Notes and materials from EDF Methane Policy Research Workshop on Feb 6 and 8, 2024

Contents

Agenda EDF Methane Policy Research Workshop:

What new research in economics and public policy can MethaneSAT and other new methane data sources enable?

Objective: To bring economics and policy researchers together with EDF methane scientists to discuss new sources of methane emissions data – like MethaneSAT – to brainstorm and identify new and policy-relevant research questions in the oil and gas sector which may soon become possible to answer empirically.

As background reading, you might want to review our EDF Economics Discussion Paper on Policy instrument options for addressing methane emissions from the oil and gas sector. In particular, **Section 6** summarizes the outstanding research questions identified in our previous EDF Methane Policy workshop in November 2021.

Session 1: New emission reduction frameworks, policies, and research initiatives in the oil and gas methane space

February 6th, 9-11 am ET/3-5 pm CET (90 min + 30 min informal chat time afterwards)

Join the Zoom Meeting here:

https://edf.zoom.us/j/89350727890

1. **Introduction to the workshop** *(Maureen Lackner, Senior Manager, EDF Economics team, 5 minutes)*

2. **Recent policy developments on oil and gas methane and associated new data sources (30 minutes)**
    a. Emerging methane emission reduction frameworks *(Hanling Yang, Senior Director, EDF Energy Transition team, 5 min)*

    b. EU regulations, incl Methane Supply Index and MRV data *(Huong Nguyen, Manager, EDF Economics team, 5 min)*

    c. US methane regulations, incl EPA GHGRP Subpart W data *(Aaron Wolfe, Senior Analyst, EDF Economics team, 5 min)*

   d. Breakout groups *(15 min)*

3. **Updates from ongoing methane research initiatives and how they plan to use new methane emissions data for their research (50 minutes)**
   a. Harvard Salata Institute: Reducing Global Methane Emissions *(Rob Stavins, Professor, Harvard University, 15 min)*

   b. Norwegian School of Economics: Equinor Academia Grant 2023-2028 on the Economics of European methane emissions *(Giacomo Benini, Assistant Professor, NHH Norwegian School of Economics, 10 min)*

   c. Call for ideas on how to broaden our research network and to stimulate more research on oil and gas methane policy in the Global South *(Kristina Mohlin, Senior Director, EDF Economics team, 5 min)*

   d. Breakout groups *(20 min)*

4. **Concluding remarks and preview of next day's session** *(Kristina Mohlin)*

5. **Informal coffee chat time (30 min).** ***Please stay around to chat with EDF staff members and other workshop participants to meet and bring up anything you're interested in that we didn't have time for in the formal agenda.***

Session 2: MethaneSAT and other new sources of methane measurement data. How to use these sources for new economics and policy research?

February 8th, 9-11 am ET/3-5 pm CET (100 min + 20 min informal chat time afterwards)

Join the Zoom Meeting here:

https://edf.zoom.us/j/83215502581

1. **Introduction to Session 2** *(Huong Nguyen)*

2. **MethaneSAT data – what will they offer and how can public policy researchers use them? (35 minutes)**
   a. Introduction to MethaneSAT data + what other satellites can offer *(Alba Lorente, EDF Scientist, 20 min)*

   b. MethaneAir overview and data *(Mark Omara, EDF Senior Scientist, 10 minutes)*

   Q&A

3. **Reflections on the structure of the MethaneSAT and other remote sensing data and how it can be used by economics and public policy researchers** *(Lauren Beatty, EDF High Meadows Postdoctoral Economics Fellow, 10 min)*

   Q&A

4. **3 min "elevator pitches" from external researchers (20 minutes)**
   a. Ambient pollution mechanisms with remote sensing technology: An application to the oil and gas industry – *Mark Agerton, Assistant Professor, UC Davis, and Ben Gilbert, Assistant Professor, Colorado School of Mines*

   b. Analysis of US LNG exports, vessel traffic, and methane emissions as detected by Tropomi – *Xinming Du, Assistant Professor, National University of Singapore*

   c. Estimating Abatement Costs Using Satellite Data – *Levi Marks, PhD Economist, and Brian Prest, Research Fellow, RFF*

   d. Performance of an Input-Based Fee to Reduce Methane Emissions – *Lauren Beatty*

5. **Discussion and brainstorming of ideas presented in Section 4 (30 minutes)**
   a. Breakout groups *(20 min)*
   b. Report back from breakout groups *(15 min)*

6. **Concluding remarks** *(Maureen Lackner)*
   We welcome suggestions for future webinar presentations and other activities to continue the research conversations started in this research workshop. If you'd like to give a presentation in such a webinar, please contact Maureen Lackner or Huong Nguyen.

7. **Informal coffee chat time (15-20 min).** ***Please stay around to chat with EDF staff members and other workshop participants to meet and bring up anything you're interested in that we didn't have time for in the formal agenda.***

Policy-relevant outstanding research questions on oil and gas methane

These questions are introduced in the EDF Economics Discussion Paper Policy instrument options for addressing methane emissions in the oil and gas sector (Section 6, page 56-58).

1. What are the barriers to adoption of methane abatement technologies and approaches in the oil and gas industry? How do these barriers differ across the oil versus gas segments and upstream versus midstream and downstream segments? Related to this, what do marginal abatement cost curves look like when estimated using methane measurement data and real-world observations on company decisions? Are net negative abatement costs real or are they explained by unaccounted for cost categories?

2. What have been the methane emission impacts of regulations such as LDAR and restrictions on venting and flaring in different jurisdictions where these regulations have already been implemented? Having methane measurement data before and after implementation and from comparable jurisdictions with and without these types of regulations will enable researchers to enhance previous findings on the effectiveness of these types of regulations.

3. How effectively have existing policies and regulations for addressing methane emissions been implemented, monitored, and enforced in different jurisdictions? How can capacity-building efforts target any identified gaps in existing monitoring and enforcement approaches?

4. What are potential opportunities for firms to misreport under MRV regulations? Under policies that price methane emissions, firms will have an incentive to look for loopholes. What are potential gaps in MRV systems or perverse incentives in the design of MRV regulations, and what are approaches for addressing them? How could policy be designed to handle MRV-related disputes? For example, how could parties resolve a situation where remote sensing at the regional level does not match the bottom-up measurements from MRV, or where an exporting country asserts MRV of emissions that the importing country refuses to accept as sufficiently robust?

5. Are there trade-offs in allocating effort to avoid super-emitting events versus managing everyday leaks? Could mechanisms such as escalating penalties for large emitting events or repeated super-emitting detections be designed to find a balance in incentives for addressing these different categories?

6. What is the estimated methane emission impact of MRV-based policy instruments such as methane emission pricing or emission performance standards in different oil- and gas-producing countries? How do these emission impacts compare to those achieved with direct regulations that do not rely on emissions quantification?

7. What is the impact on methane emissions of a methane procurement standard implemented in different oil- and gas-importing countries?

8. How does the choice of GWP for methane influence the mitigation incentives to address methane relative to other GHGs under an ETS compared to tradable and non-tradable performance standards or an emissions fee when the instruments also cover GHGs other than methane? How could the choice of conversion rate be corrected to adjust for the uncertainty in reported methane emissions and the associated probability of non-detected methane emissions?

9. What is the incidence of different policy instrument options? How are the compliance costs of these regulations distributed across different market actors? What is the ultimate impact on end users' energy bills of different policy instrument options?

10. What are the environmental justice implications in terms of local air pollution and employment impacts of different policy instrument options in different local, regional and national jurisdictions?

11. How do joint-venture contracts and production-sharing agreements affect incentives to address methane emissions and how would these interact with, or be influenced by, different policy instrument options? Which instruments are more likely to be effective for addressing methane emissions from assets with coproduction of oil and gas?

12. How do long-term contract terms in the LNG market impact the possibilities to pass through any methane emission penalties applied to the buyer's side to upstream suppliers and producers?

13. What are the potential impacts on global methane emissions of the emerging market for natural gas certified to have low methane emissions? How robust are the certification programs used and how large are the leakage effects propagated through the global market for natural gas?

New research questions raised in connection with February 2024 workshop

14. Are there adverse consequences of flaring restrictions in terms of increased venting and if so how large are they in terms of increased CH_4 emissions in different countries/regions/basins? What are possible regulatory options and solutions – beyond proportional penalties (emission prices) for the associated CO_2 and particularly the CH_4 emissions – to deal with this tradeoff? What solutions are more likely to work in developed vs developing country contexts depending on the strength of local institutions and regulatory regimes? [from Thomas Sterner] See e.g., Calel and Mahdavi (2020) here: https://www.pnas.org/doi/full/10.1073/pnas.2006774117

15. How do companies' respond to alerts and information on super-emitter events at their facilities? How does the way that the information is communicated affect company responses and behavior? Do detection thresholds influence company responses to the public availability of remote sensing data on emission events and if so, how can different remote sensing sources complement each other to address this? See e.g., Lewis, Wang, Ravikumar (2023) here: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4461096

16. What do all these international voluntary methane frameworks plus different international laws/regulations do to the global LNG spot market? One way to think of the LNG spot market is that LNG tankers decide mid-transit which port has the highest price and go there. With many regional frameworks and regulations, each port has a different set of compliance regulations for how the gas was produced upstream. If I'm an LNG tanker, I can't just go to the port with the highest price – I have to consider price and the other potentially upstream attributes of the gas I'm carrying. So many overlapping and frameworks. Does this deconstruct the law of one price, and/or lead to spatial and temporal price volatility? Could that have an impact on transition away from coal in some countries? [from Ben Gilbert]

17. What kinds of distortions of incentives are implied in these EU regs (or the new US EPA regs)? Like CAFE standards for cars, where you have an incentive to build huge SUVs and tiny commuter cars – can you be encouraged to buy a bunch of low emitting gas to balance out high emitting in order to hit intensity target? Does this distort gas supply? [from Ben Gilbert]

18. How can/should measurement and inventory estimates be resolved? This is not yet clear. The approach should be rigorous but also simple/transparent. Will everyone in a basin get the same top down correction? If so, what's the value of better spatial resolution then? [from Ben Gilbert]

19. How does private certification interact with new US regulations? Can you comply with the law using certification? Does certification get you anything more than compliance? [from Ben Gilbert]

20. Policy ambiguity: there may be strategic interpretation of the law [the new US statutes on a waste methane emission charge in particular]: not just strategic behavior in response to the law's incentives but incentives to interpret the law strategically. What does that do to models of equilibrium behavior? Could come up with very different equilibrium emissions depending on assumptions about how operators interpret the law. [from Ben Gilbert]

21. How much different is the SCC of methane if we consider climate impacts of ground level ozone (also a GHG) AND local impacts on crops and health of ground level ozone. [from Ben Gilbert] See e.g., McDuffie et al (2023) here: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2023EF003853

Select methane science papers focused on oil and gas methane emissions

1. Alvarez, R. A., Zavala-Araiza, D., Lyon, D. R., Allen, D. T., Barkley, Z. R., Brandt, A. R., ... & Hamburg, S. P. (2018). Assessment of methane emissions from the US oil and gas supply chain. *Science*, 361(6398), 186-188. https://www.science.org/doi/10.1126/science.aar7204

   Reconciliation of bottom-up estimates of methane emissions from oil and natural gas sources to top-down estimates in nine U.S. O/NG production areas.

2. Conrad, B. M., Tyner, D. R., Li, H. Z., Xie, D., & Johnson, M. R. (2023). A measurement-based upstream oil and gas methane inventory for Alberta, Canada reveals higher emissions and different sources than official estimates. *Communications Earth & Environment*, 4(1), 416. https://www.nature.com/articles/s43247-023-01081-0)%20

   A measurement-based, source-resolved, hybrid top-down/bottom-up methane inventory for conventional upstream oil and gas operations in Alberta. Demonstrating the importance of empirical data (site-level) to improve understanding of total magnitude of emissions as well as key sources of emissions.

3. Foulds, A., Allen, G., Shaw, J. T., Bateson, P., Barker, P. A., Huang, L., ... & Schwietzke, S. (2022). Quantification and assessment of methane emissions from offshore oil and gas facilities on the Norwegian continental shelf. *Atmospheric Chemistry and Physics*, 22(7), 4303-4322. https://doi.org/10.5194/acp-22-4303-2022

   Reporting CH4 fluxes derived from 13 aircraft surveys on the Norwegian continental shelf.

4. Omara, M., Zavala-Araiza, D., Lyon, D. R., Hmiel, B., Roberts, K. A., & Hamburg, S. P. (2022). Methane emissions from US low production oil and natural gas well sites, *Nat. Commun.*, 13, 2085. https://www.nature.com/articles/s41467-022-29709-3

   Integrating national site-level O&G production data and previously reported site-level CH4 measurement data and find that low production well sites are a disproportionately large source of US O&G well site CH4 emissions

5. Omara, M., Gautam, R., O'Brien, M., Himmelberger, A., Franco, A., Meisenhelder, K., ... & Hamburg, S. (2023). Developing a spatially explicit global oil and gas infrastructure database for characterizing methane emission sources at high resolution. *Earth System Science Data Discussions*, 2023, 1-35. https://essd.copernicus.org/articles/15/3761/2023/essd-15-3761-2023-discussion.html

6. Ravikumar, A. P., Tullos, E. E., Allen, D. T., Cahill, B., Hamburg, S. P., Zimmerle, D., ... & Rucker, S. (2023). Measurement-based differentiation of low-emission global natural gas supply chains. *Nature Energy*, 8(11), 1174-1176. https://www.nature.com/articles/s41560-023-01381-x

   Multi-scale measurements conducted through various technologies such as satellites, aerial systems, drone systems, OGI camera surveys and continuous monitoring systems, along with operational data, provide primary information on GHG across the natural gas supply chain to the point of delivery include (transparent and public) models, data-quality metrics, reporting frameworks, and independent verification methods.

7. Rutherford, J.S., Sherwin, E.D., Ravikumar, A.P. et al. Closing the methane gap in US oil and natural gas production emissions inventories. *Nature Communications* 12, 4715 (2021). https://doi.org/10.1038/s41467-021-25017-4

   Based on an updated synthesis of measurements from component-level field studies, the authors develop a new inventory-based model for CH4 emissions, for the production-segment only, that agrees within error with recent syntheses of site-level field studies and allows for isolation of equipment-level contributions.

8. Shen, L., Gautam, R., Omara, M., Zavala-Araiza, D., Maasakkers, J. D., Scarpelli, T. R., ... & Jacob, D. J. (2022). Satellite quantification of oil and natural gas methane emissions in the US and Canada including contributions from individual basins. *Atmospheric Chemistry and Physics*, *22*(17), 11203-11215. https://acp.copernicus.org/articles/22/11203/2022/

   Using TROPOMI satellite data to quantify methane emissions from individual oil and natural gas basins in the US and Canada using a high-resolution (~25 km) atmospheric inverse analysis. A good illustration of the limitations of using TROPOMI to produce independent, robust regional-level estimates

9. Stavropoulou, F., Vinković, K., Kers, B., De Vries, M., Van Heuven, S., Korbeń, P., ... & Röckmann, T. (2023). High potential for CH4 emission mitigation from oil

infrastructure in one of EU's major production regions. *Atmospheric Chemistry and Physics*, 23(18), 10399-10412.
https://doi.org/10.5194/egusphere-2023-247

Methane emission quantification from onshore oil production sites in Romania at source and facility level using a combination of ground-based measurement techniques.

Select economics and policy papers focused on oil and gas methane emissions

1. Agerton, M., Gilbert, B., & Upton Jr, G. B. (2023). The economics of natural gas flaring and methane emissions in US shale: An agenda for research and policy. *Review of Environmental Economics and Policy*, 17(2), 251-273.
https://www.journals.uchicago.edu/doi/abs/10.1086/725004

An interdisciplinary literature review on measurement of natural gas venting, flaring and leaking. The authors marshal granular industry data to identify constraints in the natural gas system correlated with upstream VF&L and discuss the economic reasons for VF&L and the market distortions that could exacerbate VF&L.

2. Cicala, S., Hémous, D., & Olsen, M. G. (2022). Adverse selection as a policy instrument: unraveling climate change (No. w30283). *National Bureau of Economic Research*.
DOI 10.3386/w30283

This paper evaluates a policy that gives firms the option to pay a tax on their voluntarily and verifiably disclosed emissions, or pay an output tax based on the average rate of emissions among the undisclosed firms. The certification of relatively clean firms raises the output-based tax, setting off a process of unraveling in favor of disclosure. The paper applies this policy design to internalize the cost of methane emissions from oil and gas production in the Permian basin in Texas and New Mexico.

3. Clausing, K A., Wolfram, C., Garicano, L. & Garicano, L, How an International Agreement on Methane Emissions Can Pave the Way for Enhanced Global Cooperation on Climate Change (June 13, 2023). *Peterson Institute for International Economics Policy Brief No. 23-7*, Available at SSRN:
https://ssrn.com/abstract=4477571

Clausing and colleagues recommend that the United States and the European Union coordinate their methane reduction policies and eventually impose border adjustments on imports from countries that fail to raise their standards. The aim would be to encourage oil and gas exporters to adopt comparable regulations or, if they fail to do so, pay a border adjustment fee on exports to the two jurisdictions. A US-EU methane border adjustment policy in oil and gas would reduce methane emissions by an estimated 15 to 45 percent worldwide, while having an indiscernible effect on key energy prices US and EU households face. With time, most major energy importers would ideally join the coalition of countries cooperating on both stringent domestic regulations on oil and gas production and border adjustments on any dirty, nonregulating exporters. Such an international agreement would help defuse frictions caused by differing climate policies and increase incentives for ambitious climate policy action worldwide.

4. Dunkle Werner, K. and Qiu, W. (2020). Hard to measure well: Can feasible policies reduce methane emissions? Job Market Paper 54. Berkeley, CA: University of California, Berkeley.
   https://karldw.org/papers/Karl_Dunkle_Werner_JMP.pdf

   This paper simulates the effectiveness of different audit policies through development of a theoretical model of emissions abatement at the well level. The model demonstrates that properly targeted audit programs could significantly improve policy outcomes while still only auditing a fraction of wells.

5. IEA (2023), The Imperative of Cutting Methane from Fossil Fuels, IEA, Paris
   https://www.iea.org/reports/the-imperative-of-cutting-methane-from-fossil-fuels

   In the Net Zero Emissions by 2050 Scenario, a huge scale up in clean energy drives down fossil fuel use and this naturally leads to lower methane emissions; however this report finds this is not sufficient to reduce methane emissions at the necessary pace and scale to avoid the worst effects of climate change. Additional, targeted actions to tackle methane emissions from fossil fuel production and use are essential to limit the risk of crossing irreversible climate tipping points and can also lead to benefits for public health.

6. Lackner, M., Camuzeaux, J., Kerr, S., Mohlin, K. (2021). Pricing Methane Emissions from Oil and Gas Production*. Environmental Defense Fund Economics Discussion Paper Series,* EDF EDP 21-04
   https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3834488

   This paper provides a preliminary assessment of how a well-designed price on methane emissions from oil and gas production could be implemented in addition to existing regulations in a way that incentivizes oil and gas companies to increase their mitigation efforts and improve their methane detection and measurement practices.

7. Lewis, E. and Wang, J. (Lyra) and Ravikumar, A., Incentives and Information in Methane Leak Detection and Repair (May 27, 2023). Available at SSRN: http://dx.doi.org/10.2139/ssrn.4461096

   The paper studies an experiment which randomized whether site operators were informed of methane leakage volumes. At sites with zero measured leakage, giving firms information about methane emissions increased emissions at endline. Results suggest that giving firms news of low leakage disincentivizes maintenance effort, thereby increasing the likelihood of future leaks.

8. Marks, L. (2022). The abatement cost of methane emissions from natural gas production. *Journal of the Association of Environmental and Resource Economists*, *9*(2), 165-198.
   https://www.journals.uchicago.edu/doi/epdf/10.1086/716700
   This paper estimates the cost of reducing methane emissions from the extraction segment of the industry by examining how production facilities' emissions respond to natural gas prices.

9. Mohlin, K., Lackner, M., Nguyen, H., & Wolfe, A. (2022). Policy instrument options for addressing methane emissions from the oil and gas sector. *Environmental Defense Fund Economics Discussion Paper Series,* EDF EDP 22-01
   https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4136535

   The objective of this paper is to give policy makers, regulators, and other stakeholders a description of the main policy and regulatory levers available to realize the significant methane mitigation opportunities in the oil and gas sector. It aims to provide an overview of the different policy instrument options and thereby help policy makers assess which option is most attractive given regional circumstances and the relevant regulatory and political constraints.

10. Mohlin, K., Piebalgs, A., & Olczak, M. (2021). Designing an EU methane performance standard for natural gas. European University Institute.
    https://cadmus.eui.eu/handle/1814/70535

    A methane performance standard on natural gas can be defined for the upstream segments of the gas supply chain using an existing methane emissions reporting framework (OGMP 2.0) and targets and definitions already developed by industry. A methane performance standard could take the form of a mandatory

requirement that all natural gas sold on the EU internal market meets a benchmark upstream emission intensity value equivalent to 0.2%. To cover both imported and domestically produced gas, the point of obligation for a methane performance standard would likely need to be all EU gas shippers. To incentivize shippers to conform with the performance standard, they would need to be penalized for the portion of their gas volumes for which the methane emission intensity exceeds the benchmark value.

Select environmental economics papers using satellite data

1. Jain, M. (2020). The benefits and pitfalls of using satellite data for causal inference. *Review of Environmental Economics and Policy*. https://www.journals.uchicago.edu/doi/epdf/10.1093/reep/rez023

   Abstract: There has been growing interest in using satellite data in environmental economics research. This is because satellite data are available for any region across the globe, provide frequent data over time, are becoming available at lower cost, and are becoming easier to process. While satellite data have the potential to be a powerful resource, these data have their own sources of biases and error, which could lead to biased inference, even if analyses are otherwise well-identified. This article discusses the potential benefits and pitfalls of using satellite data for causal inference, focusing on the more technical aspects of using satellite data. In particular, I discuss why it is critical for researchers to understand the error distribution of a given satellite data product and how these errors may result in biased inference. I provide examples of some common types of error, including nonrandom misclassification, saturation effects, atmospheric effects, and cloud cover. If researchers recognize and account for these potential errors and biases, satellite data can be a powerful resource, allowing for large-scale analyses that would otherwise not be possible.

2. Fowlie, Meredith, Edward Rubin, and Reed Walker. 2019. "Bringing Satellite-Based Air Quality Estimates Down to Earth." *AEA Papers and Proceedings*, 109: 283-88.
   DOI: 10.1257/pandp.20191064

   Abstract: We use state-of-the-art, satellite-based PM 2.5 data products to assess the extent to which the Environmental Protection Agency's existing, monitor-based measurements over- or underestimate true exposure to PM 2.5 pollution. Treating satellite-based estimates as truth implies a substantial number of "policy errors"—overregulating areas that are in compliance with the air quality standards and under-regulating other areas that appear to be in violation. We investigate the health implications of these apparent errors. We also highlight the importance of accounting for prediction error in satellite-based estimates. Once prediction errors are accounted for, conclusions with regards to "policy errors" become substantially more uncertain.

3. Zou, Eric Yongchen. 2021. "Unwatched Pollution: The Effect of Intermittent Monitoring on Air Quality." *American Economic Review*, 111 (7): 2101-26. [DOI: 10.1257/aer.20181346](https://doi.org/10.1257/aer.20181346)

   Abstract: Intermittent monitoring of environmental standards may induce strategic changes in polluting activities. This paper documents local strategic responses to a cyclical, once-every-six-day air quality monitoring schedule under the federal Clean Air Act. Using satellite data of monitored areas, I show that air quality is significantly worse on unmonitored days. This effect is explained by short-term suppression of pollution on monitored days, especially during high-pollution periods when the city's noncompliance risk is high. Cities' use of air quality warnings increases on monitored days, which suggests local governments' role in coordinating emission reductions.