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COMMENT

Comment on 'US power sector carbon capture and storage under the Inflation Reduction Act could be costly with limited or negative abatement potential'

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1. Introduction

Since the enactment of the Inflation Reduction Act (IRA) of 2022[1], there have been several analyses released projecting its impacts on the U.S. energy system. The March 2023 paper, 'US power sector carbon capture and storage (CCS) under the IRA could be costly with limited or negative abatement potential' by Emily Grubert and Frances Sawyer[2] and published in this journal, uses a utility sector, profit-maximizing algorithm to estimate future costs and emissions benefits from the enhancement of the 45Q carbon oxide capture tax credit[3]. The paper's algorithm projects the installed capacity and utilization of CCS equipment by existing fossil fuel electricity generating units (EGUs) through 2050. Unfortunately, the authors' simplified assumptions are flawed and fail to account for relevant regulatory constraints, IRA incentives beyond the 45Q credit, and energy system complexities that, if properly considered, would preclude the paper's results. Even though there is transparency with cost and performance assumptions that are not representative of carbon capture retrofits, the apparent inaccuracies in the paper's narrative distinguishes it from other analyses by offering an incomplete perspective. This commentary seeks to address facts that have been distorted or omitted in the original work and demonstrate that the article's modeling does not incorporate existing, new, and anticipated realities affecting EGU operations.

2. Regulatory considerations

Grubert and Sawyer are clear that their calculations do not take into account system-wide factors and obliquely urge state and local regulators to scrutinize proposed carbon capture projects, but they do not provide any evidence that electricity providers will be permitted to retrofit existing facilities with capture technology to receive the 45Q tax credit for a 12 year period, then inactivate the equipment, and subsequently emit unabated CO_2 emissions. Among the considerations described in other sections, this dystopian assertion fails to account for the role of regulatory requirements within the system.

In 2007, the Supreme Court held in *Massachusetts v. EPA*[4] that greenhouse gases (GHGs) fit within the definition of air pollutant in the Clean Air Act (CAA) and that EPA has the authority to regulate these emissions if it finds that GHGs threaten public health or welfare. EPA issued an endangerment finding in December 2009 asserting that GHGs 'may reasonably be anticipated to endanger the public health and to endanger the public welfare of current and future generations'[5]. Following the endangerment finding, EPA

[1] Inflation Reduction Act of 2022, Pub. L. No. 117–169 2022 www.congress.gov/bill/117th-congress/house-bill/5376/text.

[2] Grubert E and Sawyer F 2023 US power sector carbon capture and storage under the Inflation Reduction Act could be costly with limited or negative abatement potential *Environ. Res.: Infrastruct. Sustain.* **3** 015008.

[3] International Energy Agency 2023 Section 45Q Credit for Carbon Oxide Sequestration. www.iea.org/policies/4986-section-45q-credit-for-carbon-oxide-sequestration.

[4] *Massachusetts v. EPA* 549 U.S. **497** 532–533 2007.

[5] U.S. Environmental Protection Agency Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act. 74 Fed. Reg. 66 496, 66 523 (15 December 2009). www.epa.gov/climate-change/endangerment-and-cause-or-contribute-findings-greenhouse-gases-under-section-202a. In addition to the endangerment finding, EPA also made a cause or contribute finding in which the Administrator found that the emissions of GHGs from new motor vehicles contribute to the greenhouse gas pollution that threatens public health and welfare. In 2010, EPA issued the Light-Duty Vehicle Rule establishing GHG emission standards for vehicles.

promulgated emissions standards for light-duty vehicles; once those standards took effect, GHGs were 'subject to regulation,' triggering EPA regulation of GHG emissions from stationary sources, beginning in 2011.

Under sections 111(b) and 111(d) of the CAA, EPA is required to promulgate GHG standards for new, modified and existing stationary sources, including fossil fuel-fired electric generating units (EGUs).[6] While EPA has discretion in determining the level of stringency, the standards must reflect emissions limits that are achievable through the best system of emissions reductions (BSER) that is adequately demonstrated.[7] Therefore, economic feasibility, technological readiness, and equipment availability are used to justify the level of required emission reductions. EPA proposes, in a rule published in May 2023 (after the release of Grubert and Sawyer's paper), to revise the performance standards for GHG emissions for certain new and reconstructed fossil fuel-fired EGUs and to establish new GHG emissions guidelines for certain existing fossil fuel-fired EGUs.[8] EPA determined that 90% carbon capture with storage is cost-effective, achieves significant emissions reductions, and is adequately demonstrated and therefore constitutes BSER for several categories of EGUs.[9] If EPA promulgates these standards as proposed, many sources of fossil fuel-fired EGUs would be expected to use CCS to meet the standards, and the EGUs will be required to continue complying with the standards as long as they remain in effect.

In their 12 year plant lifespan extension scenario (the paper only measures the impact from retrofitting existing coal and natural gas facilities), it is projected that 90% of coal EGU capacity and 65% of gas capacity will elect to install capture equipment to maximize profit. Despite the economic benefits and availability of operable equipment that must be in place to bring such a reality to fruition, the authors assume that it will be turned off as a cost-saving measure upon the credit expiration without any obstacles, as decisions are only 'driven by profit' (Grubert and Sawyer 2023, p 2).

3. Modeling and technical considerations

The inability of Grubert's and Sawyer's Excel model to recognize how one aspect of the energy system affects another prevents it from issuing accurate projections. A 2021 letter by Grubert used the same methodology and noted its 'lack of explicit policy modeling' (Grubert 2021, p 4). Since, in addition to the CCS tax credits, the IRA enhances incentives for alternative low-carbon, utility-scale generation technologies, battery storage, end-use efficiency measures, and electric vehicles (EIA 2023b), the impacts of the legislation make the 2019 baseline used in Grubert's and Sawyer's analysis obsolete. Even though the authors accurately note that company-specific revenue considerations do not necessarily correlate with system-wide optimization, operational decisions cannot be made independently from policies, regulations, and the consumer response. For example, IRA provisions promoting end-use technologies such as rooftop solar and heat pumps will retard utility-scale electricity demand growth, while electric vehicle credits will accelerate it. Understanding how such effects influence overall demand is necessary to predict individual plant responses and is absent from the paper.

In its *Annual Energy Outlook 2023,* DOE's Energy Information Administration incorporated the IRA provisions into its Reference Case[10], but also included a scenario that excluded the law's impacts (EIA 2023b). Using the National Energy Modeling System (NEMS), EIA projected that the law would accelerate the deployment of renewable energy generation and battery storage while reducing fossil fuel generation. Coal generation slides from 959 billion kilowatthours (kWhs) in the 2019 baseline to 243 billion kWhs in 2050 with the IRA. This compares to a 2050 projection of 411 billion kWhs without it. Likewise, natural gas generation falls precipitously when the IRA provisions are incorporated: projected 2050 generation is 931 billion kWhs with the law, versus 1460 billion kWhs in its absence.[11] Countering such trends were large increases in renewable generation and battery storage. 2019 utility-scale renewable capacity (232 Gigawatts (GW)) is projected to increase by more than 500% by 2050 with the IRA bonus credits (1162 GW) but less than 400% without them (841 GW). While electric power sector GHGs lessen without the IRA, the rate of decline is steeper with the law. Coal-fired electric power plant emissions diminish from 967 megatonnes (Mt)

[6] 42 U.S.C. §7411(b), (d).

[7] 42 U.S.C. §7411(a).

[8] New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions From Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule. 88 Fed. Reg. 33 240, 33 243 (23 May 2023). www.federalregister.gov/documents/2023/05/23/2023-10141/new-source-performance-standards-for-greenhouse-gas-emissions-from-new-modified-and-reconstructed.

[9] *Id.* at 33 245.

[10] The *AEO 2023* Reference Case assumes that only coal plants with capacities greater than 500 MW and with heat rates lower than 12 000 Btu per kWh would be considered for CCS retrofits.

[11] Utility-scale natural gas units generated 1322 billion kWh of electricity during the 2019 baseline year.

CO_2-equivalent in 2019 to406 Mt CO_2-e in 2050 without the IRA, however 2050 coal emissions are projected to decline by an additional 162 Mt from the law's impacts. Similarly, the IRA results in anticipated 2050 natural gas emissions that are 182 Mt lower relative to the no-IRA scenario[12] (EIA 2023b). In the near term, the Rhodium Group projects 2030 electric power sector emissions to be slightly less than half of their level had the IRA not been passed; this is by far the largest reduction from any of the modeled sectors (Larsen *et al* 2022).

EPA recently released output summaries from its integrated planning model (IPM) that corroborates the *AEO* narrative (EPA 2023). With the IRA, 2050 projected renewable generation is 28% higher than without it, whereas projected coal and natural gas 2050 generation again have the inverse relationship to the law. EPA projects that 2050 coal generation will only total six billion kWhs with the law, compared to 163 billion kWhs in its absence; the IRA pushes 2050 natural gas generation nearly 50-percent lower, according to IPM.[13] EIA (NEMS) and EPA (IPM) both anticipate small amounts of electricity supplied from fossil fuel EGUs with CCS, although EPA's forecast is larger. According to the Agency, at its peak in 2040, about 1.7% of U.S. electricity will be generated from CCS-equipped units (EPA 2023).

Grubert's and Sawyer's paper notes that their modeling is 'particularly sensitive to irregularities in the base year' (Grubert and Sayer, p 4) and explains why pre-pandemic electricity data was chosen. However, as utilities face their final decision year in 2032 to retrofit existing units with CCS, assuming the credit is not extended by that time, their assets will be operating within a system that is different from the assumed baseline. According to EIA data (2023b), 231 GW of coal capacity generated 959 billion kWhs of electricity in 2019. Thirteen years later–the final opportunity to commence retrofitting while retaining 45Q credit eligibility–EIA projects that 97.3 GW of coal capacity will supply the grid with 333 billion kWhs of electricity. This results in the 2019 system-wide average of 4.2 billion kWhs per GW declining to 3.4 billion kWhs per GW in 2032. Although system-wide metrics significantly diverge from plant-level circumstances, fossil fuel units are expected to continue experiencing capacity factor (CF) declines. The core scenarios (Group 1) of the analysis assume a 90-percent minimum CF for coal-fired facilities and a 70-percent rate for natural gas generators whenever CCS equipment is operational. According to EIA Electric Power Monthly data, in 2019, the baseline used in the analysis, utility-scale U.S. coal-fired power plants ran at a 47.5-percent CF. Natural gas combined cycle units ran 53.7% of the time, while the U.S. fleet of gas turbines had an 11.3% CF (EIA 2023a). Even on the dubious assumption that increases in CF of more than 100% will clear all environmental regulatory hurdles, it does not mean that such practices will be allowed by system operators.

4. Relevant energy system factors

When assuming the sole impact of the 45Q tax credits will be to maximize electricity provider profits from CO_2 production on retrofitted units, the authors omit essential context on the role of tax credits in emissions reductions and launching nascent technologies. The low-cost renewable energy generation technologies that are now projected to reduce U.S. GHG emissions were developed by similar production and investment tax credits (PTC and ITC), beginning in 1992 and 2006, respectively (DSIRE 2022). As these credits were renewed and expanded, sometimes after lapses, the technologies became more reliable, efficient, and cost competitive. Working concurrently with federal incentives were state renewable portfolio standards. During the 2000s and 2010s, several federal renewable standards were considered, and NEMS modeling showed they were consistently less effective at near-term GHG mitigation than cap-and-trade programs (Namovicz 2008). Over the past decade, however, as the levelized costs of wind and solar technologies have dropped below those of dispatchable units (EIA 2022), fossil fuel power sector emissions have begun what is projected to be an inexorable, deepening decline. Despite the 2032 expiration date in 45Q incentive eligibility, other clean energy projects will continue to be able to select the IRA-enhanced PTC or ITC if annual power sector emissions have not fallen to 25% of the 2022 level (Bistline *et al* 2023), a glaring omission from a paper that predicts GHG impacts.

Section 45Q tax credits will also enable the development of abatement projects within sectors for which alternative GHG mitigation methods do not exist. A wide divergence of estimates is found on increased mitigation costs if carbon capture, utilization, and storage (CCUS) and carbon dioxide removal (CDR) is not available in the coming decades, but most projections show that CCUS, bioenergy with carbon capture and storage, and technological CDR are necessary to curb emissions without heavy reliance on large-scale land use, land-use change, and forestry measures (Browning *et al* 2023). These technologies can be deployed for capturing and storing emissions from industrial processes or towards achieving negative carbon lifecycles for fuel and power production (Cooper *et al* 2022). CO_2 transportation and storage expenditures range from

[12] EIA's electric power sector emissions do not include upstream emissions from fuel processing.
[13] EPA's IPM output includes end-use capacity and generation that were not included in EIA's electric power sector projections.

5%–11% of current total pre- and post-combustion system costs (Balaji and Rabiei 2022, Chen *et al* 2022). Their learning curves are projected to remain flatter than those of capture systems and will comprise a greater share of system-wide expenses as the technologies mature. Pipelines with larger diameters are more cost-effective per ton-mile of CO_2 transported (Balaji and Minou 2022). This has resulted in the planned design of capture hubs with shared infrastructure development outside the plant gate to minimize costs (U.S. Department of Energy 2022). Rather than viewing infrastructure associated with fossil-fueled generators as spurring the development of systems with more favorable carbon lifecycle estimates as learning matures and equipment is repurposed, the authors see a potential need to prioritize certain categories of capture, but do not include any evidence that electric power sector CCUS hinders industrial CCUS when the opposite appears more likely.

5. Conclusion

By not accounting for regulatory requirements, excluding other policies and incentives in the IRA, and taking a myopic view of the impact of carbon management technologies, Grubert's and Sawyer's revenue-maximizing algorithm provides an erroneous and deeply misleading assessment of the impacts of the 45Q tax credit. Furthermore, it overlooks environmental sustainability obligations, net-zero greenhouse gas emission pledges, and shareholder accountability measures that impact electric utility operational decisions (Dotson and Maghamfar 2023). Overall, the results reflect the core input assumption: fossil fuel unit operators will maximize revenue, regardless of prohibitive external factors. Such results, while provocative, do not reflect reality and require additional context.

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