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HOW BIG IS THE "BIGGEST CLIMATE SPENDING BILL EVER?" KEY FACTORS INFLUENCING THE INFLATION REDUCTION ACT'S CLEAN ENERGY IMPACTS

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How Big is the “Biggest Climate Spending Bill Ever?” Key Factors Influencing the Inflation Reduction Act’s Clean Energy Impacts

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ABSTRACT

The Inflation Reduction Act could deliver more than $1 trillion in tax expenditures and outlays targeting clean energy deployment, but considerable uncertainty characterizes the economic, emissions, energy, and fiscal implications of the law. I review the features of the political system governing implementation, the regulatory system overlaying performance standards, the innovation responding to IRA incentives, and the energy networks in which IRA-supported investments operate to identify the key factors influencing IRA’s outcomes. Drawing from past research and policy experience, I illustrate how these factors could play out and how future program evaluation could reduce uncertainty and inform better climate policy.

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1. Introduction

At the signing of the Inflation Reduction Act (IRA) of 2022 into law, President Biden referred to the legislation as "the most aggressive action ever, ever, ever, ever in confronting the climate crisis and strengthening our energy security."[1] This sentiment has been echoed by an array of observers, with commentaries from the Council on Foreign Relations, the International Monetary Fund, and EarthJustice describing the law as "the largest investment in climate action in U.S. history," "the most significant piece of climate legislation in the history of the United States," and "the biggest climate spending bill ever" (Hill and Babin, 2022; Bordoff, 2022; Hanson, 2024). In terms of the initial fiscal score produced by the Joint Committee on Taxation (JCT) and the Congressional Budget Office (CBO) (2022), IRA is expected to represent the largest combination of clean energy tax expenditures and appropriated outlays of any single piece of federal legislation, with its $391 billion well surpassing the approximately $100 billion of clean energy spending associated with the American Recovery and Reinvestment Act of 2009 (Council of Economic Advisers, 2016).

The legislative design of the IRA, however, results in considerable uncertainty around its emissions, energy, economic, and fiscal impacts. The IRA relies extensively on tax credits, most of which extend for a decade without limitation on their potential claims by taxpayers. In crafting the changes to the Internal Revenue Code (IRC), Congress created wholly new tax credit provisions – such as the hydrogen production tax credit; added multiple bonuses to tax credits based on the geography of the investment

[1] Remarks by President Biden at Signing of H.R. 5376, The Inflation Reduction Act of 2022, August 16, 2022, https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/08/16/remarks-by-president-biden-at-signing-of-h-r-5376-the-inflation-reduction-act-of-2022/.

and the sourcing of American-manufactured components – such as in the renewable power investment tax and production tax credits; and introduced an array of conditions on some existing tax credits – such as the tax credit for electric vehicles purchased by individuals. Prospective analyses of the IRA have varied in how they have interpreted the changes in tax law, which has resulted in a considerably large range in estimates of the law's likely fiscal impact (Figure 1). Some analysts project Federal tax expenditures and outlays nearly triple the initial JCT/CBO score (e.g., Bistline et al., 2023b; Della Vigna et al, 2023).

The emission impacts of the IRA also vary considerably. One recent modeling comparison exercise employing six national energy-economic models showed that U.S. greenhouse gas emissions would range between 33 and 40 percent below 2005 levels in 2030 (Bistline et al., 2023a). Given the current U.S. pledge under the United Nations Paris Agreement to cut emissions at least in half by 2030 (U.S. Government 2021), the residual effort necessary to attain that goal differs significantly over this range. It is important to recognize that in these emission scenarios, the Federal outlays and tax expenditures are much closer to (and in some cases exceed) $1 trillion than they are to the initial JCT/CBO score.

In this paper, I examine a set of key factors that influence how the political system, regulatory system, innovation, and energy networks interact with and determine the impacts of the IRA. The political system influences the interpretation of the law, such as the drafting of implementation rules and guidance, and hence the incentives faced by businesses and households. The regulatory system layers on performance standards for specific energy-intensive sectors that can amplify the incentives for clean energy investment. Innovation by clean energy firms responds to deployment subsidies, with stronger incentives for commercially-oriented research and development (R&D) that can improve technical efficiency, lower costs, and accelerate greater adoption of clean energy technologies. The energy network in which each new element of clean energy capital operates can either enhance its emissions

impact – e.g., a subsidized electric vehicle powered by zero-carbon electricity in the local power grid – or limit its benefits – e.g., insufficient supply of public charging systems may limit EV adoption.

I review and synthesize the relevant literature to identify how these factors may influence the performance of the IRA. Specifically, I highlight key insights from past Federal efforts to subsidize clean energy investment. In addition, I illustrate how recent political and regulatory actions may affect the emissions, economic, energy, and fiscal outcomes of the IRA, and address next steps for scholarship and ex post performance evaluation of the law.

2. The Political System: Translating Statutory Authority into Implementation

The IRA reveals the political preferences of the pivotal decision-makers – in Congress and the White House – necessary to ensuring the bill's passage into law. Some politicians focused on cutting greenhouse gas emissions, while others focused on increasing U.S. manufacturing capacity. Some politicians called for targeting spending on historic fossil fuel-reliant communities, while others called for targeting spending on low-income and historically disadvantaged communities. To secure majorities in the U.S. House of Representatives and Senate, the IRA became much more than simply climate change policy. In the IRA, there are numerous statutory provisions in which their design reflects multiple social goals, including industrial, labor, distributional, and place-based objectives. The expanded set of legislative goals and the associated novel legislative designs have precipitated extensive review and revision of the Internal Revenue Service (IRS) guidance documents and rules.

In crafting policies that attempt to address multiple goals, the IRA has made the clean energy tax landscape more complicated. The expanding complexity of tax credits and the introduction of new tax credits requires Treasury and IRS staff to interpret the authority specified in the law in drafting implementation guidance and regulations for taxpayers. The need for such guidance and regulations

creates opportunities for interested parties to lobby the Treasury, the White House, and other executive branch agencies with equities in the tax rule-writing process (e.g., Department of Energy in some contexts, the Department of Transportation in others).

Consider the production tax credit (PTC) for producing power from a wind farm (and other renewable sources). Before IRA, every wind tower built in a given year enjoyed the same PTC per megawatt-hour of output. These varied over time, reflecting both inflation indexing and modest adjustments in Congressional tax extender bills, but the rules and the value of the PTC have always been the same for taxpayers associated with wind towers that enter into service in the same year. Under the IRA, the PTC for generating power at a wind farm may vary based on the use of American-manufactured content (such "Buy American" provisions elicit support among representatives of districts with significant manufacturing activity), employment of labor consistent with prevailing local wages and apprenticeship programs (provisions typically associated with and supported by unionized labor), operation in a low-income community (supported by progressives who called for more clean energy spending in historically disadvantaged communities), or operation in a historical energy community (supported by Senator Manchin of West Virginia with the aim of attracting more investment to Appalachian coal country). While the tax credit would not vary based on the carbon intensity of power displaced by the wind farm, the value of the credit could range from $5 per megawatt-hour to at least $30 per megawatt-hour based on the labor, industrial, and place-based characteristics of the projects.

In the IRA, Congress established a new tax credit to support a low-carbon hydrogen industry, the section 45V hydrogen PTC. The value of this tax credit varies with the carbon intensity of production, which effectively requires an assessment of the carbon intensity of the power coming from the electricity grid serving a hydrogen production facility. Treasury and IRS staff must confront an issue that rarely arises in the tax code: how to structure a tax credit for a taxpayer that accounts for the environmental attributes of a good produced by a third party and used by the taxpayer in its production

process. Should the value of the PTC reflect the average annual carbon intensity of the grid? Should the taxpayer demonstrate that the sourced electricity is additional to what the grid would have produced, and then account for the carbon intensity of this additional power? Should the taxpayer account for the carbon intensity of locally-sourced power, or may it contract for zero-carbon power elsewhere and employ the environmental attribute of this contracted power for purposes of claiming the tax credit? How the investment fits within and interacts with the existing (and evolving) energy system prompts fairly technical, untraditional tax questions that have major stakes. LCRI et al. (2023) modeled a set of scenarios with various interpretations of the section 45V tax provision. They found that how IRS answers these questions could determine whether this tax credit decreases or increases emissions, i.e., it's possible that a subsidy intended to support "green" hydrogen could increase emissions relative to the status quo. Moreover, they found that some interpretations could result in tax expenditures from this one IRA provision alone of up to $750 billion.

An array of special interests lobbied Treasury extensively on the Section 45V hydrogen production tax credit implementation regulation. The IRS issued a proposed regulation in December 2023, and as of the two-year anniversary of the IRA becoming law, taxpayers were still waiting for the promulgation of the final implementation regulation. And once Treasury and IRS finalize the rules governing a tax provision, it will take time for taxpayers (and the tax law firms advising them) to understand how the guidance influences their investment and operational decision-making.

In the context of electric vehicle (EV) subsidies, the political imperative to modify the individual tax credit to address industrial policy and distributional objectives has prompted interesting diplomatic and business responses. Prior to the passage of the IRA, an individual buying an EV could claim a $7,500 tax credit. Under the IRA, the tax credit is reduced (or eliminated) for an EV if its battery components do not meet minimum thresholds for sourcing critical minerals extracted or processed in the United States or a country with which the U.S. has a free trade agreement. The full value of the tax credit also requires EV

assembly in North America. In addition, the law imposes eligibility constraints on the individual tax credit with the intent of directing EV sales towards middle- and lower-income households that may be more likely than higher-income households to switch from an internal combustion engine vehicle to an EV in response to a subsidy. A new EV buyer would qualify for the tax credit if their income did not exceed $150,000 and the vehicle price did not exceed $55,000. . Given that high-income households traditionally claim the vast majority of EV tax credits (Borenstein and Davis, 2016, 2024), the income and vehicle price limits could make this tax credit more progressive.

The design of the EV tax credit spurred two unintended actions. First, leasing of EVs, especially for vehicles that would not satisfy the price limits or the battery and assembly conditions under the individual tax credit, has increased dramatically. The leasing arms of major automobile manufacturers serve as the corporate buyer of EVs, qualifying for the $7,500 federal tax credit on the corporate side of the internal revenue code (IRC). These leasing firms have typically set leasing terms that pass the tax credit through to the leasee. In the fourth quarter of 2022, just after the passage of the Inflation Reduction Act, 1 in 20 EVs were leased; 95 percent were purchased by a consumer. In the first quarter of 2024, the lease share of the new EV market exceeded 60 percent (Libby, 2024). Indeed, a number of foreign-owned manufacturers, including Audi, BMW, Lexus, Mercedes-Benz, Mini Cooper, Nissan, and Polestar, have models with lease penetration rates exceeding 90 percent in 2024.

Automakers and political leaders in Japan and the European Union criticized the requirement that the manufacturing of the battery should source critical minerals from the United States or a country with which the U.S. has a free trade agreement. Since the IRA does not define or specify “free trade agreement,” some creative discretion coupled with diplomacy has developed a work-around for Japanese companies. The United States and Japan negotiated a narrow free-trade agreement addressing exclusively the critical minerals used in battery manufacturing (Kitamura, 2024). The net effect of these implementation responses – through the so-called “lease loophole” and the tailored U.S.-Japan free-

trade agreement – will enable greater options for subsidized EV adoption in the United States, but with a weakened industrial policy incentive for enhancing domestic production to deliver these vehicles.

3. The Regulatory System: Layering Mandates on Industries Eligible for Clean Energy Tax Credits

U.S. clean energy investments have often benefitted from an overlapping mix of subsidies and regulations. Corn-based ethanol qualified for the volumetric ethanol excise tax credit as well as satisfied the requirements under the oxygenated fuel standard and, then subsequently, the renewable fuel standard under the Clean Air Act (Aldy, 2019). Wind, solar, and other renewable sources of power have generated revenue streams through the sale of credits under state renewable portfolio standards and qualified for Federal tax credits (Aldy et al., 2023). EVs satisfy the California Zero Emissions Vehicle Standard, serve as zero-emissions vehicles for automaker compliance under the EPA tailpipe emissions standard, generate bonus compliance credits under the Department of Transportation fuel economy standard, and qualify for Federal and, in some cases, state tax credits.

Layering regulatory mandates on top of tax credits has potentially significant environmental, fiscal, cost-effectiveness, and political economy implications. Before addressing these questions, consider how recent regulations mandating biofuels and establishing power sector greenhouse gas performance standards could increase the clean energy investment and tax expenditures associated with this investment compared to what would have been expected under only the IRA.

The IRA extended tax credits to subsidize cellulosic ethanol ($1.01/gallon) and biodiesel ($1.00/gallon) through the end of 2024, followed by a transition to a $1.00/gallon clean fuel production tax credit, which would apply to both types of fuels starting in 2025. The Energy Independence and Security Act of 2007 amended the Clean Air Act by vesting authority with the EPA to set volumetric targets for various types of biofuels, including cellulosic ethanol and biodiesel. In 2023, the EPA issued a

final regulation setting new Renewable Fuel Standard targets for these and other categories of biofuels over 2023-2025 (U.S. EPA, 2023). In the absence of the 2023 regulation, cellulosic and biodiesel production was projected to decline from its 2022 levels through 2025 (see Table 1). With the rule, EPA projects that in 2025, cellulosic ethanol will nearly double its 2022 level and biodiesel to increase by nearly one-third. Assuming all producers of these fuels claim (or transfer) their biofuel tax credits, the new renewable fuel targets under this EPA regulation would result in a more than doubling of tax expenditures relative to the U.S. EPA no-regulation baseline. Without the regulation, tax expenditures would sum to about $7 billion over 2023-2025, and with the rule they would exceed $15 billion.

In the power sector, the IRA modified and extended the Section 45Q tax credit for carbon sequestration. For example, a coal-fired or natural gas-fired power plant that captures carbon dioxide from its combustion process and stores the captured gas can claim up to $85 per metric ton of carbon dioxide. The amount of the tax credit varies with the nature of the storage – dedicated geologic storage earns the maximum, while using the carbon in products or storing in oil and gas fields yields up to $60 per metric ton (Jones and Marples, 2023). The tax credit is also reduced by 80 percent for carbon capture projects that fail to satisfy prevailing local wage and apprenticeship program labor requirements.

In 2024, U.S. EPA promulgated greenhouse gas emission standards for fossil fuel-fired power plants. This regulation compels new and existing coal-fired and natural gas-fired power plants – at various dates over the next decade – to install carbon capture equipment with a capture efficiency of at least 90 percent of the carbon dioxide produced in combustion. This regulatory mandate interacts in two ways with the IRA's tax provisions. First, the regulation increases demand for carbon capture activity that will spur greater claims of the 45Q tax credit. Second, the regulation will accelerate fossil fuel power plant retirements, increasing demand for alternative sources of electricity, including renewable sources that will result in more claims of the PTC or investment tax credit (ITC).

U.S. EPA (2024c) illustrates the emissions and energy impacts of the tax-regulation interaction and, with some assumptions about the value of the claimed tax credits, can inform an estimate of the change in tax expenditures expected under full implementation of the rule. In 2032, the U.S. EPA rule plus the IRA tax credits result in 59 Terawatt-hours (TWh) of coal and natural gas production with carbon capture and storage technology, nearly double the 33 TWh expected under only the IRA (see Table 2). The EPA rule is also expected to stimulate an additional 54 TWh of non-hydropower renewable generation in 2032. While the IRA extends (with modification) the 45Q tax credit and the 45Y tax credit (for clean electricity production) through the end of 2032, any project placed into service by the end of that year can generate tax credits for the first 12 years of operation under 45Q and first 10 years of operation under section 45Y for clean electricity production.

Assuming a 90 percent efficiency in capturing carbon dioxide, the minimum required under the EPA rule, the cumulative quantity of carbon dioxide captured would exceed 288 million metric tons ($MMTCO_2$) over 2029-2043. If all relevant projects satisfy the prevailing wage and apprenticeship program labor requirements, the EPA regulation would increase cumulative tax expenditures for carbon capture and sequestration under 45Q by about $31 billion and cumulative tax expenditures for renewable power generation under 45Y by about $17 billion. This illustrates how a regulation targeting one set of sources – coal and gas-fired power plants – can influence demand for and associated tax expenditures for other sources – renewable power plants – operating in the same energy markets.

Employing multiple policy instruments to target one market failure, such as the carbon dioxide pollution externality, risks reducing cost-effectiveness and efficiency. Indeed, such a belt and suspenders approach to policy could increase costs with no incremental change in environmental outcomes (Goulder and Stavins, 2011; Levinson, 2011). These two examples of layering regulations on top of IRA tax credits may reflect a political economy that suggests some incremental benefits from combining policy instruments. U.S. EPA (2023, 2024b) acknowledges that the presence of the clean energy tax credits

increases the feasibility of setting more ambitious environmental standards and enables it to select carbon capture and storage technology as one option for a "best system of emission reduction," the guiding statutory requirement under the Clean Air Act. Indeed, U.S. EPA (2024) notes in the first paragraph of the 260+ page final rule that "a range of cost-effective technologies and approaches to reduce greenhouse gas emissions (GHG) from these sources is available to the power sector – including carbon capture and sequestration/storage (CCS), co-firing with less GHG-intensive fuels, and more efficient generation. Congress has also acted to provide funding and other incentives to encourage the deployment of various technologies, including CCS, to achieve reductions in GHG emissions from the power sector (p. 39799).

Employing a combination of policy instruments may also serve as insurance against future political or judicial reversal of policies. On the one hand, if a future Congress rewrites the IRC to reduce or eliminate access to these tax credits, then the regulation would deliver some energy and environmental outcomes. On the other hand, if a future Federal court strikes down the U.S. EPA regulation, then the IRA subsidies would deliver at least some of the envisioned energy and environmental outcomes. There is historical precedent for this combining of tax and regulatory policies in the energy sector. In 2015, the U.S. EPA issued the Clean Power Plan, emission performance standards for the electric power sector, and Congress passed an omnibus legislative package that included 5-year extensions to the renewable power production tax credit and investment tax credit.[2] U.S. EPA never implemented the Clean Power Plan, with Federal courts staying its implementation and the Trump Administration withdrawing the regulation and substituting the Affordable Clean Energy rule in its place (U.S. EPA, 2024b). Despite the absence of the power sector regulation, the increasing deployment of renewable power enabled by the tax credits resulted in the U.S. power sector meeting the emission goals set in the Clean Power Plan nearly a decade earlier than the rule's deadlines (Ramseur, 2023). This rapid transformation of the power sector's

[2] Consolidated Appropriations Act, 2016, Public Law 114-113, December 18, 2015.

emissions profile reflects in part the impact subsidies have had on cost-reducing technological innovation.

4. Innovation: Endogenous Technological Change under Clean Energy Subsidies

A clean energy technology may merit a subsidy under two conditions: the adoption of the technology would reduce adverse environmental externalities and, in the absence of the subsidy, the cost of the technology is prohibitive for potential adopters. The risk, however, in subsidizing novel energy technologies is that the subsidy necessary to spur adoption may be quite costly per unit of environmental benefit. For example, Marcantonini and Ellerman (2015) evaluated German subsidies for solar power over 2006-2010 and estimated that the program reduced carbon dioxide emissions at a cost in excess of €500 per ton. The cost-effectiveness of this program compared quite poorly to the EU Emission Trading System which had marginal abatement costs of about one-fiftieth the level of the solar subsidy program during this time. Such a static analysis, however, fails to account for the impacts of innovation in driving down costs over time and enabling greater adoption in future time periods (Gillingham and Stock, 2018).

To explore the impacts of generous solar subsidies on innovation, Gerarden (2023) studied how such subsidies build out a market that induces innovation by manufacturers over time. He shows how solar panel manufacturers responded to the German subsidy regime by investing in new processes that both lowered costs and improved the conversion efficiency of solar panels. As a result, Gerarden finds that pre-2010 German subsidies resulted in large, global dynamic spillovers. This innovation increased solar adoption by more than 50 percent over 2010-2015 and more than 80 percent of the incremental solar adoption induced by this innovation occurred outside of Germany.

The dramatic decline in solar panel prices contributed to significantly more solar adoption – and associated tax expenditures – in the United States than initially anticipated. In 2008, Congress passed legislation that extended the ITC for solar power through 2016 and increased its value to 30 percent of eligible investment expenses. At the time, the JCT estimated that this provision would result in about $2 billion in tax expenditures. Over 2009-2016, a taxpayer could claim either the ITC or the section 1603 grant in lieu of tax credit for investment in a solar power project under the American Recovery and Reinvestment Act. The grant in lieu of tax credit was designed to be on par with the ITC, with both subsidies covering 30 percent of eligible investment expenses (Aldy, 2013). By the end of 2016, outlays through the grant programs plus tax expenditures for solar projects through the ITC exceeded $30 billion, about 15 times the *ex ante* fiscal estimate issued by the JCT. While investment costs fell, the increased adoption more than offset the cost-reductions from the tax expenditure perspective. Today, solar power represents the single largest category of new electric power investment in the United States (U.S. EIA, 2023).

Similarly in the wind power context, Covert and Sweeney (2024) estimate a structural industrial organization model of wind turbine manufacturing to show that manufacturers likewise realize benefits from learning by doing. While most of these benefits are appropriated within the firm, they estimate that some learning spills over to competitors. Each doubling of manufacturing output enables these firms to reduce their manufacturing costs by 14 to 29 percent. Just as in the solar case, a subsidy in one period can facilitate lower-cost adoption in a later period. Such learning-by-doing could play an important role in the next generation of emerging clean energy technologies, such as utility-scale battery storage, green hydrogen, and more.

Firm innovation is reflected in both lower costs of manufacturing wind turbines and in improved efficiency of producing electricity from wind. The rate of change in both cost-reductions and efficiency enhancements has exceeded expectations. For example, the U.S. Energy Information Administration

(EIA) projects the capacity factor and estimates the levelized cost of electricity (LCOE) for new wind farms as a part of its *Annual Energy Outlook* modeling exercise. In addition to these forward-looking projections, the National Renewable Energy Laboratory (NREL) reports realized capacity factors and technology costs (to produce a measure comparable to the LCOE) as a part of its annual *Cost of Wind Energy* publication series. As illustrated in the first row of Table 3, the forecast of onshore wind LCOE that the U.S. EIA made in 2011 for the year 2016 was nearly double the realized cost reported by NREL. Moreover, NREL reported that onshore wind turbines installed in 2016 realized a capacity factor of 41 percent, considerably higher than the 35 percent projection made by U.S. EIA in 2011 for that year. This trend continues over time, as costs fall to lower levels than projected by U.S. EIA and realized capacity factor utilization rates exceed their projections.

The dynamic impacts of innovation not only improve the cost and technical efficiency profiles of clean energy technologies, but may also enable greater distribution and adoption of clean energy. The initial adopters of clean energy technologies have typically skewed towards higher-income households (Borenstein and Davis, 2016 and 2024; Barbose et al., 2020). As early adopters build out the market, creating the incentive for manufacturers to innovate and drive down costs, this could benefit later adopters who enter a market characterized by lower-priced clean energy options. This could more equally distribute the benefits of tax credits for EVs and other novel energy technologies and play a key role in making progress on the Biden Administration's Justice40 goal that 40 percent of the benefits of clean energy investments flow to disadvantaged communities in the United States. Moreover, the global spillovers reflected in Gerarden (2023) indicate that subsidizing clean energy could enable adoption of inexpensive solar modules in developing countries, facilitating lower-cost decarbonization of their electric power systems.

Making available subsidies for clean energy technology does not guarantee deployment, learning-by-doing, and cost savings over time. Take the case of the section 45J nuclear power PTC established in the

Energy Policy Act of 2005.[3] This provision aimed to subsidize new nuclear power construction built over 2005-2021 through a production subsidy of 1.8 cents per kilowatt-hour for the first 8 years of service. A taxpayer could claim up to a maximum of $125 million per 1,000 MW of capacity (and prorated based on allocated capacity), with a national cumulative allocated capacity of 6,000 MW. Following the announcement of the tax credit, the U.S. Energy Information Administration (EIA) forecast a 6 gigawatt (GW) increase in nuclear generating capacity by 2020. Based on JCT projections in 2005, the 10-year cost of the credit for production from advanced nuclear power facilities was estimated at $278 million, wholly incurred between 2013 and 2015.

In practice, no new nuclear facilities came online before 2021, the Energy Policy Act's eligibility window for this tax credit. Despite the optimistic rhetoric of an emerging "nuclear renaissance" in the U.S. power sector when Congress passed this 2005 law, other factors in U.S. energy markets undermined the incentive to invest in new nuclear power plants. First, the price of natural gas fell considerably after 2008 and has remained low, enabling the growth of low-cost, gas-fired power. Second, the failure to pass carbon dioxide cap-and-trade legislation in 2009-2010 facilitated continued low-cost use of coal-fired and gas-fired plants, further reducing the need for new nuclear facilities.

In addition to spurring technological innovation, clean energy subsidies have spurred financial innovation. After Congress established the renewable power PTC through the Energy Policy Act of 1992, project developers faced a challenge in securing the full value of the subsidy; they typically had tax liabilities that fell far short of the value of their tax credits (as well as the value of their accelerated depreciation benefits). With tax liabilities limiting the extent to which a wind farm operator, for example, could claim tax credits, financial innovation enabled an alternative approach to monetizing the full value of these clean energy subsidies. In structuring the financing for a new wind farm project, an investor would provide so-called tax equity, an equity investment in which the investor's return on equity is

[3] Public Law 109-58, section 1306, August 8, 2005.

represented by securing the right to claim the project's tax credits and accelerated depreciation benefits. The emergence of the tax equity market – with large financial companies typically supplying this type of equity – enabled renewable power project developers to secure much more of the value of the clean energy tax expenditures under Federal law.

The supply of tax equity fell considerably during the 2008 financial crisis and, in response, the American Recovery and Reinvestment Act of 2009 gave taxpayers associated with a renewable power project the option of claiming either the PTC, the ITC, or the section 1603 grant in lieu of tax credit (Aldy, 2013). Project developers flocked to the grant in lieu of tax credit program, with grant outlays to wind power and solar power projects outpacing tax expenditures (Aldy et al., 2023). This reflected both the limited supply of tax equity, but also the substantial "haircut" in tax equity financing; the tax equity providers claimed about 15 percent of the value of the tax credits through these transactions (Johnston, 2019). In effect, the grants enabled the developer to capture much more of the Federal subsidy for clean energy than the tax credits.

The IRA introduced the option to taxpayers to transfer their tax credits. This transferability applies to most of the corporate tax provisions in the law, covering EVs, renewable power, hydrogen production, clean energy manufacturing, and more. For a given investment or production activity, the associated tax credits may be transferred once. Transferability provides much greater flexibility and lower transaction costs than tax equity deals. The supplier of tax equity for a wind farm, for example, would typically provide resources before the project has broken ground and would be a partner in the project for a decade after it has entered into service. A taxpayer buying transferable tax credits may do this on an annual basis after the project is in operation and could also purchase only a fraction of a project's credits. Such transactions involve bearing less risk about the project's prospects and less required due diligence. Moreover, the Treasury Department's online portal for registered projects enhances market

transparency. This can facilitate lower-cost search and matching of buyers and sellers as well as reduce the likelihood of fraud.

Early media reports of tax credit transfers indicate significantly lower transaction costs than under the old tax equity regime. Trade industry commentary suggests that transfer prices are likely to be on the order of 95 cents on the dollar (Martin, 2023). For example, First Solar announced that it would sell as much as $700 million in clean energy manufacturing tax credits to Fiserv for 96 cents on the dollar (Dwelt, 2023).

By lowering the transaction costs to claim tax credits, transferability increases the effective subsidy for clean energy through the tax code. As clean energy investment continues to grow in the U.S. economy, the difference between 95 cents on the dollar under transferability and 85 cents on the dollar through the former tax equity framework becomes significant. Given recent independent estimates that IRA clean energy tax expenditures could exceed $100 billion per year by the end of this decade (Bistline et al., 2023b), that difference represents about $10 billion per year in subsidies for clean energy developers. By increasing the returns to new clean energy projects, this policy and financial innovation should spur greater clean energy investment.

5. Energy Markets: Network Externalities and Clean Energy Subsidies

The economic, energy, and environmental impacts of many clean energy technologies depend, at least in part, on the characteristics of the broader energy system in which they operate. The emission benefits of subsidizing a wind farm will depend on the emission intensity of the alternative source of power that it displaces. The emission benefits of a new hydrogen facility will depend on the emission intensity of the grid. The emission benefits of a heat pump will likewise depend on the emission intensity of the local sources of power. Moreover, the scope and stringency of infrastructure siting policies and

processes may amplify or restrain the effectiveness of any subsidy to spur investment in new energy infrastructure.

Consider the case of electric vehicles. The adoption of EVs reflects not only the relative costs of electric and internal combustion engine vehicles, which targeted tax credits can address, but also access to networks of charging and refueling stations. The status quo technology and network enable quick, easy, nearby access for most owners of internal combustion engine vehicles to refueling. The time burden for owning and operating an EV differs considerably across owner types. The EV owner with the means for at-home charging may enjoy time savings, on the order of about $700 per vehicle, associated with avoided trips to a refueling stations (Dorsey et al., 2024). In contrast, the EV owner without a home-charging option (e.g., an individual who rents an apartment and only has on-street parking) could bear nearly $8,000 over the vehicle's lifetime in waiting and travel time associated with using public charging systems. This additional cost for using an EV for select types of owners may hinder widespread adoption.

Public investing in charging systems could accelerate EV adoption, as reflected in the policy experience in Norway (Springel, 2021). Over the past decade, Norway has employed generous subsidies for both EVs and for public charging stations, and the electric share of all new vehicles sold was about 95 percent in 2023 (International Energy Agency, 2024). In the early phase of EV adoption, Springel (2021) shows that each dollar of subsidy for public charging stations was nearly twice as effective in increasing EV adoption as each subsidy dollar for purchasing an EV. As the network of public charging grows and becomes saturated, the marginal impact of charging subsidies falls relative to the impact of EV purchase subsidies. In the United States, the Infrastructure Investment and Jobs Act of 2021 appropriated $5 billion for investment in public charging stations, but the roll-out of spending has been tepid with only 19 public chargers installed in the nearly first three years of the program (Ferris, 2024). This has reflected the challenges of integrating transportation and electrification planning among state agencies, electric utilities, and property owners who all must coordinate in charging station buildout.

Like other new clean energy technologies sourcing power from electricity, the climate benefits of EVs will depend on the carbon intensity of the local grid used for charging the vehicles. In the early phase of EV adoption in the United States, Holland et al. (2016) showed how large state-level EV purchase subsidies in Georgia, in conjunction with Federal tax credits, resulted in Atlanta having the most EVs of any major city in 2014, but at a cost to the environment. Given the coal-intensive power market at that time in Georgia, the pollution damage from an EV charged in Georgia exceeded the pollution damage of burning gasoline in an internal combustion engine in the state. At that time, EVs risked increasing carbon dioxide emissions relative to internal combustion engines given the reliance on coal for power in some regions of the country. With continued decarbonization of the power sector over the past decade, the switch from conventional gas-power cars to EVs generally reduce, on net, the carbon dioxide emissions associated with transportation. But it illustrates a broader phenomenon that still applies to other technologies in which the climate pay-off of the investment will depend on the continued building out and decarbonization of the electric power sector.

An array of factors can slow down the siting, permitting, and construction of clean energy infrastructure, such as renewable power facilities, as well as the transmission lines necessary to carry their power to consumers. The emergence of public processes and reviews for infrastructure development have created veto points and slow-down points that can increase the costs and reduce the probability of a developer successfully building a project. Litigation affecting clean energy projects based on claims of National Environmental Policy Act violations has become common, with nearly two-thirds of solar projects, more than one-third of wind projects, and nearly one-third of transmission projects subject to predevelopment litigation (Bennon and Wilson, 2023). Longer-distance transmission lines that span multiple utility jurisdictions and multiple states find that the potential allocation of winners and losers, especially among incumbent utilities, can create incentives for the potential losers to challenge new construction (Davis et al., 2023).

The nature of energy networks draws attention to two elements of clean energy policy that could play critical roles in decarbonizing the U.S. economy but were not incorporated in the IRA. First, the IRA did not address issues related to reforming the processes that govern the siting of energy infrastructure. Such policy and regulatory reforms were beyond the scope of what is permissible in a budget reconciliation legislative vehicle. The absence of meaningful reform of siting and permitting processes – across all levels of government – risks the IRA's clean energy provisions falling short of their full potential in decarbonizing the economy. Senator Manchin proposed a set of energy infrastructure permitting reforms that could not be incorporated into the IRA legislative package in a 2022 bill he intended as a companion bill to the IRA. The permitting reform bill did not become law in 2022.

Second, there is little implicit or explicit coordination of the decarbonization process across the energy system, which could be addressed by a carbon price. The patchwork of technology- and sector-specific tax expenditures and grants does not facilitate coordination on the objective of reducing emissions. The appeal of an economy-wide carbon price is that it can enable the firm or household deciding on an investment in a given clean energy technology to account for both the direct carbon impacts of the investment and its indirect effects through energy networks (as reflected in energy prices). A carbon price would also address the challenge of accelerating the retirement of coal-fired power plants. Subsidizing renewable and nuclear power as well as subsidizing electricity-consuming equipment and facilities (such as electric vehicles, heat pumps, and hydrogen manufacturing plants) may result in little market pressure to retire coal-fired power plants.

In the context of the EV example at the start of this section, a carbon price raises the cost of operating an internal combustion engine vehicle and it raises the cost of burning coal to produce power. The first effect can spur switching to EVS, while the second effect could spur switching to renewable, nuclear, and natural gas sources of power. In power markets dominated by coal, the price of electricity may increase significantly in response to a carbon price, especially if coal is the marginal source of power

in a given market. This may offset the cost advantage of buying an EV over an internal combustion engine vehicle, which is the socially desirable outcome if the EV would run on carbon-intensive power. The current mix of subsidies under the IRA deliver neither such coordination or a penalty on emission-intensive coal-fired power plants.

6. Conclusion and Opportunities for Future Research

The considerable uncertainty characterizing the IRA highlights the potential value of learning through the implementation of the law. Such learning would advance several policy goals. First, the IRA represents a large policy experiment across the U.S. energy system. Some policies will turn out to be more effective in cutting emissions, while others will fall short of initial expectations. These variations in realized outcomes may, as described above, reflect how political and regulatory interventions play out, the direction and pace of innovation, and interactions among energy networks. They may also reveal other factors, such as the evolution of consumer behavior. Identifying the most effective policies and understanding their primary reasons for success can then inform extensions and modifications of those policies in future legislation. And identifying the less-effective policies can motivate early rescissions and reallocation of resources and efforts to more socially valuable policies.

Second, learning how taxpayers respond to a given tax provision (and its associated guidance) may reveal unintended consequences that could be remedied through revised guidance. For example, in June 2011, Treasury updated its guidance for evaluating the cost basis of solar projects under the section 1603 grant program in response to concerns of excess grant payments for solar projects (U.S. Department of the Treasury, 2011). Learning of the need for more substantial reforms to the tax code could prompt efforts by the Treasury and IRS to work with committees of jurisdiction in Congress to craft necessary legislative revisions.

Third, rigorous evaluation of the performance of the IRA can inform the public, stakeholders, and policymakers about the impacts, benefits, and costs of the leading Federal clean energy policy. Given the large scope of policy objectives advocated by various special interests, Senators, and Members of Congress through the legislative process, there will undoubtedly be interested consumers of estimates of the emissions, labor market, manufacturing, innovation, and place-based outcomes caused by IRA tax expenditures and outlays. Enhancing the understanding of the social welfare impacts of this law could facilitate a more-informed public debate about the future of climate change policy.

Facilitating policy learning –to reduce IRA uncertainty, enable targeted policy reforms, and to enable better climate policy over time – requires the planning and execution of program evaluation (Aldy 2022). Such an approach has become an increasingly important part of Federal agencies' strategic planning and assessment. Under the Foundations for Evidence-based Policymaking Act of 2018, agencies publish period "learning agendas" that highlight their primary goals, metrics for demonstrating progress toward those goals, and strategies for program evaluation. Specifically, implementation guidance issued by the U.S. Office of Management and Budget emphasizes the implementation of program evaluation of important policies and programs.[4] Undertaking policy performance evaluations of IRA tax provisions, grant programs, and loan guarantee programs can advance learning on climate change and distributional outcomes that have been identified as strategic priorities in many agencies' learning agendas, including the U.S. Department of the Treasury's agenda. Given the novelty, complexity, and count of IRA clean energy provisions, many agencies would benefit from the contributions of research scholars to collaborate with government analysts to employ empirical evaluation strategies that produce rigorous evidence of the impacts of the law.

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[4] Refer to the U.S. Government's online program evaluation portal at https://www.evaluation.gov/.

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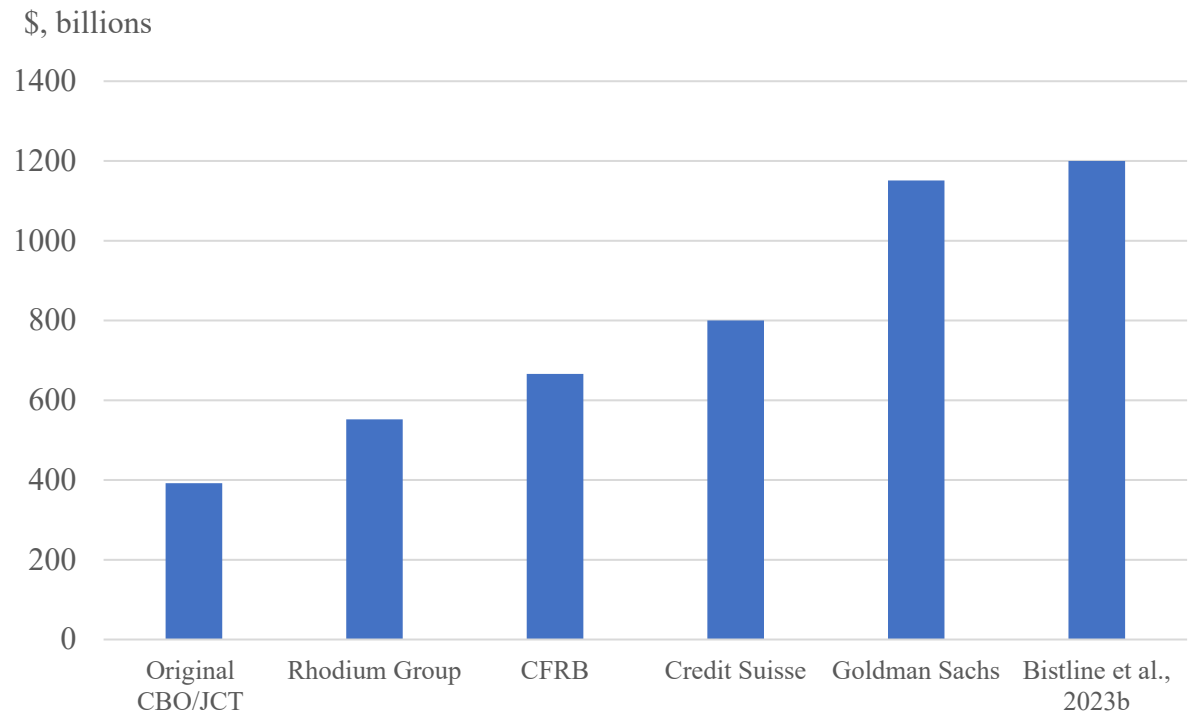
7. Figures and Tables

Figure 1. Estimated Tax Expenditures and Appropriations of the Inflation Reduction Act's Clean Energy Provisions



Notes: Estimates sourced from: Original CBO/JCT – Joint Committee on Taxation, 2022 and Congressional Budget Office, 2024; Rhodium Group – Larsen et al., 2023; CFRB – Committee for a Responsible Budget, 2024; Credit Suisse – Jiang et al., 2023; Goldman Sachs – Della Vigna et al., 2023; Bistline et al., 2023 refers to the upper end of the range presented in Bistline et al., 2023.

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Table 1. Biofuels Production and Tax Expenditures under the IRA and U.S. EPA Renewable Fuel Standard (RFS) Regulation for 2023-2025

		Production (million gallons)			Tax expenditures (million dollars)		
Scenario	Fuel	2023	2024	2025	2023	2024	2025
Baseline	Cellulosic	343	402	444	346	406	444
(No RFS)	Biodiesel	1719	1921	2132	1719	1921	2132
RFS	Cellulosic	838	1090	1376	838	1090	1376
	Biodiesel	3710	3846	4239	3710	3846	4239

Notes: Produced by author based on estimated production in Tables 2.1.5-2, 3.1-4, and 3.2-2 of U.S. EPA (2023). Both scenarios account for IRA tax credits for cellulosic ethanol and total biomass-based diesel. The RFS scenario also includes the U.S. EPA 2023-2025 RFS volumetric fuel targets for each fuel.

Table 2. Change in Electricity Generation, Carbon Dioxide Sequestered, and Tax Expenditures Expected under U.S. EPA Power Plant Performance Standard versus an IRA-only Scenario

Metric	Source	2028	2032	2036	2040
Change in Generation (TWh)	Coal + CCS	0	24	24	24
	Gas + CCS	0	2	2	2
	Renewable	50	54	54	2
Change in CO_2 Sequestered ($MMTCO_2$)	Coal + CCS	0	22.6	22.6	22.6
	Gas + CCS	0	1.5	1.5	1.5
	Renewable	–	–	–	–
Change in Tax Expenditures (million dollars)	Coal + CCS	0	2,201	2,383	2,579
	Gas + CCS	0	147	159	172
	Renewable	1,464	1,711	1,852	74

Notes: Produced by author based on estimated capacity investment and generation data presented in Tables 3-13 and 3-14 of U.S. EPA (2024c). For 45Q carbon capture tax credits and 45Y renewable production tax credits, all taxpayers are assumed to satisfy the prevailing wage and apprenticeship program labor requirements. Tax expenditures reflect the estimated impact of investment before the IRA sunset date for sections 45Q and 45Y plus the 12-year and 10-year, respectively, period of production after placement in service eligible for tax credit claiming under these provisions. Carbon capture efficiency assumed to be 90 percent in calculating the change in CO_2 sequestered. Tax credits are assumed to be indexed to a 2 percent annual inflation rate.

Table 3. Levelized Cost of Electricity, Onshore Wind Power, Forecast versus Realized, 2016-2022

EIA Annual Energy Outlook Publication Year	EIA Annual Energy Outlook Forecast Year	EIA Forecast LCOE ($/MWh)	NREL Realized LCOE ($/MWh)	EIA Forecast Capacity Factor	NREL Realized Capacity Factor
2011	2016	135	69	34	41
2012	2017	134	62	33	42
2013	2018	119	52	34	42
2014	2019	108	44	35	43
2015	2020	97	41	36	42
2016	2022	83	42	40	47
2017	2022	81	42	39	47
2018	2022	74	42	41	47

Notes: All costs expressed in 2024 dollars, converted using the GDP implicit price deflator for the first quarter of 2024. The Energy Information Administration (EIA) Annual Energy Outlook LCOE and capacity factor estimates are sourced from the online EIA AEO model documentation available at https://www.eia.gov/outlooks/aeo/. The realized National Renewable Energy Laboratory (NREL) LCOE and capacity factor estimates are sources from the online annual NREL reports on the Cost of Wind Energy available at https://www.nrel.gov/.