicals, and gas processing plants.
- Comprises hydrocarbons, H₂, CO, CO₂, N₂, H₂S.

Challenges of Flare Gas Handling:

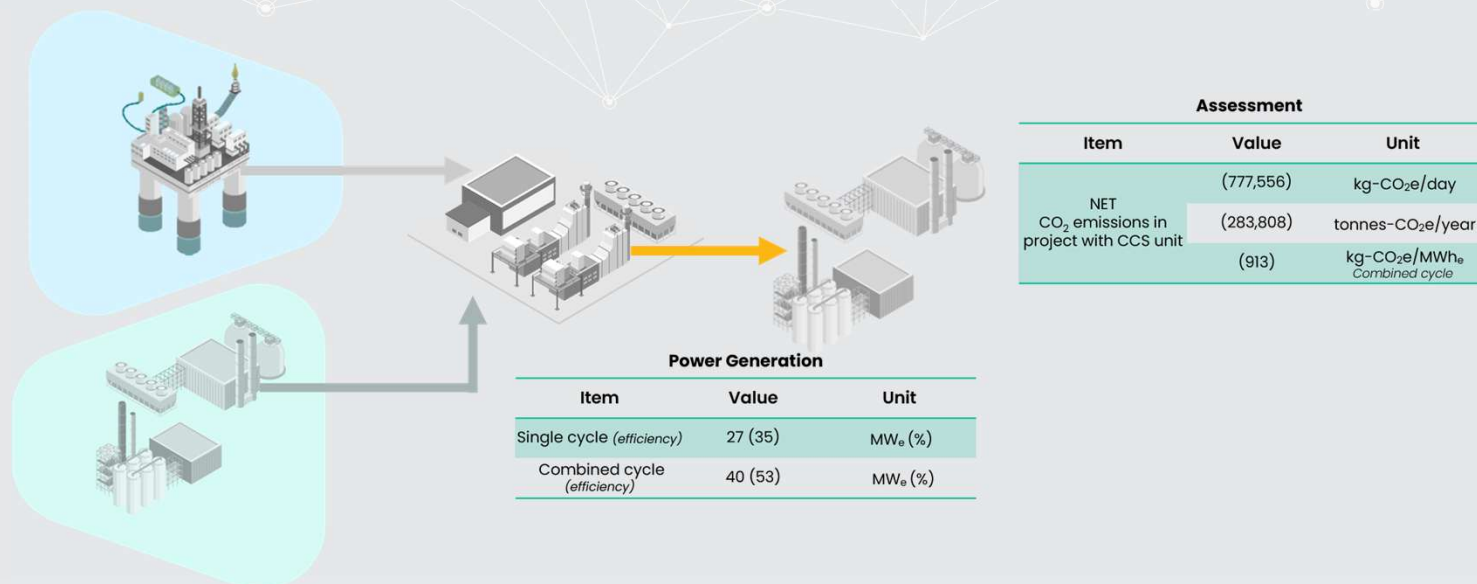
- High variability in flow & composition.
- Low pressure streams, requiring compression.
- No pipeline grade – due to inconsistency & impurities.



Advantages include GHG reduction, energy recovery, sustainability, modularized & skid-based deployment

Flare-to-Power

Use flare gas for captive/grid power!

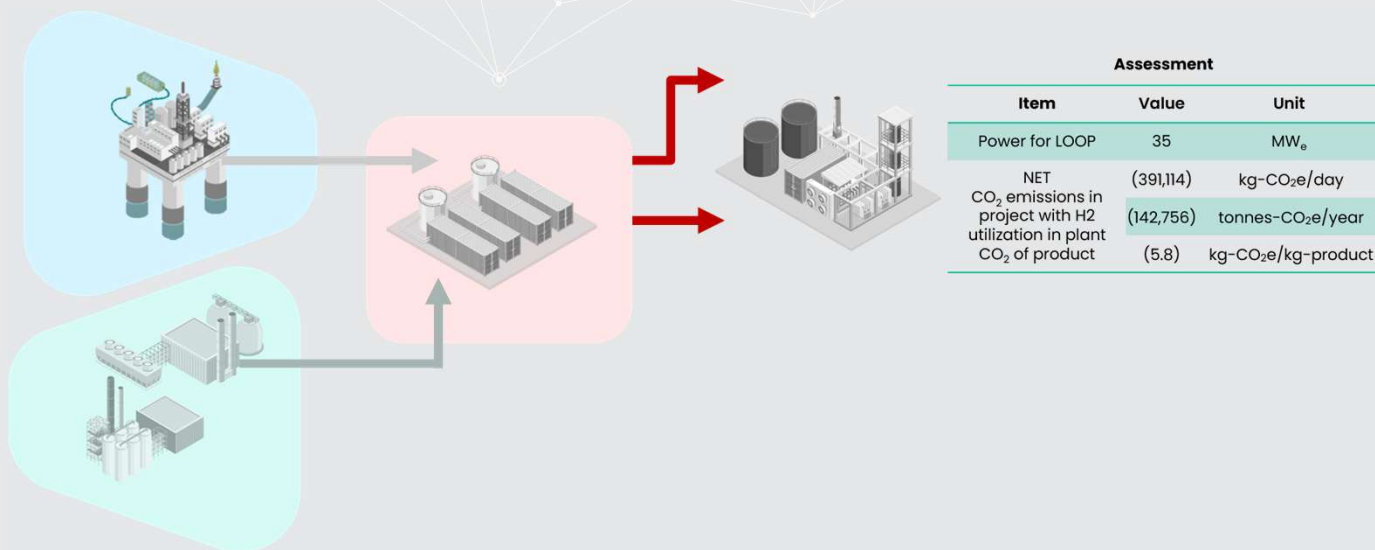


Benefits: Eliminate routine flaring; displace diesel: **~20% CO₂e** vs. diesel engines, **~45%** when factoring flare utilization; modular deployment.

Challenges → Mitigate: Variable C₂+ / N₂ / CO₂, H₂S, permitting → ZnO/HDS polishing, DLN tuning/derating maps, emissions-aware controls; consider C4+ skim if heavy.

Flare-to-Graphene

Methane cracking $\rightarrow$ graphene + H_2

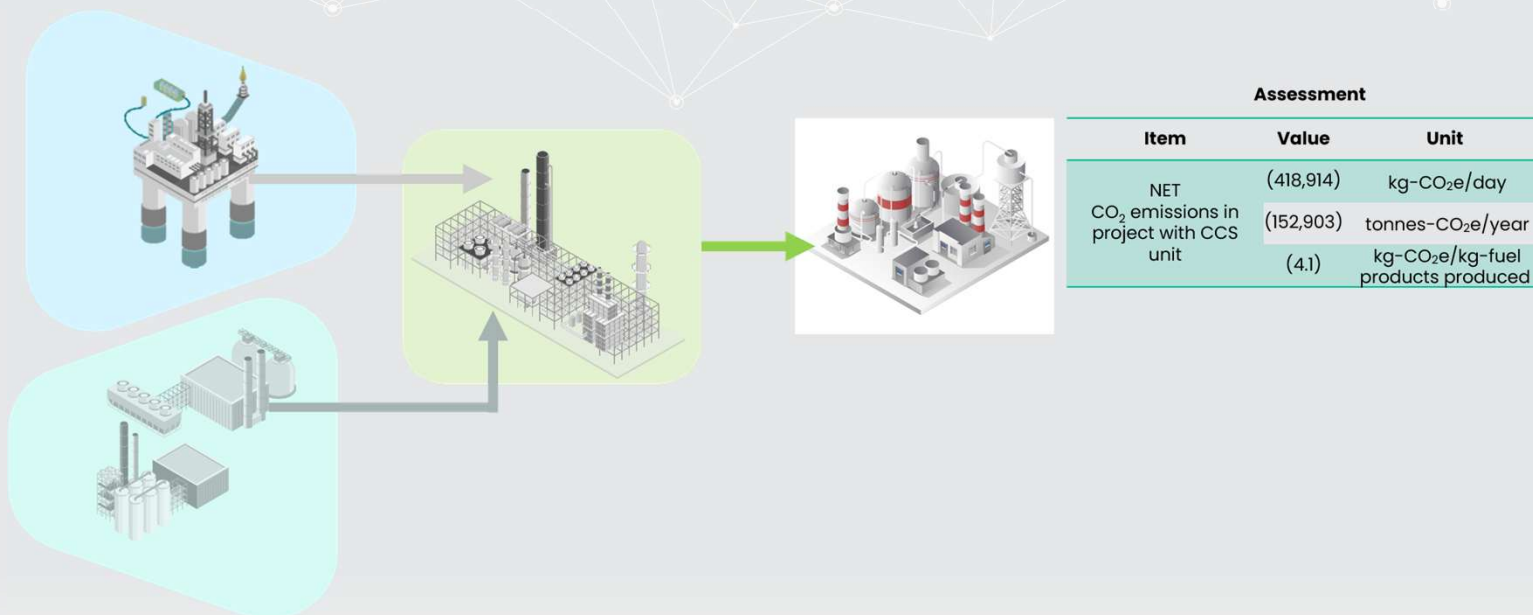


Benefits: Converts waste into **premium solids + H₂**; avoids full CO₂ formation; measurable methane abatement.

Challenges $\rightarrow$ Mitigate: **Product spec/offtake** & **sulfur risk** $\rightarrow$ secure **offtake MoUs**, add **sulfur polishing**, run **M&V** tied to flare metering

Flare-to-Methanol (MeOH)

Off-gas → syngas → MeOH; modular front-end cleanup/compression

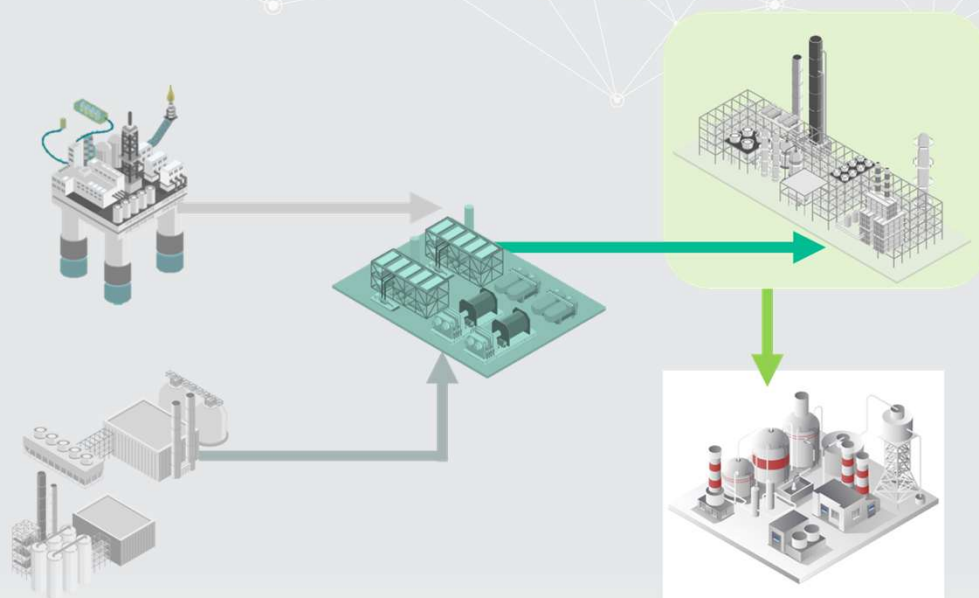


Benefits: Saleable fuels with **Low-C** routes [LCFS, Canada CFR, EU RED III/FuelEU] once LCA/CI + mass-balance certified.

Challenges → Mitigate: CI limits & non-intentionality → ISO 14040/44 LCA, rigid input, chain-of-custody

Flare-to-Fuels (diesel, jet, gasoline + LPG)

NGL (C4+/C5+) ahead of reforming: monetize **condensate/LPG**; leaner, steadier reformer feed



**without CCS*

Benefits: Higher **IRR/shorter payback**; reduced reformer duty; proven **5–50 MMSCFD** modular skids.

Challenges → Mitigate: Extra **plot/utilities** & refrigeration; risk of **over-recovering LPG** → **modular ramp** (C5+ → LPG), **flex-pipe clustering** to hit scale, optimize **JT vs. refrigeration** to feed.

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Assessment		
Item	Value	Unit
Net CO ₂ emissions with CCS unit	(415,034)	kg-CO ₂ e/day
	(151,488)	tonnes-CO ₂ e/year
	(9.8)	kg-CO ₂ e/kg-products produced



Key Takeaways

- Methane abatement technologies over the past few years have shown significant promise (TRL 3→6) in reducing methane emissions from
 - Reciprocating engines (mechanical, combustion and catalysis or a combination thereof)
 - Flares (novel designs and catalysis or a combination thereof)
 - Ventilated coal mines (catalysis)
 - Landfills, abandoned O&G wells and coal mines (bio-based remediation)
- Methane conversion/utilization technologies from sources such as flares could be used in an economic way to generate value added products such as fuels, graphene, etc.
- Both the technologies require significant investment from private and public entities such that the technical risks during scale-up could be mitigated, and the “valley of scaling” (TRL 7→9) could be avoided thus reducing the overall carbon footprint from the energy sector.



THANK YOU

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Reducing Methane Emissions from U.S. Oil & Gas:

Monitoring, Measurement, Mitigation & Verification—and What EU and U.S. Rule Changes Mean for Operators

Jessica Shumlich
September 2, 2026

WHAT WE'LL COVER

Agenda



01

Why Methane, Why Now

The climate case and the market case for acting on methane

02

Monitoring, Measurement & Mitigation

The MMM framework for regulators and operators

03

The EU Methane Regulation

Why a European rule reaches into U.S. permitting and export contracts — and what it means for U.S. operators

04

U.S. Regulatory Rollbacks

OOOOa, OOOOb, OOOOc and the Endangerment Finding — what's changed, what hasn't

05

Verification

How the industry proves that claimed reductions are real

06

Takeaways

What this means for regulators and SPE members

A Short-Lived Gas With an Outsized Impact



- Methane breaks down in the atmosphere in about 12 years, far faster than CO₂, which persists for centuries.
- That short lifetime cuts both ways: cutting methane now delivers a climate benefit almost immediately.
- Oil and gas is the largest controllable industrial source — the focus of both U.S. rulemaking and the EU Methane Regulation.

~30%

of all warming since the Industrial Revolution (UNEP)

81x

more potent than CO₂ over 20 years (IPCC AR6)

\$160B→\$400B

low-methane gas market growth by 2031

THE U.S. REGULATORY BACKDROP, AT A GLANCE

- NSPS OOOOb & EG OOOOc (2024): since 2025, the Environmental Protection Agency (EPA) has narrowed several provisions and pushed back deadlines. (see Section 4).
- IRA Waste Emissions Charge: repealed by the 119th Congress via the Congressional Review Act (Feb 2025).
- State programs: Colorado, New Mexico, Wyoming, North Dakota and Texas layer on top of the federal floor, and matter more as it softens.

The MMM Framework, and Where Emissions Come From



Know what's leaking. Quantify it. Fix it.

1

MONITORING

Ongoing surveillance — surveys, point sensors, aerial/satellite passes.

2

MEASUREMENT

Quantifying how much is emitted, component to company inventory.

3

MITIGATION

Engineering/operational changes that eliminate or reduce the source.

WHERE EMISSIONS COME FROM AT A FACILITY

1

Pneumatic controllers & pumps

2

Compressors (recip. & centrifugal)

3

Storage tanks (flash & working losses)

4

Dehydrators (glycol reboilers)

5

Flares & combustion devices

6

Fugitive components (valves, connections)

7

Liquids unloading & workovers

8

Blowdowns (planned depressurization)

Fugitives, compressors, and tanks are consistently the largest sources — the priority order for most mitigation programs.

The Toolbox: From Handheld to Space-Based



GROUND-BASED

Finest detail, most frequent

- Optical gas imaging (OGI) cameras
- Handheld / walking LDAR surveys
- Continuous point sensors

AERIAL

Site to multi-site coverage

- Drone & fixed-wing surveys
- e.g., Bridger, SeekOps

SATELLITE

Broadest coverage, less frequent

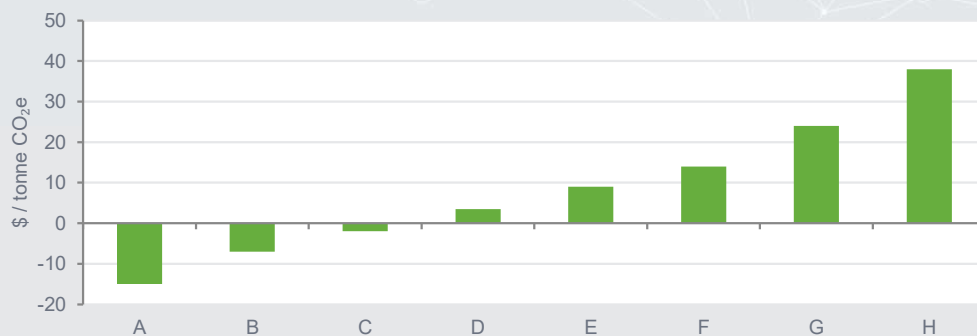
- TROPOMI, GHGSat, Carbon Mapper

The trade-off: satellites cover huge areas often but at coarser resolution; ground surveys see fine detail but reach fewer sites as frequently.

How a Marginal Abatement Cost Curve Works



Illustrative Cost Curve (Not U.S. Data)



- Bars sorted cheapest to most expensive; width = emissions abated, height = \$/tonne CO₂e.
- Bars below zero are net cost-saving — captured gas is worth more than the fix.

MITIGATION MENU HIGHLIGHTS

- Pneumatics: bleed-rate retrofit, instrument-air conversion, electrification, or vent capture to a VRU.
- Compressors, tanks & dehydrators: dry seals/rod-packing, vapor recovery + enclosed combustion, glycol still-vent control.

FLARING IN THE U.S.

Concentrated, and Increasingly Avoidable



87%

of upstream flaring is associated gas at oil wells

120 Bcf/d

onshore gas production in 2021, up 64% since 2012

~90%

of onshore flaring from just 5 states

70%

of flared volume from just 7% of wells

SIX WAYS TO CAPTURE INSTEAD OF FLARE

Technology	Net cost/(profit) \$/kcf	Net cost/(profit) \$/MT CH ₄
Gas-to-wire (on-site power gen)	\$0	\$0
CNG (trucked)	\$1.8	\$94
Pipeline gathering	\$3.1	\$162
Reinjection	\$3.4	\$177
LNG (trucked)	\$5.6	\$292
On-site use (fuel switching)	\$8.6	\$449

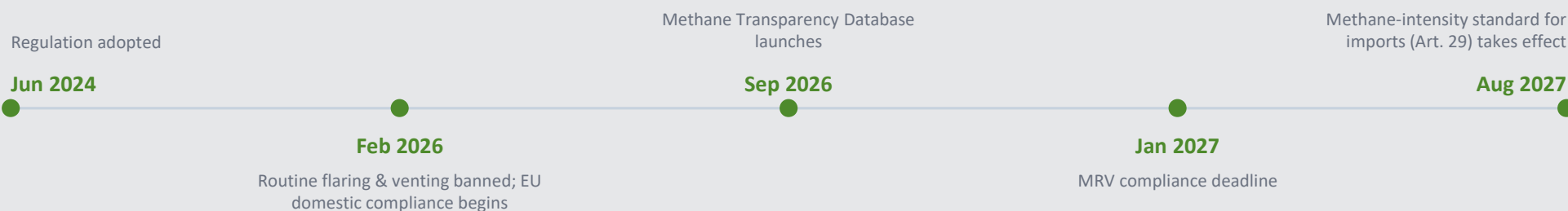
Source: Rystad Energy for EDF, 2022 (Cost of Flaring Abatement). Pipeline gathering remains the default, most scalable option; gas-to-wire/CNG are often cheapest where pipeline access is limited.

03 · THE EU METHANE REGULATION

What Is the EUMR, and Why Now?



- Regulation (EU) 2024/1787, adopted June 2024.
- Covers methane from oil, gas and coal placed on the EU market, including imports.
- Sets monitoring, reporting and verification (MRV) obligations plus venting/flaring restrictions.



The Transparency Database's statutory Feb 5, 2026 deadline has already slipped to a Commission target of Sept 2026 — implementation is running behind the text.

THE EU METHANE REGULATION

Where Things Stand — and the Paths to Equivalence



- Jun 26, 2026: over half of EU Member States told the Commission voluntary penalty relief isn't enough — asking for a legal 3-year postponement or faster guidance.
- Jul 20, 2026: the Commission adopted recommendations letting Member States temporarily suspend penalties during supply disruptions — non-binding; MRV/import obligations still apply.

THREE PATHS TO “EQUIVALENCE” — REQUIREMENTS TRAVEL BY CONTRACT: EU IMPORTER → U.S. EXPORTER → MIDSTREAM → PRODUCER

Country-level (Art. 28(5)(b))

Not yet available for the U.S. — federal rollbacks are eroding the case further (see Section 4).

Company — OGMP 2.0 (Art. 28(5)(a))

Level 5 reporting plus independent third-party verification.

Company — Article 12 (Art. 28(6))

Monitoring/reporting equivalent to Art. 12, plus independent verification.

The Commission has signaled company-level equivalence will be the path most companies use — and likely the only realistic path for commingled U.S. gas.

Contracts, Costs & Market Access



WHO'S EXPOSED

Not just companies selling directly into Europe. Any U.S. producer, gatherer, processor, or exporter whose gas — or contractual share of it — ends up in an EU-bound cargo can be asked for EUMR-aligned data.

CONTRACT FLOW-DOWN

EU importers are pushing MRV-equivalent data clauses into new supply contracts. FOB buyers and sellers are still negotiating who absorbs the compliance cost.

FINANCIAL EXPOSURE

EUMR penalties can reach 20% of an importer's annual EU turnover. Importers will pass that risk upstream through contract terms, warranties, and price.

OPERATIONAL FRICTION

U.S. gas markets are highly liquid and commingled — it may not be possible to trace a molecule to a single well, making attribution a real engineering problem.

Midstream isn't off the hook either: even without a direct MRV obligation, gatherers and processors are increasingly asked to pass along segment-level supplier data so LNG exporters and EU importers can build an auditable chain.

VOLUNTARY VS. BINDING, AND GETTING READY

OGMP 2.0 vs. the EUMR



Dimension	OGMP 2.0	EUMR
Authority	Voluntary partnership (UNEP)	Binding regulation (EU law)
Verification	Annual UNEP review	Third-party, “reasonable assurance”
Transparency	Aggregated, publicly available	Methane Transparency Database
Consequence	Reputational; UNEP labeling	Penalties; loss of market access
Methane accounting	Principles-based, flexible	Regulatory, auditable

GETTING READY: A QUARTER-BY-QUARTER ROADMAP

Q1

Scope assessment — map EU-linked supply chains

Q2

Gap diagnostic against OGMP 2.0 / EUMR

Q3

Systems investment — close data gaps

Q4

Pilot verification on one asset or basin

OGMP 2.0 in its current form is not, by itself, sufficient for EUMR compliance — it's one input toward equivalence, not a substitute.

The Rule Stack, Explained



Rule	Applies To	Status (Aug 2026)
NSPS OOOOa (2016)	New/modified sources built Sep 2015 – Dec 2022	Legacy standard; still governs that vintage
NSPS OOOOb (2024)	New/modified sources built after Dec 2022	Current standard; narrowed by Apr 2026 reconsideration
EG OOOOc (2024)	Existing sources, via state plans	State plan deadline extended to Jan 22, 2027

- All three sit under Clean Air Act Section 111 — new-source performance standards (NSPS) and emission guidelines (EG) for existing sources.
- OOOOb functionally supersedes OOOOa for anything built after December 2022; OOOOc doesn't regulate operators directly — EPA sets targets and each state writes its own plan, which is why state-plan timing is the current pressure point.

U.S. REGULATORY ROLLBACKS

What's Changed — and What Hasn't



ROLLED BACK

- Feb 2025: Waste Emissions Charge repealed via CRA; EPA barred from collecting until 2034.
- Feb–Nov 2025: deadlines extended (closed-vent systems, controllers, Super-Emitter Program, NHV monitoring).
- Apr 4, 2026: flaring limits extended 24→72 hrs; NHV monitoring narrowed. EPA estimates ~\$2.5B savings, 2024–2038.
- Ongoing: an EPA enforcement memo deprioritized methane-focused inspections.

STILL IN FORCE / WHAT'S NEXT

- Core LDAR, fugitive-component monitoring, and work-practice standards are untouched.
- Courts denied industry's emergency-stay requests; merits litigation is in abeyance pending EPA's reconsideration.
- Key dates: NHV monitoring Jun 1, 2026; first annual reports Nov 30, 2026; state plans Jan 22, 2027.
- Phase 2 reconsideration: expected 2H 2026 — closed-vent systems, Super-Emitter Program, combustion devices, marginal wells.

THE BIGGER PICTURE

Endangerment Finding Repeal & the “Methane Exception”



- Feb. 2026 – Endangerment Finding repealed: EPA rescinded the 2009 GHG Endangerment Finding and vehicle GHG standards, challenging EPA’s broader authority to regulate GHGs under the Clean Air Act. This does not automatically invalidate oil & gas methane rules under Section 111.
- Why methane is different: Congress rejected EPA’s 2020 methane rollback through the Congressional Review Act in 2021, limiting EPA’s ability to issue another “substantially the same” rollback. Congress then went further in the 2022 IRA, explicitly legislating methane controls for the oil & gas sector and linking them to Section 111 methane standards.
- What this means for OOOOb/c: EPA has a stronger legal basis for modifying how OOOOb/c works than eliminating methane regulation altogether. So far, the rollback has therefore focused on targeted technical changes, such as flaring and monitoring requirements, rather than wholesale repeal.

Litigation on the Endangerment Finding repeal itself is expected to run for years and may reach the Supreme Court.

THE BIGGER PICTURE

Losing the Data Backbone — Why It Matters for EU Access



- EPA has proposed eliminating most of the Greenhouse Gas Reporting Program, including the 2024 Subpart W methane-reporting revisions.
- The proposal would exempt ~two-thirds of the ~8,000 currently-reporting facilities and could push methane disclosure out to 2034, using generic emission factors instead of measurement-informed ones.

4–10x

how much higher measured emissions can run vs.
emission-factor estimates.

A final GHGRP rule was expected imminently as of September 2026.

Why this matters for EU market access: the EUMR's country-level equivalence path depends on the EU judging U.S. regulation “equivalent” to its own MRV standard. A weaker federal data and enforcement backbone makes that case harder, not easier.

Practical result — U.S. operators with EU-linked supply chains can't wait for a federal fix: company-level compliance (OGMP 2.0 Level 5 or Article 12 equivalence, independently verified) is the only realistic path, regardless of what happens in Washington. State programs and voluntary frameworks now do double duty as domestic credibility and the evidentiary basis for EU market access.

05 · VERIFICATION

From Self-Report to “Reasonable Assurance”



- The EUMR's standard is “reasonable assurance” — rigorous enough that the verifier gives a positive opinion the numbers are materially correct.
- A new ISO standard (ISO/PWI 25624-1) is under development at the European Commission's request, covering quantification, materiality, traceability and uncertainty — for EU and non-EU producers alike.

THE VERIFICATION TOOLKIT

OGMP 2.0 Levels 1–5

A maturity ladder from generic emission factors (L1) to fully measurement-informed reporting (L5).

Satellite & aerial monitoring

Bridger, SeekOps, TROPOMI, GHGSat increasingly feed emissions data profiles.

Certification bodies

Programs such as MiQ grade delivered gas on methane performance.

Regulatory reporting

EPA GHGRP Subpart W and PHMSA pipeline data are existing U.S. inputs verifiers draw on.

Average producers today maintain 3–4 different methane inventories that can vary 2–10x from each other, a key reason measurement and independent verification matter.

BRINGING IT TOGETHER

Takeaways for Regulators & SPE Members



FOR REGULATORS

- Many regulatory instruments, including measurement technologies and performance standards, can reduce emissions even as federal enforcement priorities shift.
- Expect operators with EU-linked supply chains to bring OGMP 2.0 / EUMR-aligned data to permitting and compliance conversations regardless of federal rollbacks.
- State plans and state-level programs matter more, not less, as the federal floor softens.

FOR SPE MEMBERS

- The mitigation menu for pneumatics, compressors, tanks and flaring is mature and can be cost-effective.
- Verification is moving from voluntary to mandatory. Building measurement-informed inventories now reduces compliance risk later.
- EU market access now runs through company-level data, not a federal backstop. Get EUMR/OGMP 2.0-ready on your own timeline, not a counterparty's.

Questions & Discussion

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THANK YOU