Supply, demand, and polarization challenges facing U.S. climate policies

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Abstract

The U.S. recently passed major federal laws supporting the energy transition, and analyses suggest that their successful implementation could reduce U.S. emissions more than 40% below 2005 levels by 2030. However, achieving maximal emissions reductions would require frictionless supply and demand responses to the laws' incentives, and implementation that avoids polarization and efforts to repeal or undercut them. In this Perspective we discuss some of these supply, demand, and polarization challenges. We highlight insights from social science research, and identify open questions needing answers, regarding how to address these challenges. The stakes are high: these new laws' successes could catalyze virtuous cycles in the energy transition, or their failures could breed cynicism about major government spending on climate change.

The U.S. recently passed three major laws aiming to reduce greenhouse gas (GHG) emissions to address climate change: the Infrastructure Investment and Jobs Act (IIJA, a.k.a. The Bipartisan Infrastructure Law[1]), the Inflation Reduction Act of 2022 (IRA[2]), and the CHIPS and Science Act[3]. Analyses suggest that these laws could reduce greenhouse gas (GHG) emissions by more than 40% below 2005 levels by 2030[4–6]. However, these analyses make strong assumptions about their political, social, and technical feasibility and the changeability ('plasticity') of human behavior—assumptions that may be overly optimistic.

Social science research suggests that there may be under-appreciated resistance to expanding infrastructure that increases energy transmission and supply, changing consumer demand in response to new incentives, and changing political processes required to enact policies at municipal, state, and federal levels. At the same time, social science research also suggests how these sources of resistance can be reduced and the plasticity of human behavior can be increased across contexts and at multiple levels.

Effectively delivering on the promise of U.S. climate policies requires an integration of relevant findings from social science, an appreciation of pressing open questions, and interdisciplinary efforts to pursue that integration and appreciation. With social-behavioral insights, it is possible that the new laws could catalyze virtuous cycles in the energy transition. Without them, ineffective policies could breed cynicism that actively undermines the energy transition. These questions are urgent, given the magnitude and timeline of the new laws.

U.S. climate policies

The IIJA, enacted in November 2021, allocates an estimated $23 billion per year to energy-transition initiatives[1, 5]. These focus on expanding electric vehicle (EV) charging stations and electricity transmission infrastructure, and upgrading rail and port infrastructure. The IIJA also provides funds for increasing the resilience of infrastructure to disasters and cleaning up legacy pollution[1]. The IRA spends an estimated $43 billion per year on energy-transition initiatives[2, 5]. This spending includes tax credits and rebates incentivizing households to adopt EVs, heat pumps, and rooftop solar, as well as funding for larger-scale wind, solar, and battery deployment[2]. The CHIPS and Science Act focuses on expanding supply and research and development in high-tech sectors[3, 5], with an estimated $13 billion per year funding carbon-free energy[5]. Together, these laws more than triple U.S. government spending on the energy transition, compared to the average of the previous decade[5] (Fig. 1a).

Policy analysts estimate these three pieces of legislation could substantially reduce U.S. greenhouse gas emissions, prompting a full-scale energy transition. From 2005-2021, the U.S. reduced GHG emissions by nearly 20%: a rate of 1.2% of 2005 emissions per year[6]. This rate would need to triple to meet the Biden administration's target of reducing emissions by 50-52%, compared to 2005, by 2030[7]. Analyses of the IRA and IIJA project that their incentives could accelerate GHG emissions reductions to 3% of 2005 emissions per year or more, reaching 43-48% below 2005 levels by 2030[6] (Fig. 1b).

However, these optimistic estimates assume frictionless supply and demand responses to the incentives. They also assume that the bills are not repealed or undercut by political polarization or dysfunction. If one or more of these assumptions fail, the policies are likely to fail to deliver on their projected potential. For example, restrictions on permitting or extensive regulatory restrictions could limit the supply of renewable energy. Rigid consumer habits in transportation, housing, and food consumption could limit behavioral plasticity[100]. Polarization could result in the bills being repealed in whole or in part, could interfere with funding of the bills, or could create barriers to partisans adopting the incentivized low-carbon behaviors.

Transmission and supply

Electricity transmission is a key constraint on the supply side. Even with high behavioral plasticity resulting in perfect demand responses and no political obstacles, up to 80% of the IRA's potential emissions reductions could be lost unless the rate at which transmission comes online more than doubles, from 1%/y to 2.3%/y[8] (Fig. 1b). Transmission connecting onshore wind capacity to the grid needs to accelerate most[8].

Permitting constrains U.S. development of electricity transmission for several reasons. Transmission projects must navigate complex and sometimes competing interests across large areas having multiple jurisdictions[10]. Permits must satisfy a complicated combination of environmental regulations, including those of the National Environmental Protection Act (NEPA), which requires in-depth reviews that take years to complete[11]. Each required review creates potential litigation exposure from interests vested in blocking the project. To illustrate the scale of the permitting challenge, consider that recent federal permitting processes for transmission projects have typically taken 6-8 years[11] (Fig. 2a), to which state-and-local permitting and litigation are additional. This challenge exists against the backdrop of a decline in the U.S.'s construction productivity since the late 1950s–despite substantial technological improvements during this period–also due in part to increasing regulatory burdens[12] (Fig. 2b). Related permitting challenges confront other types of infrastructure incentivized by the IRA such as rooftop and utility-scale solar.

What causes regulations to become burdensome to infrastructure projects? There are two broad categories of reasons: (i) competing objectives that motivate the regulations; and (ii) inefficiencies in regulatory processes that, if eliminated, could allow faster permitting without costs to the competing objectives. Competing objectives for regulations include, for example, environmental protection, stakeholder consultation and community consent, and occupational health and safety[13]. Sources of inefficiency include unnecessary regulatory complexity, duplication of reviews across jurisdictions or across similar projects, understaffing of regulatory agencies, and excess detail in reviews to avoid future litigation risk[14].

Proposals to reduce permitting barriers often aim to reduce perceived inefficiencies. For example, the SITE Act[15] would have centralized permitting authority for multi-state projects to the Federal Energy Regulatory Commission (FERC) (see also ref[10]). The Energy Independence and Security Act of 2022[16] would have time-limited environmental reviews and subsequent legal challenges, combining existing electricity markets, and establishing corridors that have existing rights of way[10] or low social and environmental risks for streamlined permitting[17]. The recent bipartisan agreement to raise the debt limit includes time limits on NEPA reviews[18].

However, it is difficult to entirely avoid tradeoffs between reducing regulatory burdens and meeting the objectives underlying regulations. Centralizing and streamlining permitting might mean that some stakeholders are not consulted, consent is not unanimous, or that some details are overlooked in environmental reviews. Conversely, extended and involved permitting processes could be more aligned with principles of just transition[19] and community buy-in, but could slow infrastructure construction and emissions-reductions.

Such tradeoffs take place against a backdrop of historical injustices regarding how and where transmission, among other energy systems infrastructure, is sited that have had adverse effects on disadvantaged communities. These include[20] distributional injustices (i.e., unequal allocation of benefits and ills, including the siting and access to energy services), recognition injustices (i.e., cultural domination, non-recognition, and disrespect), and procedural injustices (i.e., lack of access to decision-making processes). Addressing distributional justice in a project might involve the redistribution of benefits, which may enhance a sense of justice, but also may increase the polarization of the project depending on the methods of redistribution[21–23]. Addressing recognition justice requires addressing concerns regarding respect and power, which interacts with socioeconomic and cultural forces much broader than the specific project. Addressing procedural justice requires not just consultation but involving stakeholders throughout decision-making processes[20].

Historical injustices also create capacity constraints that may hinder uptake of IIJA, IRA, and CHIPS and Science Act incentives in other ways. For example, these laws earmark some investments for disadvantaged communities[1–3]. Yet, small rural towns and disadvantaged communities can face economic, social, and structural capacity challenges to capitalize on such investments[24]. Labor shortages in high-tech sectors and rural areas can also present capacity constraints for renewable energy projects[25].

Key questions for social science include how to help governments and citizens recognize and reconcile tradeoffs and synergies between streamlining infrastructure projects, remedying injustices, building capacity, and other objectives. For example, social science can reveal how to mobilize local knowledge unavailable to designers, developers, and policymakers, in ways that both increase capacity and address distributional, procedural, and recognition injustices[26, 27]. To address capacity, research has found training and recruitment programs that target disadvantaged communities can reduce both labor shortages and chronic un- and under-employment in these communities[25]. Advocacy capacity can help disadvantaged communities secure government infrastructure grants[24]. When tradeoffs are unavoidable, social science can also guide structured decision-making processes that make tradeoffs explicit and resolve them with procedurally fair processes. Of course, it will be important to delineate which aspects are amenable to social scientific study and which concern normative values, principles, and ethics that must be resolved by communities.

Consumer demand

The IRA[2] provides financial incentives to boost consumer demand for EVs, heat pumps, rooftop solar, and other low-carbon technologies. For some behaviors, such as adopting EVs, these incentives could increase uptake in pivotal ways for emissions reduction (Fig. 1c). Though financial incentives matter, social science has shown that the changeability (plasticity) of adopting and maintaining new behaviors is also sensitive to many other factors. Socio-political identities and attentional myopia, for example, can both affect consumer demand in ways that are difficult to predict from incentives alone, and some behaviors are more plastic than others[28]. Analysis of the impact of U.S climate policy should therefore identify and understand non-financial considerations that affect consumer behavior.

We provide a simple, qualitative example of such an analysis, focused on the IRA-incentivized behaviors (Table 1). (Quantitative analyses are also possible[28, 29].) Many of the behaviors incentivized by the IRA require up-front costs (which may be offset by the IRA's subsidies), but do not require changes in consumers' daily routines. These characteristics give the behaviors high plasticity[28]. Weatherizing one's home is a prominent example, because it requires a one-time investment of time and resources, in contrast to changing one's driving or carpooling behavior, which requires changes to one's daily routine[28]. Some IRA-incentivized behaviors also offer long-term economic benefits to households—such as lower energy costs—which may decrease how polarizing these behaviors are along the lines of political identity (Table 1). Nonetheless, there are broader factors affecting plasticity that social science offers insight into.

One obstacle to consumer adoption is the complexity and time required to utilize many financial incentives[39]. The varying structure of incentives in the IRA based on income, location, and manufacturing practices might overwhelm some consumers, leading to decision paralysis, particularly for those with limited resources. This, combined with time and cognitive scarcity[40]–especially for households with young children or struggling to meet basic needs–could result in lower adoption rates than predicted by economic models that only consider income constraints[41].

Social-political identities can also shape consumer behavior, beyond financial incentives, in ways that can constrain or accelerate consumer demand for low-carbon behaviors. For example, conservative consumers may avoid consumption of so-called 'green' behaviors such as adopting EVs or solar panels, even if such behaviors were in their financial interests, because they view them as associated with out-group 'environmentalist' identities[42, 43]. By the same token, liberal consumers may embrace so-called 'green' behaviors, even if those behaviors are not in their financial interests, because they align with their 'environmentalist' identities[44, 45]. These examples illustrate how consumer demand can be shaped by prevailing social norms and identities associated with low-carbon behavior.

A related challenge is that consumers misperceive public opinion and therefore norms. Americans underestimate support for climate policies and behaviors amongst their compatriots by 30-40 percentage points[46], a pattern that is especially pronounced among conservatives. These misperceptions may cause consumers to avoid seemingly 'green' behaviors more than they would if they had a more accurate picture of their in-groups' opinions. An urgent question for social scientists and policy makers is to understand the degree to which correcting false perceptions of climate concern might increase consumer demand for low-carbon products[47]. It is also important to understand why climate opinion is so widely misperceived. One possibility is that negative opinions of climate policies are overrepresented in media–similar to the 'balance as bias' phenomenon, whereby contrarian views of the physical science of climate change used to be widely overrepresented in media[48, 49].

Another potential constraint on consumer demand for low-carbon behaviors is that consumers are often focused on near-term considerations such as up-front installation costs, sharply discounting future benefits, such as the long-term savings benefits from solar panels, weatherization, or heat pumps[50, 51]. Such behaviors are relatively easy to adopt (because they do not require change in habits) and have some of the most impact on emissions[28], yet may be inhibited because of the upfront costs (Table 1). In contrast, many lower-cost behaviors—turning out the lights, adjusting thermostat settings, and purchasing 'climate friendly' consumer packaged goods—are also the least impactful. Yet consumers may be drawn to these low-impact behaviors because while they are relatively low cost, they involve repeated concrete actions that may intuitively seem to have high impact[52].

Simple informational interventions can help consumers to better appreciate the carbon footprint of various behaviors[53], reduce concerns about risks associated with low-carbon behaviors such as EV range anxiety[54], and change their behaviors accordingly[55, 56]. Other research suggests that orienting attention to distant future outcomes can reduce consumer myopia[57]. That might make it possible to mitigate myopia and misperceptions of carbon impact. However, informational interventions and attentional nudges have modest behavioral impact. It will be important to study the scalability and efficacy of these strategies in the specific context of IRA incentives.

Policy implementation design can reduce other barriers. Point-of-sale rebates provided in the IRA (e.g., tax credits for EVs applied at car dealerships) are an important component of user-focused policy design, but they are not universal to all products. Another potentially high-yield approach is to focus on training industry professionals who interface with customers such as HVAC specialists and sales representatives to effectively communicate the incentives to customers. Developing user-friendly software can simplify the incentive guidance and application process. A successful example of such implementation is the National Renewable Energy Lab (NREL)'s Solar Automated Permit Processing Plus (SolarAPP+), which reduced project turnaround time by 13 days and lowered inspection failures by 29%[58]. Leveraging artificial intelligence (AI) can reduce barriers by guiding users toward the incentives best suited to their needs. User-focused policy implementation design not only improves efficiency but also addresses distributional concerns by targeting critical barriers faced by working and middle-class households[39, 41].

Another important question is the degree to which financial considerations constrain or facilitate consumer adoption of low-carbon behaviors. Even the strongest environmentalist may not purchase EVs or solar panels if the costs exceed binding budget constraints. They also might delay major purchases requiring financing if faced with high interest rates, which often accompany inflation. Conversely, even a strong skeptic of electric vehicles—for example, someone who is highly anxious about 'range restriction'—may adopt an EV given sufficient incentives coupled with rising fuel costs. Even a consumer who is highly attentive to long term outcomes will nevertheless discount future outcomes relative to short-term outcomes; in fact, uncertainty makes discounting economically rational[59]. Thus, there is a limit to increasing concern for the future. Behavioral science research often emphasizes departures from neoclassical models of rational consumer choice[60]. Doing so skirts the all-important question of the degree to which consumers are swayed by financial considerations, how well their behavior is characterized by quasi-rational models of choice, and how much so-called 'behavioral' considerations influence preferences and decisions. What is needed are precise estimates of these relative influences on the plasticity of consumer demand for low-carbon consumption.

The discussion of plasticity of consumer demand implicitly assumes that all consumer segments are equal. Yet there are institutional, structural, and other systems factors that remove or perpetuate existing disparities and costs on disadvantaged communities. For example, higher-income consumers and homeowners are better able to take advantage of incentives for EVs and heat pumps. Lower-income consumers are less likely to be homeowners and may not have access to necessary financial resources; and when climate policies expand to include carbon pricing, lower income consumers will bear the brunt of those costs. Social science research suggests that such disparities can be offset, for example, by expanding access to inexpensive credit[61], or using carbon-tax revenue to fund rebates[62] or social-welfare programs. Pro-climate policies can enjoy broader public support when they emerge from inclusive deliberation among stakeholders[63], and they minimize their financial impact on citizens.

Reducing and preventing polarization

There is always a risk that political polarization will interfere with efforts to maximize the effectiveness of climate legislation. Polarizing policies may be repealed by subsequent governments or undermined by political opponents, and polarization can limit demand among consumers. This is illustrated, for example, by the partisanship that quickly surrounded COVID-19 vaccines and policies[64].

There was little public polarization of climate change in the U.S. until the 1990s, after which both the basic facts of climate change and policies to address it became highly polarized along left-right political lines[65]. Misinformation supported by special-interest groups contributed to the polarization[66, 67], but much of it can also be explained by the clash between libertarian aspects of U.S. conservative ideology and the idea of a large market failure–the negative externality of carbon pollution–that demands some form of government intervention to fix[68].

Recently however, there are some signs that the partisan landscape may again be shifting. Polls now find high, bipartisan public support for renewable energy and many specific climate policies (e.g.,[69, 70]), including many of the major provisions of the IIJA, IRA, and CHIPS and Science Act. The IIJA and CHIPS and Science Act were both bipartisan, and there have also been over 100 bipartisan state-level climate bills since 2015, some of which contain elements similar to those of the IRA[22] (Fig. 3a). Some low-carbon energy behaviors, such as purchasing heat pumps, may not yet be polarizing (Table 1). Denial of the basic physical science of climate change seems to be in retreat in both public opinion[71, 72] and news media[49], and worry about climate change is over 50% and rising for most segments of the electorate including liberal/moderate Republicans (Fig. 3b). Despite these trends, public polarization on climate policy questions remains high[71, 72], and a recent study found that polarization of news coverage of climate policies may be increasing[73].

Climate change policies can also be polarizing in ways that are partially or completely distinct from liberal-conservative or Democrat-Republican disagreements. For example, there are ongoing debates within the political left about whether technological solutions to climate change get in the way of broader left-preferred societal changes that some hope climate change would otherwise motivate (e.g., see refs.[74, 75]). There is also a debate within the political left about whether the causes of decarbonization, sustainability, and equity require fewer or more regulations on permitting and zoning[13]. Relatedly, local residents of all political stripes sometimes oppose renewable energy and sustainable infrastructure projects out of concern for local economic, environmental, or nuisance impacts–the so-called 'not in my back yard' (NIMBY) phenomenon[76]. Ongoing litigation efforts—both related to specific projects and related to governments' responsibilities to address climate change in general[77]—add another layer of complexity that could affect both regulations and multiple dimensions of polarization.

Social science can shed light on how to prevent polarization from hindering uptake of recent climate laws in several ways. First, social science can study how to design or frame policies and consumer behaviors so as to be less polarizing, within the limits of broader societal polarization. For example, studies of state-level decarbonization bills have found that bipartisan ones tend to reduce regulatory burdens on renewable energy[78], expand consumer and business choice, use financial incentives, and frame justice aspects in economic terms[22]. These are all features of the three federal laws[1–3]. Other research suggests that policy makers can avoid partisan opposition and encourage bipartisan policy support by using policy frames less likely to trigger culturally divisive partisan identities—for example, by emphasizing economic considerations and private-sector actions in addition to government policies[79]. Policy makers can also prevent partisanship by foregrounding non-partisan experts—who are widely trusted by liberals and conservatives alike—or bipartisan groups of legislators as policy communicators[64].

Second, social science can examine how much polarization of a particular policy or behavior must be reduced for it to be durable. It may often be the case that this requires only narrow bipartisanship. For example, the IIJA only garnered 32 Republican votes in Congress (13 in the House of Representatives, 19 in the Senate[1]), but has nonetheless been framed in the public discourse as bipartisan and has not been a target in recent election campaigns. Even without bipartisan passage, a policy may become durable if it gains broad enough public support, even despite initial polarization. The rise and subsequent subsidence of efforts to repeal the Affordable Care Act (a.k.a., 'Obamacare') may provide an example of this phenomenon (though the persistent refusal of several states to accept the Medicaid expansion illustrates its limits)[80].

Third, social science can explore the importance of polarization to state- and local-level implementation of the IRA, IIJA, and CHIPS and Science Act. For example, will partisanship prevent Republican state legislatures and local governments from making use of IRA-earmarked funds? The experience of Obamacare (e.g., its Medicaid expansion) suggests this is a possibility. On the other hand, Republican-controlled states and Congressional districts are some of the largest renewable-energy producers, and stand to gain the most from the IRA funds[81]. This may facilitate uptake of the IRA funds, but if not, it would imply an especially significant barrier to the IRA's success. The reshoring aspects of the IRA and CHIPS and Science Act—both explicitly focused on bringing manufacturing jobs back to the United States[2,3]—could also boost their popularity and durability at the state and local levels, in addition to having facilitated their passage at the federal level.

Fourth and relatedly, social science can contribute to managing the energy transition in ways that minimize its adverse impacts on communities currently dependent on the fossil-fuel industry. This is important to a just transition, and it can also help to make the transition less polarizing. For example, it is often possible to convert retired coal and natural gas plant sites into renewable power sources, either by leveraging the sites' pre-existing connections to the power grid or in some cases by repurposing the plants themselves (e.g., converting coal to nuclear)[82]. Worker trade skills are often transferable between fossil and renewable as well, though workers are often unable to relocate when new renewable jobs occur in different places from the fossil-fuel jobs they replace[83]. However, there are some fossil-fuel dependent regions that are also highly endowed with renewable energy resources (e.g., wind power in parts of Wyoming)[83]. Moreover, fossil-fuel dependent regions could serve as hubs for clean-energy manufacturing facilities (e.g., battery plants located in West Virginia).

Lastly, social science can examine how to reduce broader polarization, beyond the issue of climate change or these specific policies and behaviors. This is an active area of research, which is exploring both what societal conditions broadly alleviate or exacerbate polarization, and what micro-level interventions can reduce polarization at the individual and interpersonal levels (e.g., ref.[84]). Work in this area has shown, for example, that social media and news biases towards negativity and outrage have had wide-ranging effects exacerbating polarization[85, 86]; and that correcting misperceptions of out-group opinion (e.g., ref[87]) and promoting shared identities[88, 89] can have mitigating effects.

Virtuous cycles

It has taken decades for the U.S. to pass major federal climate legislation in the form of the IIJA, IRA, and CHIPS and Science Act. Yet there remain stark challenges to supply, demand, and continued political will to realize these laws' potential. Failing to address these challenges and to realize the laws' potential emissions reductions risks breeding cynicism about future major government-backed investments in addressing climate change.

Conversely, overcoming these challenges could produce accelerating benefits through virtuous cycles (Fig. 4). Behavior change and policies can reinforce themselves through social norms[90]. Private-sector innovation and decarbonization progress can increase the economic—and consequently political—feasibility of more ambitious decarbonization policies. For example, EVs and renewable electricity becoming scalable and cost competitive makes 100% EV and renewable electricity policy targets possible. Policies, such as vehicle-emission standards and subsidies for low-carbon home improvements, affect the options and prices available to consumers. Changing policies and social norms can even motivate businesses to adopt behaviors that go well beyond what current policies require. For instance, over 1,000 businesses have committed to the Science Based Targets Initiative, which combines business commitments to reduce emissions on a 1.5°C trajectory with third-party oversight by nongovernmental organizations[91]. Environmental, Social and Governance (ESG) has become a priority consideration for some of the world's largest investors[92], though ESG has also become polarizing and its effectiveness is being debated.

Such virtuous cycles create momentum that can accelerate decarbonization non-linearly and eventually make it unstoppable[101]. Learning by doing and economies of scale lower the costs of new technologies as they become more widely adopted[93]. Technologies and social norms both diffuse through social networks in a society in a manner that accelerates once a critical mass is reached[94,95]. Each of these forces may have contributed to the dramatic decline in prices of photovoltaic solar power[96]. Some scholars argue that electric vehicles may be nearing such a critical mass[97]. Social norms around conformism further reinforce widely adopted behaviors[90], and it can become impractical or inconvenient for consumers to revert from these behaviors. Policies can seed and accelerate this momentum, by promoting research and development or (indirectly) by shifting social norms[102], and polarization may be able to impede it. However, once behaviors and technologies reach critical-mass adoption and cost competitiveness, their momentum may become overwhelming—even if polarization persists. Widespread adoption of behaviors and technologies may also make them less polarizing.

In 2009, the Obama administration proposed the American Clean Energy and Security Act ('Waxman-Markey bill'), which would have implemented a cap-and-trade system, as well as renewable energy standards and subsidies[98]. Its goal was to reduce U.S. GHG emissions by 17% below 2005 levels by 2020. Its success might have faced similar challenges to those we describe above. The bill did not pass, but actual 2005-2020 U.S. emission reductions met the bill's target anyway[8] (Fig. 1b), due to a combination of increased efficiency, less expensive natural gas displacing coal, and cost-effective renewable expansion[99]—helped by bipartisan federal wind energy support and state-level renewable energy policies. Similarly, future decarbonization efforts by governments, businesses, and civil society can build on and support the incentives and ambitions of the IIJA, IRA, and CHIPS and Science Act. Integrated social science research and the application of social-behavioral insights can help to ensure that the benefits of these efforts are indeed realized.

Data availability

All data shown in Figs. 1-3 are attached as source data.

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Acknowledgements

We thank the participants of an October 2022 workshop on Social Science and Sustainability Technology at the University of Colorado Boulder for helpful comments and insights that inspired this article. We thank the Cooperative Institute for Research in Environmental Sciences (MGB, MB, LD) and the Center for Creative Climate Communication and Behavior Change (LVB) at the University of Colorado Boulder for funding.

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Ethics declarations

Competing interests

The authors declare no competing interests.

Table 1. Summary of information about technical potential, behavioral plasticity, and polarization for key household behaviors incentivized by the Inflation Reduction Act (IRA). Technical potential refers to the potential emission savings from adopting the behavior. We classify behaviors as having 'low', 'medium', or 'high' technical potential based on large studies[28, 29] comparing a wide range of behaviors. Behavioral plasticity refers to a behavior's changeability[28].

Individual action	Technical potential	Behavioral plasticity	Polarization information or hypothesis
Electric vehicle	High[29]: It decarbonizes a major source of transportation emissions, once the electricity grid is decarbonized.	Moderate or high[28]: It requires an upfront cost, but does not require changes to daily routine thereafter. Its plasticity could be affected by range concerns and polarization.	Previous research has found Democrats are more willing to buy EVs, but Republicans are more able to pay a price premium[30]. Car dealers are also predominantly Republican[31], and some prefer not to offer EVs[32].
Rooftop solar	High[29]: It decarbonizes household electricity.	Probably high: Like other one-time renovations, it has a large upfront cost, but does not require changes to daily routine thereafter[28].	Studies have found adoption slightly more common among Democrats, but with relatively little polarization[33, 34].
Electric heat pump for space heating and cooling	High[29]: It decarbonizes a major source of energy use.	High[28], for reasons similar to rooftop solar above.	Polarization may be low for home improvements, as climate change and politics may often not be the primary decision variable[35]. However, if heat pumps provide incomplete winter heating, that could increase polarization by making climate change more influential in adoption decisions.
Heat pump water heater	Probably moderate to high: water heating accounts for 20% of U.S. household energy use[36].	High[28], similar to heat pumps for heating and cooling.	We hypothesize that polarization is similar as for heat pumps for heating and cooling.
Insulation and air heating	High[29]: It can save energy on heating and cooling,	Probably high, based on estimates for similar	We hypothesize that polarization is low, as this is a

	but does not decarbonize the energy source.	behaviors[28], for reasons similar to rooftop solar above.	home improvement with economic benefits[37].
Weatherize windows and doors	High[28], due to the energy savings.	High[28], due to modest upfront cost, economic benefits of energy savings, and no changes required to daily routine.	We hypothesize that polarization is low, due to the economic rationale.
Electric heat pump clothes dryer	Dietz et al.[28] estimate that appliance upgrades have moderate technical potential, given that their energy use is substantial, but is small compared to space heating and cooling.	High[28]: a modest onetime cost, with no required changes to daily routine.	We hypothesize that it is moderate or low for reasons similar to heat pumps for heating and cooling.
Electric stove or oven	Moderate, similar to other appliances[28].	Probably high, similar to other appliances[28]. Some individuals may have emotional attachments to cooking with gas, but electric stoves may also have large health benefits[103], awareness of which could increase plasticity.	Polarization could be low if climate change is not the main deciding factor, but electric vs. gas stoves in a climate context have also featured into the culture wars recently[38].

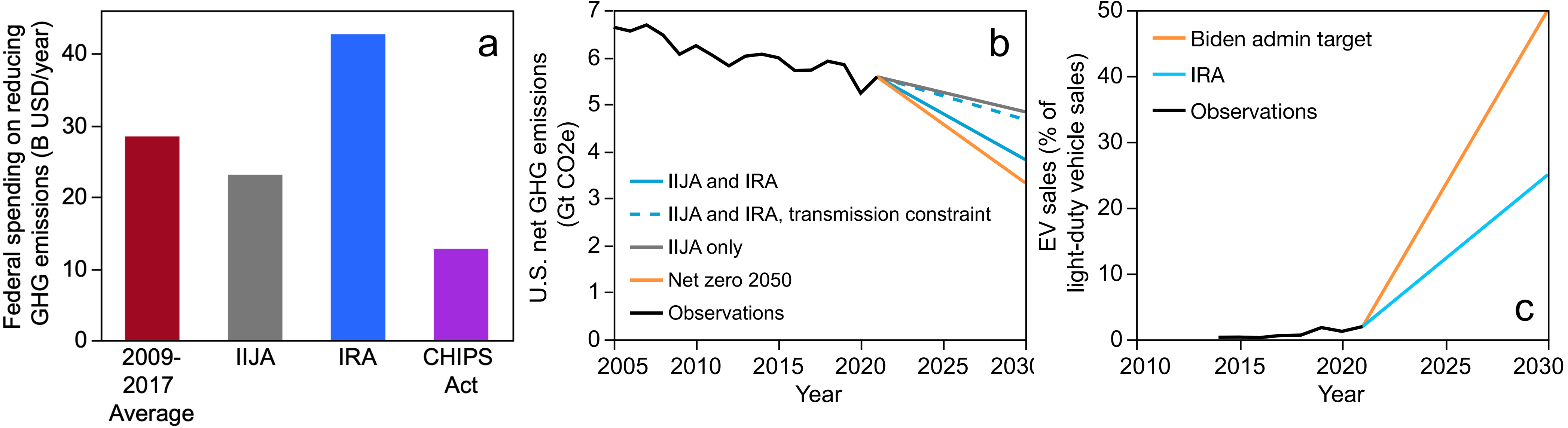
Figure captions:

Figure 1. Spending and targets of recent U.S. climate policies. (a) Spending on reducing greenhouse gas emissions (not including adaptation) from the Bipartisan Infrastructure Law (IIJA), Inflation Reduction Act (IRA), and CHIPS and Science Act (CHIPS Act), compared to a 2009-2017 baseline[5]. (b) Historical net greenhouse gas (GHG) emissions (including land-based carbon sinks), compared to net-zero targets, and projections to 2030 from policy scenarios[8]. Lines shown connect 2021 observations to projected 2030 values, for simplicity. (c) Historical electric-vehicle (EV) sales (% of light-duty vehicles), compared to a Biden-administration target[7] and a simulated IRA scenario[9]. Data available in Supplementary Information as Supplementary Data 1.

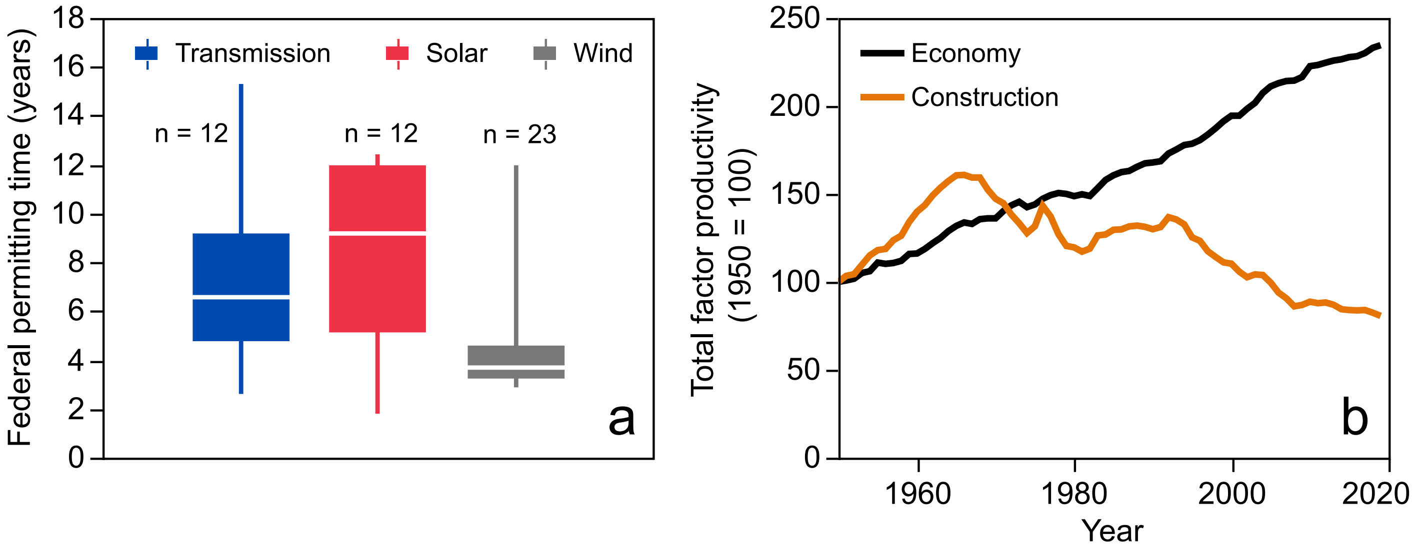
Figure 2. Federal permitting times and construction productivity. (a) Federal permitting times of completed and in-progress transmission and utility-scale solar and wind energy projects listed on the U.S. federal infrastructure projects permitting dashboard, as of May 29, 2023[11]. Boxes represent 25th to 75th percentile ranges. Whiskers represent minimum and maximum values. (b) Trends in total factor productivity (TFP, in value-added terms) in the U.S. economy as a whole (black) and in construction (orange)[12].

Figure 3. Partisanship of climate policy and opinion. (a) Sponsorship and partisan control of state-level decarbonization bills from 2015-2020[22] (n = 385). (b) Fractions of U.S. survey respondents of different political affiliations who report being “somewhat worried" or “very worried" about climate change from 2008-2022[71, 72].

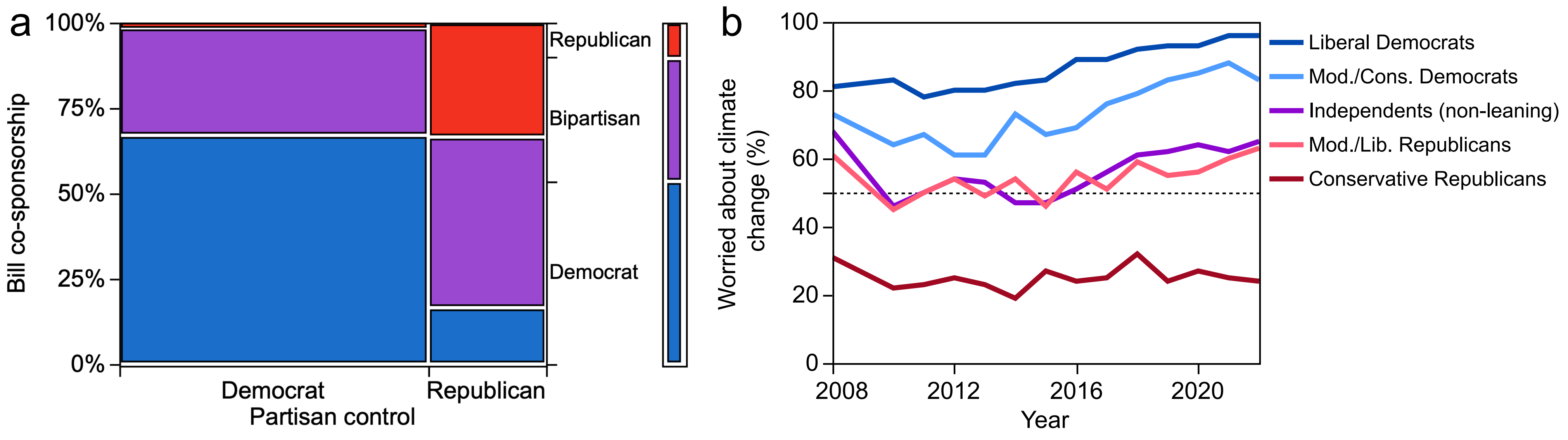
Figure 4. Virtuous cycles. An illustration of the potential virtuous cycle between individual and firm behaviors, social norms, and policies.

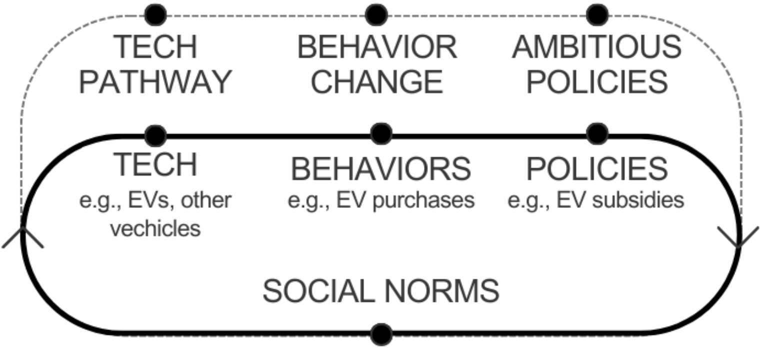


Federal spending on reducing GHG emissions (B USD/year)
a
2009-2017 Average
IIJA
IRA
CHIPS Act
U.S. net GHG emissions (Gt CO2e)
b
IIJA and IRA
IIJA and IRA, transmission constraint
IIJA only
Net zero 2050
Observations
Year
EV sales (% of light-duty vehicle sales)
c
Biden admin target
IRA
Observations
Year



Federal permiting time (years)
18
16
14
12
10
8
6
4
2
0
Transmission
Solar
Wind
n = 12
n = 12
n = 23
a
Total factor productivity
(1950 = 100)
250
200
150
100
50
0
Economy
Construction
b
1960
1980
2000
2020
Year


a
100%
75%
50%
25%
0%
Bill co-sponsorship
Republican
Bipartisan
Democrat
Democrat
Republican
Partisan control
b
100
80
60
40
20
0
Worried about climate change (%)
2008
2012
2016
2020
Year
Liberal Democrats
Mod./Cons. Democrats
Independents (non-leaning)
Mod./Lib. Republicans
Conservative Republicans


TECH PATHWAY
BEHAVIOR CHANGE
AMBITIOUS POLICIES
TECH
e.g., EVs, other vechicles
BEHAVIORS
e.g., EV purchases
POLICIES
e.g., EV subsidies
SOCIAL NORMS