Energy Policy

Incentivizing Household Action: Exploring the Behavioral Wedge in the 2021 Infrastructure Investment and Jobs Act and the 2022 Inflation Reduction Act

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Abstract:	In the 2021 Infrastructure Investment and Jobs Act (IIJA) and the 2022 Inflation Reduction Act (IRA), the United States (U.S.) Congress placed a major bet on the importance of household actions, and the incentives for these actions may yield disproportionately large emissions reductions. Modeling estimates from Rapid Energy Policy Evaluation and Analysis Toolkit (REPEAT) suggest that the IRA's $331 billion investment can reduce carbon emissions by as much as 42% below a 2005 baseline by 2030, assuming a low-friction economic environment. To evaluate the role of household actions, we use a two-part method: 1) Policy analyses of the IRA and IIJA to identify household incentives; 2) Secondary data analysis of REPEAT's policy models to identify the potential for emissions reductions associated with household action. We find that $39 billion, or 12% of climate and energy funds in the IRA and $4.3 billion or 5.7% of clean energy and power funds in the IIJA, target voluntary household actions, and that these actions contribute 40% of the cumulative emissions reductions under the IRA and IIJA, assuming a mid-range scenario for uptake. The importance of household actions to achieving IRA and IIJA's emissions reduction goals suggests that actual impacts will likely vary by behavioral plasticity, and that program design should reflect social and behavioral science insights.
Suggested Reviewers:	Thomas Dietz, PhD University Distinguished Professor, Michigan State University tdietz@msu.edu Dr. Thomas Dietz is a leader in the field of environmental behavioral policy and has authored dozens of peer-reviewed articles and book chapters on the subject.
	Shahzeen Attari, PhD Associate Professor, Indiana University Bloomington School of Public and Environmental Affairs sattari@iu.edu Dr. Attari's research focuses on the psychology of resource use and how to motivate climate action. She is well-established in the energy behavior discipline.

Reviewer #1 Evaluation:

This well-written paper addresses a timely and significant aspect of the IRA that the authors correctly identify can often be overlooked. That said, the paper exhibits a few weaknesses that should be addressed.

Authors' Response to Evaluation: Thank you for your thoughtful feedback. We have revised the manuscript to reflect your suggestions in your evaluation. More details about these revisions are captured in the following pages and a tracked changes document. We would also like to emphasize that our piece is a Policy Perspective, which Energy Policy defines as "a relatively short contribution that offers judgment on an energy policy issue-normally without original research. Nonetheless, a Policy Perspective should present well-reasoned and fully considered thinking to reach conclusions that are germane to important policy issues in energy supply or use".

Reviewer 1 comment 1: The authors can strengthen their paper by adding the following points: Precise purposes of this study link with addressing current research goals at the beginning of this paper.

Authors' response comment 1: We thank the reviewer for their feedback. We have added a sentence in the introduction to emphasize the relevance of our perspective to current research goals related to addressing household-related emissions.

Page 5 paragraph 2 original lines: *"To demonstrate the substantial role of household actions in the IRA, we followed a two-part methodological approach…"*

Page 5 paragraph 2 revised lines: *"Given the ongoing scholarly debates surrounding the value of household action in reducing climate emissions, the analysis we present here demonstrates that household actions play a substantial role in the IIJA and IRA and suggests opportunities for programmatic design given evidence-based findings based on behavioral plasticity".*

Reviewer 1 comment 2: Provide more robust justifications for using BBBA and IIJA as stand-ins for IRA. (It appears REPEAT does have project findings on the emissions Impacts of the IRA).

Authors' response comment 2: We thank the reviewer for their attention to detail regarding data source usage. When the data analysis was initially conducted in the spring of 2023, the IRA data had yet to be publicly released by REPEAT (the release date was July 2023). In our resubmission, we have re-analyzed the data to reflect the IRA's release and removed any mention of policies that have not been passed (namely the BBBA).

Reviewer 1 comment 3: A more transparent overview of the REPEAT methodology for emissions calculations.

Authors' response comment 3: We thank the reviewer for their suggestion. We have clarified the data analysis methodology to reflect our approach. Because the changes to this section are quite lengthy, we ask that you see pages 10 and 11 of the attached tracked changes document. The authors have also attached an RMarkdown with our resubmission to ensure readers can replicate the paper's findings using the publicly available data.

Reviewer 1 comment 4: More explicit research questions or hypotheses should be added to clarify the purpose of this study.

Authors' response comment 4: We thank the reviewer for their suggestion. Although this is a perspective piece rather than an original research article, we have clarified the text in our resubmission to emphasize the perspective's intent to highlight the importance of household behavior in the IRA's energy and climate provisions. Please refer to our response to reviewer 1 comment 1.

Reviewer 1 comment 5: Literature review- The literature review can be improved by adding the following points: Examining the effectiveness of current programs (EV Tax credit, weatherization, etc.) in terms of enrollment, reducing energy consumption, and emissions reduction.

Authors' response comment 5: We thank the reviewer for their suggestion. We have supplemented our literature review to explore the current effectiveness of household energy policies, the disproportionate exclusion of renters in household energy policies, and regional differences in household energy programs (comments 5-7).

Page 4-5 additional lines: *Importantly, behavioral plasticity related to household action varies significantly by geography, demographics, and identity, which may be related to the degree of agency a household possesses. For example, research suggests an "emissions paradox" exists in the US, where white communities tend to emit more carbon than Black communities, despite living in more energy-efficient homes (Goldstein et al., 2020). Similarly, renters are more likely to be excluded from energy efficiency programs, a phenomenon called "the split incentive", where landlords are discouraged from investing in energy efficiency because the savings benefit the renter (Bird & Hernández, 2012). Further, energy efficiency programs vary significantly by state, where state-level disparities can be seen in low-income investments by utilities (T. G. Reames et al., 2019). These variations influence the efficacy of programmatic implementation and should be considered in tandem with behavioral plasticity to ensure a just energy transition.*

Bird, S., & Hernández, D. (2012). Policy options for the split incentive: Increasing energy efficiency for low-income renters. *Energy Policy*, *48*, 506–514. https://doi.org/10.1016/j.enpol.2012.05.053

Goldstein, B., Gounaridis, D., & Newell, J. P. (2020). The carbon footprint of household energy use in the United States. *Proceedings of the National Academy of Sciences, 117*(32),

19122–19130. https://doi.org/10.1073/pnas.1922205117

Reames, T. G., Stacey, B., & Zimmerman, M. (2019). *A Multi-State Analysis of Equity in Utility-Sponsored Energy Efficiency Investments for Residential Electric Customers*. https://poverty.umich.edu/publications/a-multi-state-analysis-of-equity-in-utility-sponsored-energy-efficiency-investments-for-residential-electric-customers/

Reviewer 1 Comment 6: Describe more details on renter households being disproportionately excluded from potential policies.

Authors' response comment 6: We thank the reviewer for their suggestion. We have added a citation to our introduction that discusses the disproportionate exclusion of renters in household energy policies. Please see our response to comment 5.

Reviewer 1 Comment 7: Discuss potential regional differences (states, urban/rural) that impact behavioral policy and behavioral plasticity.

Authors' response comment 7: We thank the reviewer for their suggestion. We have added supporting literature to our introduction to highlight the regional differences in household energy programs. Please see our response to comment 5.

Reviewer 1 Comment 8: The BBBA as the baseline for Fig.2, Fig.3, and Fig.4 is not immediately apparent and may lead to initial confusion about the true aspect of the data visualization. Recommend considering alternative designs to showcase this better.

Authors' response comment 8: We thank the reviewer for their feedback. We have reanalyzed our data to reflect current policies (i.e., IIJA and IRA) and have changed figures 2-4 so that the baseline is now frozen policy.

Reviewer #2 Evaluation:
Thank you for the opportunity to review the article "Incentivizing Household Action: Exploring the Behavioral Wedge in the 2022 Inflation Reduction Act." The article focuses on the projected effect of IRA provisions on household energy efficiency investment. While the topic is pertinent and timely, there are significant problems with the clarity of research questions, the originality of the data and analyses, the transparency of research methodology, and the extent of contributions. I provide suggestions on developing an original and rigorous research agenda for the author(s)' consideration.

Authors' Response to Evaluation: Thank you for your thoughtful feedback. We have revised the manuscript to reflect your suggestions in your evaluation. The following pages and the attached tracked changes document capture more details about these revisions. We would also like to emphasize that our piece is a Policy Perspective, which Energy Policy defines as "a relatively short contribution that offers judgment on an energy policy issue-normally without original research. Nonetheless, a Policy Perspective should present well-reasoned and fully considered thinking to reach conclusions that are germane to important policy issues in energy supply or use".

Reviewer 2 Comment 1: In the abstract, the author(s) mentioned that the incentives for household actions yield "disproportionately large emissions reductions"; it is not clear what this means. It would be interesting if, years into the implementation of IRA, the policy measures yield emission reduction outcomes that exceed the initial projections due to the spill-over effect. In that case, talking about "disproportionately large reductions" would make sense given the initial investment.

Authors' response comment 1: We thank the reviewer for their suggestion. We have clarified the statement in our abstract to reflect our original intent: by 'disproportionately large', we mean that 12% of IRA funding and 6% of IIJA funding could produce 40% of the cumulative emissions reductions between now and 2050. Thus, the percentage of the emissions reductions from individual actions is substantially larger than the total investments made through the legislation.

Abstract original lines: *We conclude that $39 billion, or 12% of climate and energy funds in the IRA, target voluntary household actions. These funds could contribute a disproportionately large share of the IRA's emissions reductions: up to 40% of reductions from the IRA's legislative predecessor, the Build Back Better Act (BBBA), which closely resembles the IRA, can be attributed to household actions.*

Abstract revised lines: *We find that $39 billion, or 12% of climate and energy funds in the IRA and $4.3 billion or 5.7% of clean energy and power funds in the IIJA, target voluntary household actions, and that these actions contribute 40% of the cumulative emissions reductions under the IRA and IIJA, assuming a mid-range scenario for uptake.*

Reviewer 2 Comment 2: The author(s) mentioned how REPEAT uses "low friction assumption" in its projection and how in reality, there are many obstacles preventing consumers from making good of the policy incentives, such as navigating eligibility standards for tax credits, assessing cost savings, etc. These challenges are not "behavioral plasticity," as the paper suggests. They are potentially due to behavioral biases such as imperfect optimization or context-dependent preferences, which are well documented in the behavioral economics literature. Another particularly relevant area of literature is the administrative burden regarding means-tested programs. It would be interesting to study how consumers do or do not take up the incentives provided by IRA, which requires a solid grounding in the literature.

Authors' response comment 2: We thank the reviewer for the suggestion. Although there may be disciplinary differences in the definition of behavioral plasticity, we use the definition put forward by Dietz et al. and Stern et al. (2009, 2010), which frames behavioral plasticity as the extent to which behavior changes in response to interventions. In other words, we agree that policy incentives, behavioral biases, and administrative burdens are not behavioral plasticity. Still, they affect behavioral plasticity, which is the phenomenon we are addressing and which is a consideration that should be accounted for in the design and analysis of interventions that target household actions. We suggest that targeted interventions can effectively modify human behavior, especially when designed intentionally. We sincerely appreciate your suggestions for new literature and research agenda, as they support our argument in this perspective piece.

Dietz, T., Gardner, G. T., Gilligan, J., Stern, P., & Vandenbergh, M. P. (2009). Household actions can provide a behavioral wedge to rapidly reduce US carbon emissions. *The Proceedings of the National Academy of Sciences*. https://doi.org/10.1073/pnas.0908738106

Stern, P. C., Gardner, G. T., Vandenbergh, M. P., Dietz, T., & Gilligan, J. M. (2010). Design Principles for Carbon Emissions Reduction Programs. *Environmental Science & Technology*, *44*(13), 4847–4848. https://doi.org/10.1021/es100896p

Reviewer 2 comment 3: As a reader, my initial understanding was that the paper used an energy modeling approach called REPEAT to project IRA's emission reduction results. Instead, it seems that the paper summarized the results from a REPEAT report about the Build Back Better Act and projected that these results would apply to IRA. Without original research questions, data, modeling approaches, or findings, it cannot be said that the paper made original academic contributions.

Authors' response comment 3: We thank the reviewer for their feedback. We have clarified the text to clarify our methodologic approaches to align with feedback received from reviewers 1 and 2 (please see author's response to Reviewer 1 comment 2). Our approach used publicly available data from REPEAT's emissions modeling results to support our perspective's objectives, highlighting the importance of household action in the IIJA and IRA's climate and energy provisions and providing research-based design principles for implementation.

Reviewer 2 comment 4: In the abstract, the author(s) described the methodology of the article as (1) policy analysis of the IRA and (2) data analysis of REPEAT's policy models. In the main text, (1) turns out to be a summary of the measures targeting household energy investment in IRA. At the same time, it's not clear what constituted the data analyses of REPEAT in (2). Without a transparent discussion of the data and methodology, (2) seems to entirely reference the results from REPEAT with the summary of behavioral wedge items as its primary analysis. The summaries in (1) and (2) do not qualify as academically rigorous methodology.

Authors' response comment 4: We thank the reviewer for their feedback. Bearing in mind that a policy perspectives piece does not constitute original research and instead puts forth an argument that is relevant to energy-related policies, we have revised the text to clarify our methodologic approaches to align with feedback received from reviewers 1 and 2 (please see author's response to Reviewer 1 comment 2).

Reviewer 2 comment 5: One main finding of this paper is that IRA devoted major investment to household-level mitigation efforts. Another finding--reductions from the BBBA (not the IRA) household measures are significant--is summarized from existing REPEAT results. These do not constitute academically original and rigorous findings.

Authors' response comment 5: We thank the reviewer for their feedback. While Energy Policy does not require original academic research for policy perspectives, we used policy summaries and secondary data analysis to support our perspective, which is that the IRA and IIJA have made major investments directed toward household actions, but the investments are smaller than those directed toward other some other actions (12% and 6%, respectively, of their total spending), and our analysis of the REPEAT models produces a novel result by disaggregating the return on investment in household actions, finding that the return on these investments is especially large (40% of the total cumulative emissions reductions from 12% and 6% of the spending). Our approach to calculating the contribution from individual actions requires a nontrivial analysis and provides important, policy-relevant information that is not directly available from REPEAT. We have also updated our analysis with recently released data from REPEAT to reflect projections for the IRA and IIJA (not the BBBA). In light of the ongoing vigorous debate in academic and policymaking circles about the appropriate role of household actions in climate mitigation policy, this quantitative assessment of the return on investment in household actions represents an important advance relevant to academic research and practical policy design.

Title: *Incentivizing Household Action: Exploring the Behavioral Wedge in the 2021 Infrastructure Investment and Jobs Act and the 2022 Inflation Reduction Act*

Article Type: Policy Perspective

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Abstract: In the 2021 Infrastructure Investment and Jobs Act (IIJA) and the 2022 Inflation Reduction Act (IRA), the United States (U.S.) Congress placed a major bet on the importance of household actions, and the incentives for these actions may yield disproportionately large emissions reductions. Modeling estimates from Rapid Energy Policy Evaluation and Analysis Toolkit (REPEAT) suggest that the IRA's $331 billion investment can reduce carbon emissions by as much as 42% below a 2005 baseline by 2030, assuming a low-friction economic environment. To evaluate the role of household actions, we use a two-part method: 1) Policy analyses of the IRA and IIJA to identify household incentives; 2) Secondary data analysis of REPEAT's policy models to identify the potential for emissions reductions associated with household action. We find that $39 billion, or 12% of climate and energy funds in the IRA and $4.3 billion or 5.7% of clean energy and power funds in the IIJA, target voluntary household actions, and that these actions contribute 40% of the cumulative emissions reductions under the IRA and IIJA, assuming a mid-range scenario for uptake. The importance of household actions to achieving IRA and IIJA's emissions reduction goals suggests that actual impacts will likely vary by behavioral plasticity, and that program design should reflect social and behavioral science insights.

Keywords: Inflation Reduction Act; Infrastructure Investment and Jobs Act; Household Energy Behavior; Energy Justice; Behavioral Plasticity; Behavioral Wedge

1. Introduction

Scholars and advocates have long debated the importance of household behavior in climate mitigation initiatives. Household actions to increase home energy efficiency and conservation have the potential to yield substantial carbon emissions reductions. Despite this, some argue that interventions aimed at household actions will not yield substantial change (Nisa et al., 2019), or that

they are an attempt by commercial interests to shift responsibility onto consumers, disincentivizing regulation and evading meaningful change (Buse et al., 2022; Chater & Loewenstein, 2022; Supran & Oreskes, 2021). Whether household initiatives can contribute prompt, large emissions reductions and complement rather than undermine corporate and government initiatives remains a central climate policy question. Still, as Sunstein has concluded, "there is no empirical support for the proposition that interventions aimed at helping individuals, which are numerous and often effective, make systemic reform less likely" (2023, p. 1).

Households are integral to energy demand and carbon emissions in the United States. For example, the residential sector represented 19.1% of the United States' (US) CO_2 emissions from fossil fuel combustion) in 2021, while passenger vehicles and light-duty vehicles (of which over 90% are likely used for personal use) represented 22.2%, for a total equivalent to 41.3% of the US annual GHG emissions in 2021. (United States Department of Transportation, 2021a, 2021b; United States Environmental Protection Agency, 2023). Importantly, a 2009 study estimated that 7.4% of national emissions could be curbed by household actions (Dietz et al., 2009). A single initiative, the uptake of more efficient lightbulbs, may have accounted for the first reduction in per capita electricity use by U.S. households since the Second World War (Davis, 2017), reducing US GHG emissions by approximately 130 million metric tons (MMT) of carbon dioxide (CO_2) per year (Gilligan & Vandenbergh, 2020).

Although critiques of household behavior have focused on the political and practical barriers to regulating behavior, the subsidy approach taken in recent years by the US Congress represents a shift away from prohibiting undesired behaviors toward encouraging desired behaviors (Vandenbergh, 2022). US government laws and policies have previously achieved significant reductions in household emissions, but their adoption and implementation have been heavily

contested (Gayer & Viscusi, 2013). If effective, the recent subsidy-based legislation could achieve significant emissions reductions from the household sector using a less intrusive approach that may provoke less resistance and be easier to implement from a regulatory standpoint.

Several bills and statutes, such as the Infrastructure Investment and Jobs Act (IIJA) of 2021 and the Inflation Reduction Act (IRA) of 2022, represent a choice by Congress to incentivize household actions in climate mitigation efforts. In 2021, Congress passed the IIJA, which invests significantly in transportation, climate-resilient infrastructure, and household-level actions such as weatherization (Supplementary Table 1) (Infrastructure Investment and Jobs Act, 2021; The White House, 2022a). Following the IIJA, in August 2022, Congress passed the IRA, boasting climate and energy provisions totaling $331 billion to support climate and energy actions through 2031 (Table 1) (Congressional Budget Office, 2022; The White House, 2022b). Although media accounts frequently point to a $369 billion total (Nelson, 2023), that number is based on a previous version of Congressional Budget Office estimates. In contrast, we use the final version of the legislation adopted on August 16, 2022 and the September 7, 2022 Congressional Budget Office analysis of the final legislation. IRA provisions targeting households include tax credits for new and used personal electric vehicles, credits for door and window replacements, heat pump installation, and distributed power generation projects (Glavinskas, 2022). The incentivized actions in all three policies align with Dietz et al.'s concept of Behavioral Wedge Action Types (2009), which we define as the actions that many people or households have the agency to address, such as residential energy upgrades, travel and commute patterns, and resource consumption.

The growing role of household actions in climate legislation suggests the need to update models to fully account for the influences on individual behavior. Modeling efforts such as those from the Rapid Energy Policy Evaluation and Analysis Toolkit (REPEAT) have been used to estimate the

social, environmental, and health-related impacts of the IIJA and IRA (Jenkins, Mayfield, et al., 2022). Notably, the models use economic forecasts to identify the least-cost scenario to determine the most plausible decarbonization pathway (Jenkins, Mayfield, et al., 2022). These models estimate the change in household technologies using various scenarios for implementation and programmatic uptake, noting the challenges that may be associated with creating that environment, such as rapidly expanding transmission to meet the energy demands of new technology (Jenkins, Farbes, et al., 2022; Jenkins, Mayfield, et al., 2022).

In the same vein, we posit that the 2022 IRA and 2021 IIJA will pose significant behavioral challenges associated with uptake of efficient technologies at the household-level, such as navigating eligibility standards for tax credits, assessing cost savings, accessing new technologies locally, and contracting with qualifed local installers. These challenges can be classified using the term *behavioral plasticity*, or the proportion of individuals who could be influenced to take an action, and the concept can be used to estimate the plausible emissions reductions arising from use of state of the art interventions (Dietz et al., 2009). Behavioral plasticity has been widely used in studies of climate-relevant behaviors (Kaplowitz & Boucher, 2022; van der Linden & Goldberg, 2020).

Importantly, behavioral plasticity related to household action varies significantly by geography, demographics, and identity, which may be related to the degree of agency a household possesses. For example, research suggests an "emissions paradox" exists in the US, where white communities tend to emit more carbon than Black communities, despite living in more energy-efficient homes (Goldstein et al., 2020). Similarly, renters are more likely to be excluded from energy efficiency programs, a phenomenan called "the split incentive", where landlords are discouraged from investing in energy efficiency because the savings benefit the renter (Bird & Hernández, 2012). Further, energy efficiency programs vary significantly by state, where state-level disparities can be

seen in low-income investments by utilities (T. G. Reames et al., 2019). These variations influence the efficacy of programmatic implementation and should be considered in tandem with behavioral plasticity to ensure a just energy transition. Social and behavioral science insights may enable program managers to design and implement programs that better account for human decisionmaking (Dietz et al., 2009; Kaplowitz & Boucher, 2022; van der Linden & Goldberg, 2020).

Given the ongoing scholarly debates surrounding the value of household action in reducing climate emissions, the analysis we present here demonstrates that household actions play a substantial role in the IRA and IIJA and suggests opportunities for programmatic design, given evidence-based findings based on behavioral plasticity. We followed a two-part methodological approach: 1) policy analysis of the IRA and IJJA to identify household incentives; and 2) secondary data analysis of REPEAT's policy model results to identify the potential for emissions reductions associated with household actions.

2. IRA and IIJA Policy Analysis

We assessed final versions of the IRA and IIJA to examine the emissions reductions associated with household actions (signed August 16, 2022, and November 14, 2021, respectively). We identified actions that many individuals or households have the agency to address, such as residential energy upgrades, travel and commute patterns, or resource consumption. For instance, replacing an aging car with an electric vehicle or replacing an old water heating system with a new heat pump water heater represent actions that many households have the agency to address.

Using this definition, we identified several provisions in the IRA and IIJA that target individual or household actions. Actions incentivized by the IRA include weatherization, distributed energy generation, personal electric vehicles, heat pumps, and others (Table 1, Figure 1). In all, the IRA

dedicated $38.8 billion to incentivizing household behaviors (11.7% of all funds aimed at energy and climate), while the IIJA dedicated $4.3 billion to household behaviors (5.7% of clean energy and power funds) (Tables 1 and 2, Figure 1).

Table 1. Household action types, section, description, and legislative funds in the 2022 IRA. Note: Tax credits do not explicitly allocate funds, and several action types are often mentioned in each section.

Action Type	***IRA Section***	***Description***	***Legislative Funds***
Residential HVAC/ Building Shell	60103	Creation of grants for states, municipalities, and Tribal governments to promote rapid deployment of low- and zero- emission technologies in the residential sector, including distributed energy generation projects and other greenhouse gas reduction efforts. A portion must be allocated to low and moderate income and disadvantaged communities.	$27 billion
Residential HVAC/ Building Shell	60201	Creation of grants for activities and technical assistance to implement community-led projects in disadvantaged communities. Community-engaged projects associated with pollution monitoring and prevention, climate and health risk mitigation, low-and zero-emission technology implementaton, and the reduction of indoor air pollution exposure are considered eligible.	$3 billion
Residential HVAC/ Building Shell	50121	Creation of grants for state energy offices to implement a Home Owner Managing Energy Savings (HOMES) rebate program. Additional funds available for low to moderate income individuals.	$4.3 billion
Residential HVAC/ Building Shell	50122	Creation for grants for state energy offices and Indian Tribes to implement a high-efficiency electric home rebate program among low and moderate income households. Weatherization upgrades include heat pumps for space heating/cooling, electric stoves/cooktops, an electric heat pump clothes dryer, breaker upgrades, insulation, air sealing, panels/wiring; not to exceed $14,000 per eligible entity.	$4.5 billion
Residential HVAC/ Building Shell	13301	Extends the credit in section 25c of the Internal Revenue Code of 1986 and increases the credit rate from 10% to 30% for qualified energy efficiency improvements. Replaces the lifetime credit limitation with an annual limit of $1,800 or $600 for qualified energy property. This includes up to $600 for windows and $500 for doors. However, heat pump space heaters and biomass stoves are not subject to per item limitation and if installed, the annual credit limit is lesser of 30% of cost or $2,000.	N/A
Residential HVAC/ Building Shell	13304	Extends the credit in section 45L of the Internal Revenue Code of 1986 and increases the amount for single family and manufactured homes to $2,500 that meet recent Energy Star Single-Family New Homes or Manufactured Home Program requirements and $5,000 credit for a certified zero energy ready home under DOE Zero Energy Ready Home Program.	N/A
Water Heating	50122	Support for state energy offices and Indian Tribes to implement a high-efficiency electric home rebate program. Appliance upgrades include up to $1,750 for a heat pump water heater.	Included above
Water Heating	13301	Extends the credit in section 25c of the Internal Revenue Code of 1986 and increases the credit rate from 10% to 30% for qualified energy efficiency improvements. Replaces the lifetime credit limitation with an annual limit of $1,800 or $600 for qualified energy property. Heat pump water heaters and biomass water boilers are not subject to per item limitation and if installed, the annual credit limit is lesser of 30% of cost or $2,000.	Included above
Light Duty Electric Vehicles	13401	Keeps the current $7500 credit in section 30D of the Internal Revenue Code of 1986 but reduces the credit if a percentage of the battery is not extracted/processed in the US or with an FTA or recycled in North America. The percentage increases from 40% in 2024 to 80% in 2026. Limits application of credit for individuals whose income exceeds $150,000 or $300,000 for joint filers. Limits credit for purchases less than or equal to $80,000 for vans, SUVs and pickups and $55,000 for other vehicles.	N/A
Light Duty Electric Vehicles	13402	Creates tax credit (section 25E of the Internal Revenue Code of 1986) for consumers to purchase a previously owned electric vehicle, equivalent to $4,000 or 30% of the total cost and limits eligibility for individuals making more than $75,000 or $150,000 for joint filers. Limits credit's utility to previously owned vehicles which are at least 2 years older than the year of sale and does not exceed $25,000.	N/A
			Total Funds: $38.8 Billion

Table 2. Household action types, section, description, and legislative funds in the 2021 IIJA.

Action Type	***IIJA Section***	***Description***	***Legislative Funds***
Residential HVAC/ Building Shell	40502	Provides funds to establish the Energy Efficiency Revolving Loan Fund Capitalization Grant program under the State Energy Program for states to conduct commercial or residential energy audits or upgrades and retrofits.	$0.25 billion
Residential HVAC/ Building Shell	40551	Increases funding for the Weatherization Assistance Program (WAP), a federal program dedicated to reducing residential energy costs and improving health and safety for low-income households.	$3.5 billion
Residential HVAC/ Building Shell	40552	Provides block grants to cities, communities, states, U.S. territories, and Tribal communities to develop, promote, implement, and manage energy efficiency and conservation projects.	$0.55 million
			Total Funds: $4.3 Billion

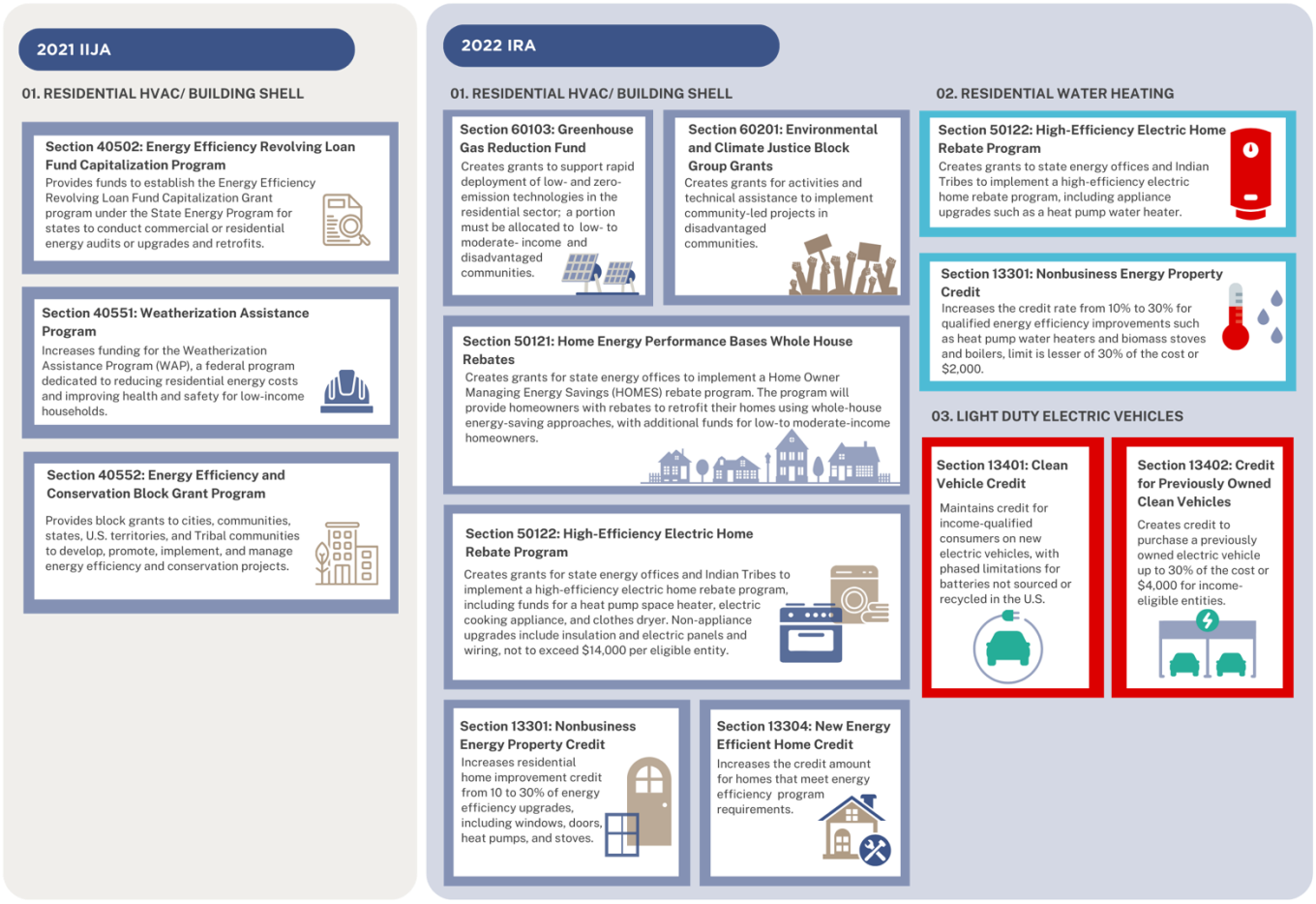

Figure 1. Three sections in the IIJA and eight sections in the IRA incentivize household actions spanning three behavioral wedge action types.

3. REPEAT Case Study

To understand the relationship between household actions incentivized by the IRA and estimated emissions, we utilized modeling results from REPEAT as a case study. REPEAT provides more technical documentation for its models than the two other leading models of IRA emissions reductions (Rhodium and Energy Innovation). REPEAT also provides summaries of its assumptions and inputs for all environmental sections of the IRA—information that was not as readily available from other groups (Jenkins et al., 2023).

REPEAT utilizes a cost-optimized modeling approach that draws on energy service demand assumptions largely based on the United States Energy Information Administration's Annual Energy Outlook 2021 and technology costs from the National Renewable Energy Laboratory Annual Technology Baseline 2021 (Jenkins, Mayfield, et al., 2022). Once macro-energy estimates for energy demand and technology costs are created, the model optimizes a supply-side scenario to meet demand at the lowest cost (Jenkins, Mayfield, et al., 2022; Larson et al., 2021).

REPEAT estimates of emissions under the Current Policies Scenario (IRA and IIJA) were made available to the public in July of 2023. The IIJA and IRA are represented using a trio of scenarios, which represent different estimates for the effectiveness of implementing the programs under 'Conservative', 'Mid-Range', and 'Optimistic' assumptions (Supplementary Table 1). In addition to historic scenarios such as Frozen Policy, which represents the policies in place when President Biden was inaugurated in January 2021, and the IIJA alone, scenarios such as the Net-Zero Pathway Benchmark, a yardstick assessment tool created by REPEAT to measure US progress, are estimated (Jenkins et al., 2023). We used these publicly-available model results to explore the potential contributions of household actions to calculated emission reductions.

To analyze the future impacts of energy and climate policies (e.g., Frozen Policy and the trio of scenarios associated with Current Policy), we used REPEAT's estimated emissions by fuel type and energy use for the residential and transportation sectors, except for various oil products, such as heating oil, gasoline fuel, and diesel fuel, as we explain below (REPEAT 2023). We used the emissions intensity of coal and natural gas provided by REPEAT. Further, because the REPEAT analysis aggregates emissions from all oil products into one category, we calculated disaggregated emissions for gasoline and diesel fuel, and home heating oil, by multiplying the REPEAT estimates of energy consumption for gasoline, diesel fuel, and home heating oil by carbon emissions factors for each fuels as reported by the EPA (US Energy Information Administration, 2023). Lastly, because data on emissions from electricity generation was not available, we converted the

emissions intensity associated with electricity generation from quadrillion BTU to Million Metric Tons (MMT) using the Environmental Protection Agency's (EPA) Greenhouse Gas Equivalencies Calculator (US EPA, 2015), based on the mix of fuels used for generation according to the REPEAT analysis for the different scenarios. Using these values, we summarized energy use and associated emissions for household actions for each policy scenario, using Frozen Policy as a baseline. All data analyses were conducted using R (v. 4.3.1)(R Core Team 2023).

We concluded that actions proposed in the Mid-Range Current Policies Scenario could considerably lower total emissions, up to 1008 MMT of CO_2 could be reduced annually when compared to Frozen Policy (Figure 2).

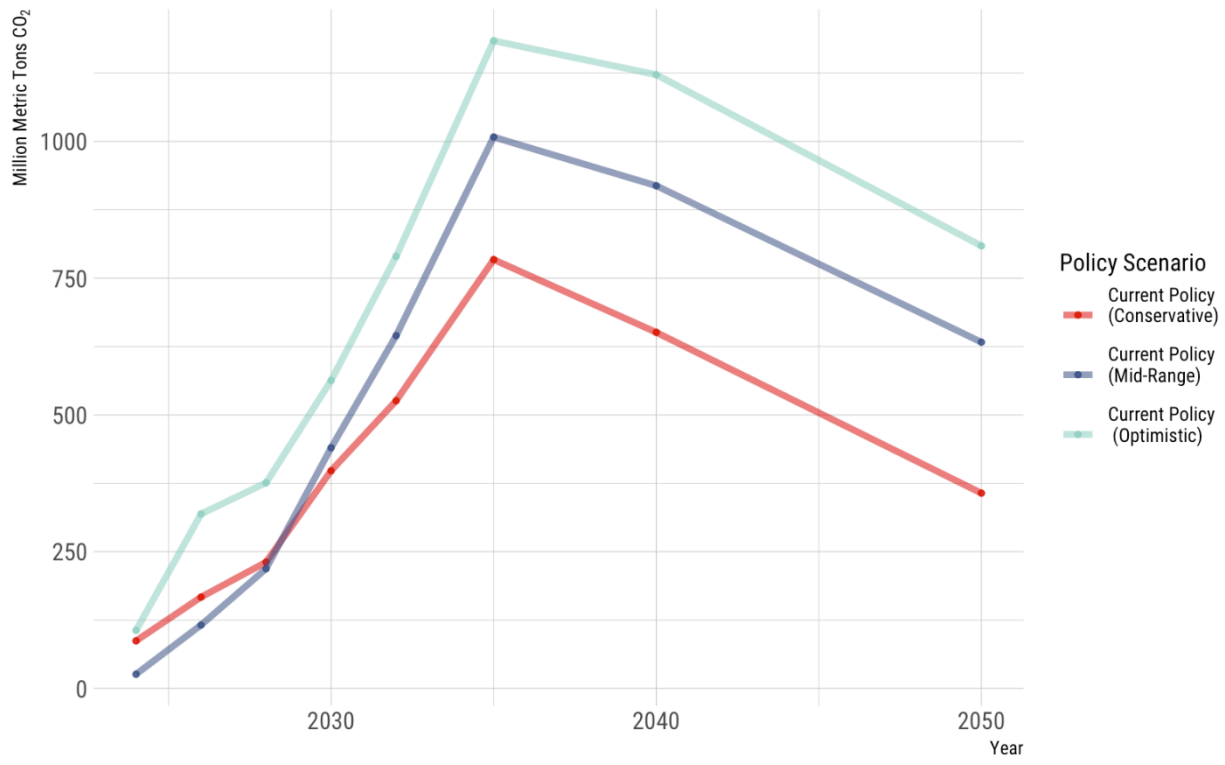

Figure 2. Total emissions reductions estimated under the trio of Current Policy Scenarios from 2024 to 2050, using Frozen Policy as a baseline.

To assess the role of household actions in the IRA, we disaggregated the effects of those actions on household energy consumption by fuel from the impacts of actions outside the household's purview on the carbon intensity of those fuels. For instance, if utility companies shift the mix of electrical generation away from fossil fuels and toward renewable or nuclear energy sources, the emissions reduction associated with household electricity consumption would not be due to household actions. We performed this disaggregation by recalculating three baseline scenarios, each corresponding to the household energy consumption under the frozen policy scenario, but using greenhouse gas emissions coefficients for each energy source that correspond to current policies, under conservative, mid-range, and optimistic assumptions. We then calculated the emissions reduction associated with household energy consumption changing to the current-policy scenario from the corresponding baseline. By taking emissions factors from the current policy for both the baseline and current-policy scenarios, we were able to calculate the effect of changing household energy demand and fuel mix separately from changes in energy supply, infrastructure, and carbon intensity that are beyond the household's control.

When considering household actions proposed in the Current Policy Scenarios, we concluded that provisions supporting residential space and water heating in the Mid-Range Policy Scenario could result in emissions reductions of up to 261.6 MMT of CO_2 annually (199 and 62.6 MMT of CO_2, respectively), as compared to Frozen Policy. Further, provisions supporting changes to light-duty trucks and autos could result in emissions reductions of up to 191 MMT in the Mid-Range Current Policy Scenario as compared to Frozen Policy (Figure 3).

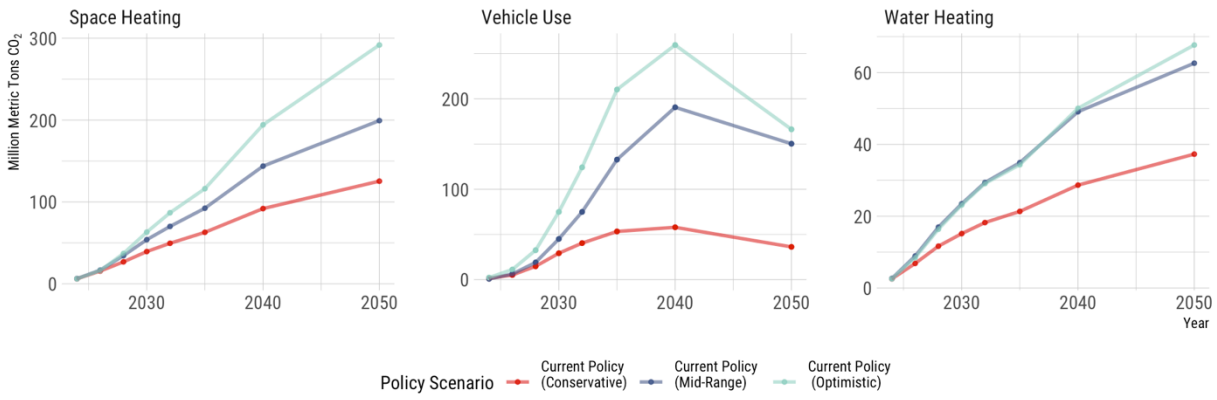

Figure 3. Total emissions reductions estimated under the trio of current policy scenarios for household actions such as a) vehicle use, b) residential heating, and c) residential water heating as compared to Frozen Policy.

Finally, we calculated the cumulative emissions reductions due to household actions from 2024-2050 and compared them to the total cumulative emissions reductions reported by the REPEAT project. This suggests that under the Mid-Range and Optimistic current policy scenarios, 40% of the expected cumulative emissions reductions through 2050 under IRA and IIJA will be due to household actions (Figure 4).

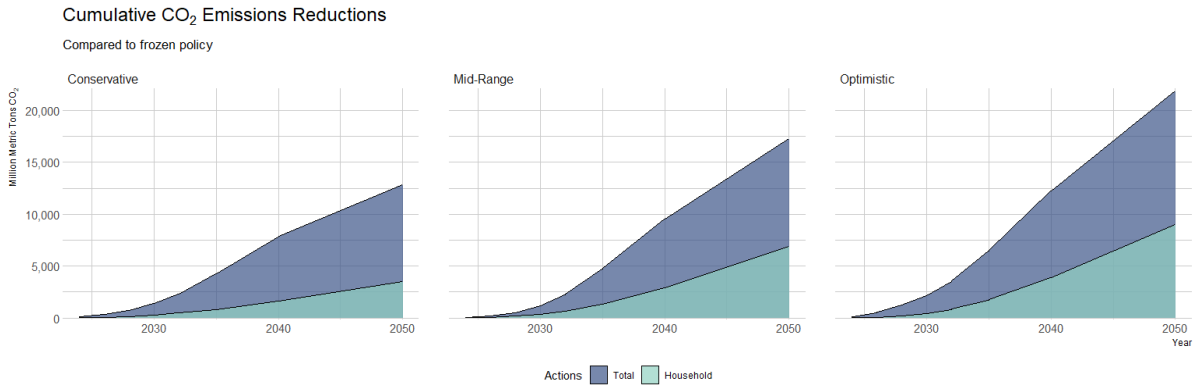

Figure 4. Household Action and Total emissions reductions for the Trio of Current Policy Scenarios as compared to the Frozen Policy Scenario.

4. Conclusions and Policy Implications

Our results suggest that household actions play a substantial role in the IRA and IIJA. The IRA and IIJA include a combined eleven sections that directly incentivize these actions, including the uptake of efficient heat pumps, water heaters, and personal electric vehicles, and these types of household actions account for roughly $38.8 billion or 11.7% of the climate and energy funds in the IRA and $4.3 billion or 5.7% of clean energy and power funds in the IIJA. Although our budgetary analysis considers appropriated funds, it is essential to note that uncapped tax credits associated with clean energy and efficiency incentives represent more than two-thirds of the climate and energy provisions in the IRA and are challenging to model (Bistline et al., 2023).

The relatively small financial subsidies in the IRA and IIJA as compared to subsidies for non-household actions could produce a disproportionately large share of the estimated emissions reductions from these laws. Based on models of the Mid-Range Current Policy Scenario, we estimated that 40% of annual estimated emissions reductions could be attributable to household actions. In short, roughly 12% of the climate and energy spending in the IRA and 5.7% of clean energy and power funds in the IIJA are focused on household actions, which may produce 40% of the total cumulative emissions reductions through 2050.

The household actions subsidized by the IRA and IIJA are only a beginning, and the recent legislative embrace of these types of actions may continue or increase. The large and growing role of household actions thus suggests the need to increase the research base and agency expertise on household policies and programs (Stern et al., 2023). An important aspect of this research and agency expertise is a better understanding of the behavioral plasticity of households, which may differ substantially from that of the traditional industrial targets of environmental laws and policies. Integrating behavioral plasticity into policy modeling estimates and program design will be critical for exploiting the opportunity to harness household actions in climate change mitigation.

To augment future policy models and programmatic interventions, we also suggest the following implementation strategies for the IIJA and IRA, aligned with the policy design principles enumerated in Stern et al. (2010) and Vandenbergh et al. (2010): 1) Ensure household programs prioritize impactful action. For example, while re-insulating one's home may effectively curb emissions (technical potential), individuals may be more likely to take advantage of smaller projects, such as replacing windows or doors (behavioral plasticity). Designing programs to balance technical potential and behavioral plasticity will help ensure rapid and widespread emissions reductions (Dietz et al., 2009). 2) Provide significant financial incentives. While the IRA offers many financial incentives in its provisions, programmatic design should focus on lowering the barriers to accessing those funds. For example, if eligibility requirements are unclear for the used clean vehicle credit program, household decision-makers may be disincentivized to take advantage of credits. 3) Strongly market the program. Although media campaigns can be effective, research suggests that local context matters in home energy efficiency programs and community-based programs can be more effective (T. Reames, 2016). 4) Provide valid information from credible sources at the points of decision. For example, if HVAC contractors are equipped with credit options in the IRA, they can advise their customers on savings options at the time of replacement. 5) Keep it simple. Programs are more likely to be successful if they minimize the burden on the consumer. Thus, lessening the paperwork, timelines, and organizational navigation associated with the IIJA and IRA's household provisions may significantly increase uptake. A recent example of this is the US Department of the Treasury's rule proposal, intended to provide immediate rebates for the IRA's EV tax incentives at the point of sale (US Department of the Treasury, 2023). 6) Provide quality assurance. Household decision-makers should be confident that their decision to take advantage of the IIJA and IRA's incentives will be worth the additional time spent identifying qualified car salespeople, eligible appliances, and certified contractors.

Household behavior is also significantly tied to a household's level of agency. For example, replacing an old water heating system with a new heat pump water heater in a single-family home represents an action that many households have the agency to address. In contrast, the same replacement in a multi-family dwelling is likely to be limited by external constraints or coordination requirements associated with a renter's or unit owner's agency. Behavioral wedge actions are also likely to vary by community and household-level structural inequities. For example, low-income homeowners requiring health and safety upgrades will likely be deterred from participating in low-income weatherization assistance programs until costly repairs are made (Tonn et al., 2015). At the same time, high-socioeconomic status households are responsible for far more consumption-based CO_2 emissions than their low-income counterparts, presenting a significant potential for emissions reductions (Nielsen et al., 2021). Thus, targeting higher-income households and addressing structural inequities concomitantly should be prioritized for IIJA and IRA program design.

Household action not only presents important pathway for emissions reductions, but also provides opportunities to increase efficiency and reduce the inequitable energy burdens of low-income households. The growing focus on household action thus can promote both climate change mitigation and energy justice.

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Appendix

	Infrastructure Investment and Jobs Act November 6, 2021		**Inflation Reduction Act,** July 27, 2022			
Action Type	**Section**	**REPEAT Modeled Funds**	**Section**	**REPEAT Modeled Scenarios**		
				Conservative	**Mid-Range**	**Optimistic**
Residential HVAC/ Building Shell	40502-- Energy efficiency revolving loan fund capitalization grant program	$0.25	60103-- GHG Reduction Fund	$13.3 modeled funds, assuming total loan volume is $40 and 10% program effectiveness	$20 modeled funds, assuming total loan volume is $60 and 20% program effectiveness	$33.3 modeled funds, assuming total loan volume is $100 and 40% program effectiveness
	40551-- Weatherization assistance program	$3.5	60201-- Environmental and Climate Justice Block Grants	$1.5 modeled funds, assuming 10% program effectiveness	$1.5 modeled funds, assuming 20% program effectiveness	$1.5 modeled funds, assuming 40% program effectiveness
	40552-- Energy Efficiency and Conservation Block Grant Program	$0.55	50121-- Home Energy Performance-Based, Whole House Rebates	$4.3 modeled funds, assuming 10% program effectiveness	$4.3 modeled funds, assuming 20% program effectiveness	$4.3 modeled funds, assuming 40% program effectiveness
			50122-- High-efficiency electric home rebate program	$2.25 modeled funds, assuming 10% program effectiveness	$2.25 modeled funds, assuming 20% program effectiveness	$2.25 modeled funds, assuming 400% program effectiveness
			13301-- Extension, increase, and modification of nonbusiness energy property credit (25C)	N/A		
			13304-- Extension, increase, and modification of new energy efficient home credit (45L)	N/A		
Water Heating			50122	$2.25 modeled funds, assuming 10% program effectiveness	$2.25 modeled funds, assuming 20% program effectiveness	$2.25 modeled funds, assuming 400% program effectiveness
			13301	N/A		
Light Duty Vehicles			13401-- Clean Vehicle Credit	N/A		
			13402-- Credit for previously-owned clean vehicles	N/A		
		Total Funds: $4.3 Billion		**Total Funds:** $23.6 Billion	$30.3 Billion	$43.6 Billion

Supplementary Table 1. Policy comparison for the the IIJA and the IRA, including household action type, section, and funds and scenarios as modeled by REPEAT

Title: *Incentivizing Household Action: Exploring the Behavioral Wedge in the 2021 Infrastructure Investment and Jobs Act and the 2022 Inflation Reduction Act*

Article Type: Policy Perspective

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Abstract: In the 2021 Infrastructure Investment and Jobs Act (IIJA) and the 2022 Inflation Reduction Act (IRA), the United States (U.S.) Congress placed a major bet on the importance of household actions, and the incentives for these actions may yield disproportionately large emissions reductions. Modeling estimates from Rapid Energy Policy Evaluation and Analysis Toolkit (REPEAT) suggest that the IRA's $331 billion investment can reduce carbon emissions by as much as 42% below a 2005 baseline by 2030, assuming a low-friction economic environment. To evaluate the role of household actions, we use a two-part method: 1) Policy analyses of the IRA and IIJA to identify household incentives; 2) Secondary data analysis of REPEAT's policy models to identify the potential for emissions reductions associated with household action. We ~~conclude~~find that $39 billion, or 12% of climate and energy funds in the IRA and $4.3 billion or 5.7% of clean energy and power funds in the IIJA, target voluntary household actions~~. These funds could~~, and that these actions contribute ~~a disproportionately large share~~40% of the ~~IRA's~~cumulative emissions reductions~~: up to 40% of reductions from the IRA's legislative predecessor, the Build Back Better Act (BBBA), which closely resembles~~ under the IRA~~, can be attributed to household actions.~~ and IIJA, assuming a mid-range scenario for uptake. The ~~IRA's focus on~~importance of household actions to achieving IRA and IIJA's emissions reduction goals suggests that actual impacts will likely vary by behavioral plasticity, and that program design should reflect social and behavioral science insights.

Keywords: Inflation Reduction Act; Infrastructure Investment and Jobs Act; Household Energy Behavior; Energy Justice; Behavioral Plasticity; Behavioral Wedge

1. Introduction

Scholars and advocates have long debated the importance of household behavior in climate mitigation initiatives. Household actions to increase home energy efficiency and conservation have

the potential to yield substantial carbon emissions reductions. Despite this, some argue that ~~behavioral~~ interventions aimed at household actions will not yield substantial change (Nisa et al., 2019), or that they are an attempt by commercial interests to shift responsibility onto consumers, disincentivizing regulation and evading meaningful change (Buse et al., 2022; Chater & Loewenstein, 2022; Supran & Oreskes, 2021). Whether household initiatives can contribute prompt, large emissions reductions and complement rather than undermine corporate and government initiatives remains a central climate policy question. Still, as Sunstein has concluded, "there is no empirical support for the proposition that interventions aimed at helping individuals, which are numerous and often effective, make systemic reform less likely" (2023, p. 1).

Households are integral to energy demand and carbon emissions in the United States. For example, the residential sector represented 19.1% of the United States' (US) CO_2 emissions from fossil fuel combustion) in 2021, while passenger vehicles and light-duty vehicles (of which over 90% are likely used for personal use) represented 22.2%, for a total equivalent to 41.3% of the US annual GHG emissions in 2021. (United States Department of Transportation, 2021a, 2021b; United States Environmental Protection Agency, 2023). Importantly, a 2009 study estimated that 7.4% of national emissions could be curbed by household actions (Dietz et al., 2009). A single initiative, the uptake of more efficient lightbulbs, may have accounted for the first reduction in per capita electricity use by U.S. households since the Second World War (Davis, 2017), reducing US GHG emissions by approximately 130 million metric tons (MMT) of carbon dioxide (CO_2) per year (Gilligan & Vandenbergh, 2020).

Although critiques of household behavior have focused on the political and practical barriers to regulating behavior, the subsidy approach taken in recent years by the US Congress represents a shift away from prohibiting undesired behaviors toward encouraging desired behaviors.

(Vandenbergh, 2022). US government laws and policies have previously achieved significant reductions in household emissions, but their adoption and implementation have been heavily contested (Gayer & Viscusi, 2013). If effective, the recent subsidy-based legislation could achieve significant emissions reductions from the household sector using a less intrusive approach that may provoke less resistance and be easier to implement from a regulatory standpoint.

Several bills and statutes, such as the ~~Build Back Better Act (BBBA) of 2021, the~~ Infrastructure Investment and Jobs Act (IIJA) of 2021~~,~~ and the Inflation Reduction Act (IRA) of 2022, represent a choice by Congress to incentivize household actions in climate mitigation efforts. ~~Passed by the House of Representatives, but not the Senate, in November 2021, the BBBA contained over $500 billion in clean energy provisions, many of which were focused on household-level change (Supplementary Table 1)(*Build Back Better Act*, 2021). Following consideration of the BBBA~~In 2021, Congress passed the IIJA, which invests significantly in transportation, climate-resilient infrastructure, and household-level actions such as weatherization ~~and EV charger stations (Supplementary Table 1) (Infrastructure Investment and Jobs Act, 2021). Finally, in August 2022, Congress passed the IRA, which incorporated many of the goals and policies of the BBBA, including many of the same sections regarding household actions with minimal changes in funding allocations (Supplementary Table 1). The climate and energy provisions in the IRA total $331 billion in investments~~(Supplementary Table 1) (Infrastructure Investment and Jobs Act, 2021; The White House, 2022a). Following the IIJA, in August 2022, Congress passed the IRA, boasting climate and energy provisions totaling $331 billion to support climate and energy actions through 2031 (Table 1) ~~(Congressional Budget Office, 2022; The White House, 2022).~~(Congressional Budget Office, 2022; The White House, 2022b). Although media accounts frequently point to a $369 billion total (Nelson, 2023), that number is based on a previous version of Congressional Budget Office estimates. In contrast, we use the final version of the legislation adopted on August 16, 2022 and the September

7, 2022 Congressional Budget Office analysis of the final legislation. IRA provisions targeting households include tax credits for new and used personal electric vehicles, credits for door and window replacements, heat pump installation, and distributed power generation projects (Glavinskas, 2022). ~~The incentivized actions in all three policies align with Dietz et al.'s concept of *Behavioral Wedge Action Types*,~~The incentivized actions in all three policies align with Dietz et al.'s concept of Behavioral Wedge Action Types (2009), which we define as the actions that many people or households have the agency to address, such as residential energy upgrades, travel and commute patterns, and resource consumption.

The growing role of household actions in climate legislation suggests the need to update models to fully account for the influences on individual behavior. Modeling efforts such as those from the Rapid Energy Policy Evaluation and Analysis Toolkit (REPEAT) have been used to estimate the social, environmental, and health-related impacts of the ~~BBBA, IIJA, and IRA (Jenkins, Mayfield, et al., 2022)~~IIJA and IRA (Jenkins, Mayfield, et al., 2022). Notably, the models use economic forecasts to identify the least-cost scenario to determine the most plausible decarbonization pathway (Jenkins, Mayfield, et al., 2022). These models estimate the change in household technologies using ~~a "low-friction" assumption~~various scenarios for implementation and programmatic uptake, noting the challenges that may be associated with creating that environment, such as rapidly expanding transmission to meet the energy demands of new technology ~~(Jenkins, Farbes, Jones, et al., 2022; Jenkins, Mayfield, et al., 2022).~~(Jenkins, Farbes, et al., 2022; Jenkins, Mayfield, et al., 2022).

In the same vein, we posit that the 2022 IRA and 2021 IIJA will pose significant behavioral challenges associated with uptake of efficient technologies at the household-level, such as navigating eligibility standards for tax credits, assessing cost savings, accessing new technologies locally, and contracting with qualifed local installers. These challenges can be classified using the term *behavioral*

plasticity, or the proportion of individuals who could be influenced to take an action, and the concept can be used to estimate the plausible emissions reductions arising from use of state of the art interventions (Dietz et al., 2009). Behavioral plasticity has been widely used in studies of climate-relevant behaviors (Kaplowitz & Boucher, 2022; van der Linden & Goldberg, 2020). ~~By integrating concepts of behavioral plasticity into policy-based assessments, program managers may be able to design and implement programs that better account for human behavior~~

Importantly, behavioral plasticity related to household action varies significantly by geography, demographics, and identity, which may be related to the degree of agency a household possesses. For example, research suggests an "emissions paradox" exists in the US, where white communities tend to emit more carbon than Black communities, despite living in more energy-efficient homes (Goldstein et al., 2020). Similarly, renters are more likely to be excluded from energy efficiency programs, a phenomenan called "the split incentive", where landlords are discouraged from investing in energy efficiency because the savings benefit the renter (Bird & Hernández, 2012). Further, energy efficiency programs vary significantly by state, where state-level disparities can be seen in low-income investments by utilities (T. G. Reames et al., 2019). These variations influence the efficacy of programmatic implementation and should be considered in tandem with behavioral plasticity to ensure a just energy transition. Social and behavioral science insights may enable program managers to design and implement programs that better account for human decisionmaking (Dietz et al., 2009; Kaplowitz & Boucher, 2022; van der Linden & Goldberg, 2020).

~~To demonstrate~~Given the ~~substantial role~~ ongoing scholarly debates surrounding the value of household action in reducing climate emissions, the analysis we present here demonstrates that household actions play a substantial role in the IRA~~,~~ and IIJA and suggests opportunities for programmatic design, given evidence-based findings based on behavioral plasticity. We followed a

two-part methodological approach: 1) policy analysis of the IRA and IJJA to identify household incentives; and 2) secondary data analysis of REPEAT's policy model results to identify the potential for emissions reductions associated with household actions. ~~We argue for incorporating behavioral plasticity into policymaking and programmatic design to increase emissions reductions that will be achieved in household-level energy transitions.~~

2. IRA and IIJA Policy Analysis

~~The final version of the IRA was~~We assessed final versions of the IRA and IIJA to examine the emissions reductions associated with household actions (signed August 16, 2022~~). Although the emissions estimates from REPEAT's policy modeling efforts utilize earlier versions of the law (Released by Senate Democratic Leadership on July 27, 2022 and placed on the Senate Calendar August 03, 2022), there is a no difference in household-level funds between the two versions (Supplementary Table 2).~~

~~The IRA was analyzed to identify~~, and November 14, 2021, respectively). We identified actions that many individuals or households have the agency to address, such as residential energy upgrades, travel and commute patterns, or resource consumption. For instance, replacing an aging car with an electric vehicle or replacing an old water heating system with a new heat pump water heater ~~represents an action~~represent actions that many households have the agency to address.

Using this definition, we identified several provisions in the IRA and IIJA that target individual or household actions. Actions incentivized by the IRA include weatherization, distributed energy generation, personal electric vehicles, heat pumps, and others (Table 1, Figure 1). In all, the IRA dedicated $38.8 billion to incentivizing household behaviors (11.7% of all funds aimed at energy and climate~~) (Table 1, Figure 1).~~

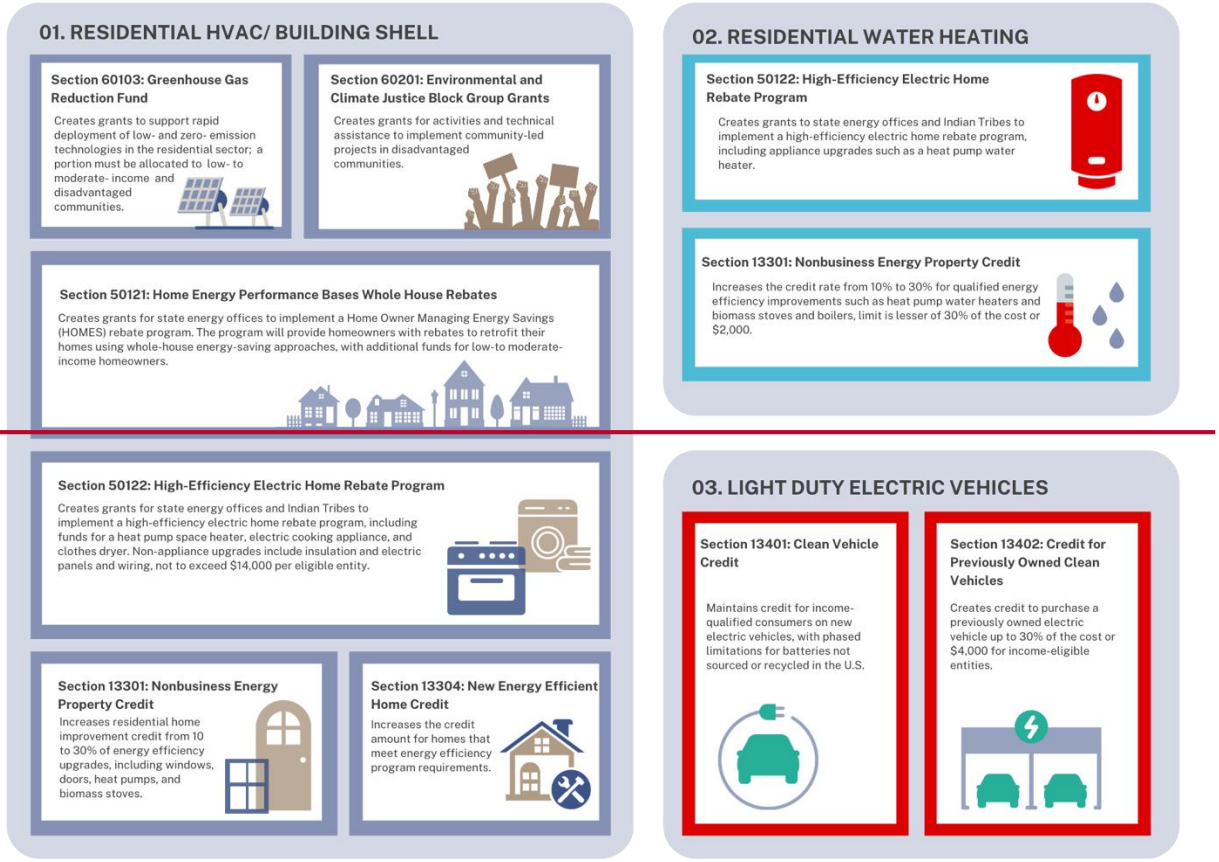
~~Table 1.~~), while the IIJA dedicated $4.3 billion to household behaviors (5.7% of clean energy and power funds) (Tables 1 and 2, Figure 1).

Table 1. Household action types, section, description, and legislative funds in the 2022 IRA. Note: Tax credits do not explicitly allocate funds, and several action types are often mentioned ~~within~~in each ~~IRA~~ section.

Action Type	*IRA Section*	*Description*	*Legislative Funds*
Residential HVAC/ Building Shell	60103	Creation of grants for states, municipalities, and Tribal governments to promote rapid deployment of low- and zero- emission technologies in the residential sector, including distributed energy generation projects and other greenhouse gas reduction efforts. A portion must be allocated to low and moderate income and disadvantaged communities.	$27 billion
Residential HVAC/ Building Shell	60201	Creation of grants for activities and technical assistance to implement community-led projects in disadvantaged communities. Community-engaged projects associated with pollution monitoring and prevention, climate and health risk mitigation, low-and zero-emission technology implementaton, and the reduction of indoor air pollution exposure are considered eligible.	$3 billion
Residential HVAC/ Building Shell	50121	Creation of grants for state energy offices to implement a Home Owner Managing Energy Savings (HOMES) rebate program. Additional funds available for low to moderate income individuals.	$4.3 billion
Residential HVAC/ Building Shell	50122	Creation for grants for state energy offices and Indian Tribes to implement a high-efficiency electric home rebate program among low and moderate income households. Weatherization upgrades include heat pumps for space heating/cooling, electric stoves/cooktops, an electric heat pump clothes dryer, breaker upgrades, insulation, air sealing, panels/wiring; not to exceed $14,000 per eligible entity.	$4.5 billion
Residential HVAC/ Building Shell	13301	Extends the credit in section 25c of the Internal Revenue Code of 1986 and increases the credit rate from 10% to 30% for qualified energy efficiency improvements. Replaces the lifetime credit limitation with an annual limit of $1,800 or $600 for qualified energy property. This includes up to $600 for windows and $500 for doors. However, heat pump space heaters and biomass stoves are not subject to per item limitation and if installed, the annual credit limit is lesser of 30% of cost or $2,000.	N/A
Residential HVAC/ Building Shell	13304	Extends the credit in section 45L of the Internal Revenue Code of 1986 and increases the amount for single family and manufactured homes to $2,500 that meet recent Energy Star Single-Family New Homes or Manufactured Home Program requirements and $5,000 credit for a certified zero energy ready home under DOE Zero Energy Ready Home Program.	N/A
Water Heating	50122	Support for state energy offices and Indian Tribes to implement a high-efficiency electric home rebate program. Appliance upgrades include up to $1,750 for a heat pump water heater.	Included above
Water Heating	13301	Extends the credit in section 25c of the Internal Revenue Code of 1986 and increases the credit rate from 10% to 30% for qualified energy efficiency improvements. Replaces the lifetime credit limitation with an annual limit of $1,800 or $600 for qualified energy property. Heat pump water heaters and biomass water boilers are not subject to per item limitation and if installed, the annual credit limit is lesser of 30% of cost or $2,000.	Included above
Light Duty Electric Vehicles	13401	Keeps the current $7500 credit in section 30D of the Internal Revenue Code of 1986 but reduces the credit if a percentage of the battery is not extracted/processed in the US or with an FTA or recycled in North America. The percentage increases from 40% in 2024 to 80% in 2026. Limits application of credit for individuals whose income exceeds $150,000 or $300,000 for joint filers. Limits credit for purchases less than or equal to $80,000 for vans, SUVs and pickups and $55,000 for other vehicles.	N/A
Light Duty Electric Vehicles	13402	Creates tax credit (section 25E of the Internal Revenue Code of 1986) for consumers to purchase a previously owned electric vehicle, equivalent to $4,000 or 30% of the total cost and limits eligibility for individuals making more than $75,000 or $150,000 for joint filers. Limits credit's utility to previously owned vehicles which are at least 2 years older than the year of sale and does not exceed $25,000.	N/A
			Total Funds: $38.8 Billion

Table 2. Household action types, section, description, and legislative funds in the 2021 IIJA.

Action Type	*IIJA Section*	*Description*	*Legislative Funds*
Residential HVAC/ Building Shell	40502	Provides funds to establish the Energy Efficiency Revolving Loan Fund Capitalization Grant program under the State Energy Program for states to conduct commercial or residential energy audits or upgrades and retrofits.	$0.25 billion
Residential HVAC/ Building Shell	40551	Increases funding for the Weatherization Assistance Program (WAP), a federal program dedicated to reducing residential energy costs and improving health and safety for low-income households.	$3.5 billion
Residential HVAC/ Building Shell	40552	Provides block grants to cities, communities, states, U.S. territories, and Tribal communities to develop, promote, implement, and manage energy efficiency and conservation projects.	$0.55 million
			Total Funds: $4.3 Billion


01. RESIDENTIAL HVAC/ BUILDING SHELL
Section 60103: Greenhouse Gas Reduction Fund
Creates grants to support rapid deployment of low- and zero- emission technologies in the residential sector; a portion must be allocated to low- to moderate- income and disadvantaged communities.
Section 60201: Environmental and Climate Justice Block Group Grants
Creates grants for activities and technical assistance to implement community-led projects in disadvantaged communities.
Section 50121: Home Energy Performance Bases Whole House Rebates
Creates grants for state energy offices to implement a Home Owner Managing Energy Savings (HOMES) rebate program. The program will provide homeowners with rebates to retrofit their homes using whole-house energy-saving approaches, with additional funds for low-to moderate-income homeowners.
Section 50122: High-Efficiency Electric Home Rebate Program
Creates grants for state energy offices and Indian Tribes to implement a high-efficiency electric home rebate program, including funds for a heat pump space heater, electric cooking appliance, and clothes dryer. Non-appliance upgrades include insulation and electric panels and wiring, not to exceed $14,000 per eligible entity.
Section 13301: Nonbusiness Energy Property Credit
Increases residential home improvement credit from 10 to 30% of energy efficiency upgrades, including windows, doors, heat pumps, and biomass stoves.
Section 13304: New Energy Efficient Home Credit
Increases the credit amount for homes that meet energy efficiency program requirements.
02. RESIDENTIAL WATER HEATING
Section 50122: High-Efficiency Electric Home Rebate Program
Creates grants to state energy offices and Indian Tribes to implement a high-efficiency electric home rebate program, including appliance upgrades such as a heat pump water heater.
Section 13301: Nonbusiness Energy Property Credit
Increases the credit rate from 10% to 30% for qualified energy efficiency improvements such as heat pump water heaters and biomass stoves and boilers, limit is lesser of 30% of the cost or $2,000.
03. LIGHT DUTY ELECTRIC VEHICLES
Section 13401: Clean Vehicle Credit
Maintains credit for income-qualified consumers on new electric vehicles, with phased limitations for batteries not sourced or recycled in the U.S.
Section 13402: Credit for Previously Owned Clean Vehicles
Creates credit to purchase a previously owned electric vehicle up to 30% of the cost or $4,000 for income-eligible entities.

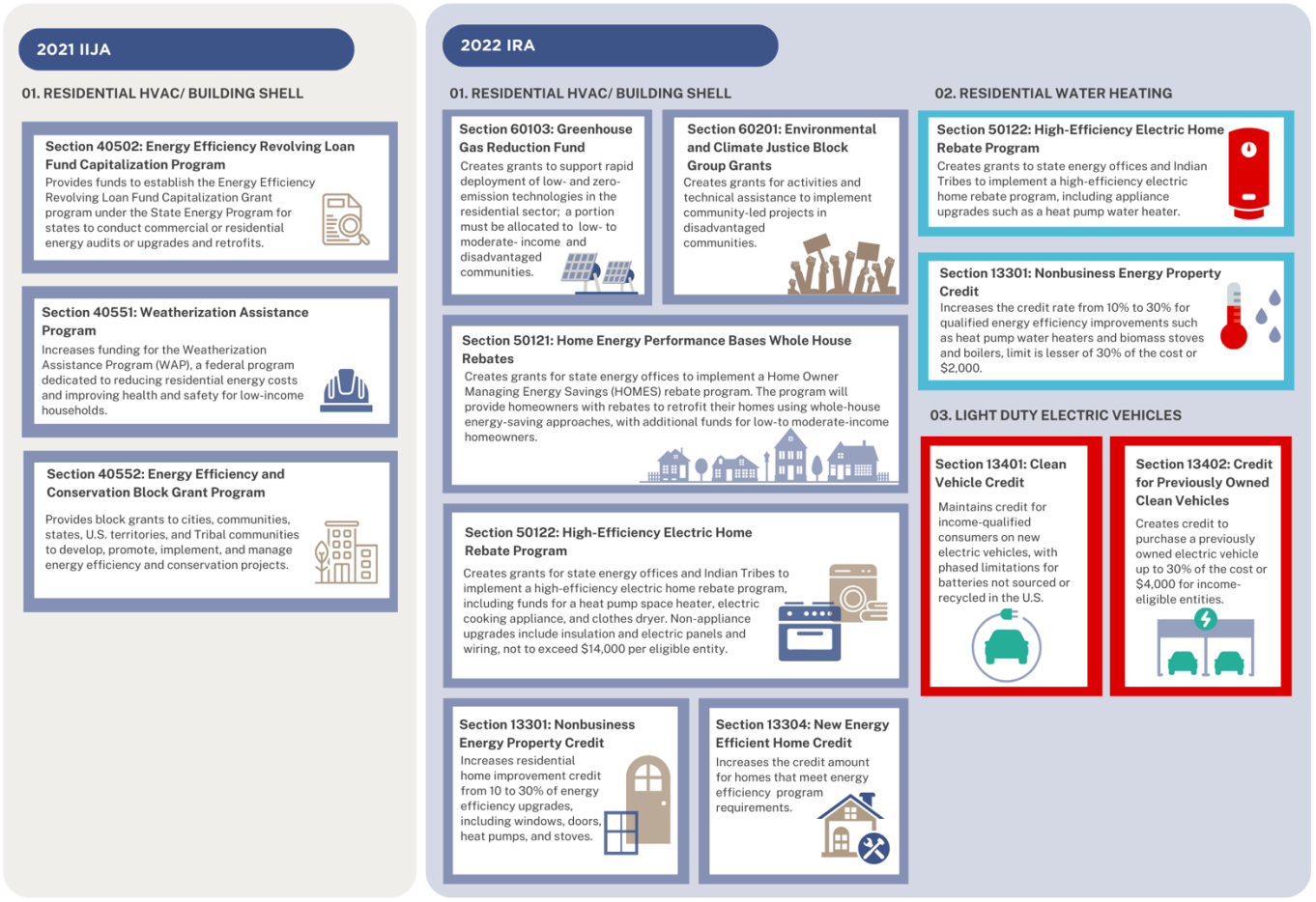


Figure 1. Three sections in the IIJA and eight sections in the IRA incentivize household actions spanning three behavioral wedge action types.

3. REPEAT Case Study

To understand the relationship between household actions incentivized by the IRA and estimated emissions, we utilized ~~REPEAT as a case study. REPEAT provides more technical documentation for its models than the two other leading models of IRA emissions reductions (Rhodium and Energy Innovation). REPEAT also provides summaries of its assumptions and inputs for all environmental sections of the IRA—information that was not as readily available from other groups (Jenkins, Farbes, & Jones, 2022).~~ modeling results from REPEAT as a case study. REPEAT provides more technical documentation for its models than the two other leading models

of IRA emissions reductions (Rhodium and Energy Innovation). REPEAT also provides summaries of its assumptions and inputs for all environmental sections of the IRA—information that was not as readily available from other groups (Jenkins et al., 2023).

REPEAT utilizes a cost-optimized modeling approach that draws on energy service demand assumptions largely based on the United States Energy Information Administration's Annual Energy Outlook 2021 and technology costs from the National Renewable Energy Laboratory Annual Technology Baseline 2021 (Jenkins, Mayfield, et al., 2022). Once macro-energy estimates for energy demand and technology costs are created, the model optimizes a supply-side scenario to meet demand at the lowest cost (Jenkins, Mayfield, et al., 2022; Larson et al., 2021).

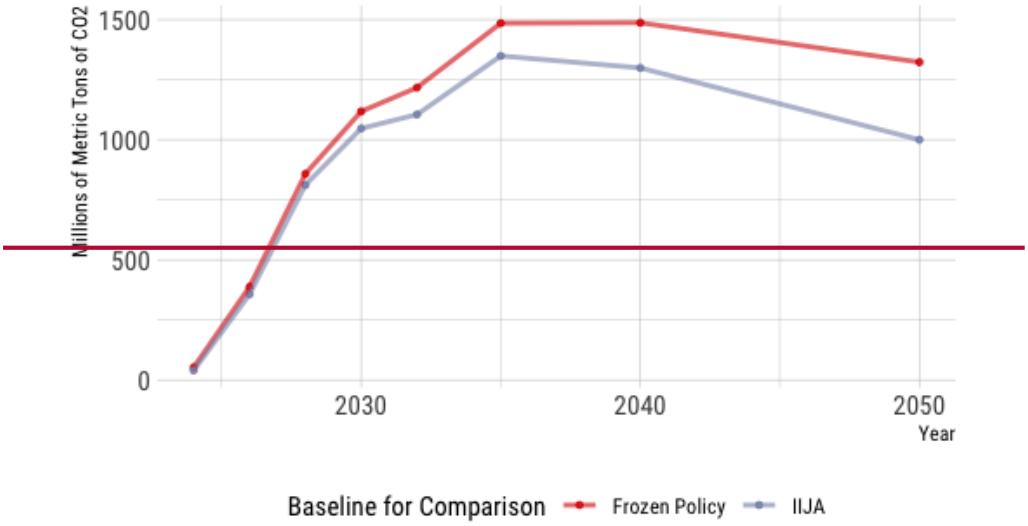
~~Although the full details of the REPEAT estimates of emissions under IRA are not yet available to the public, details of previous analyses of scenarios such as Frozen Policy, which represents the policies in place when President Biden was inaugurated in January 2021, the IIJA, and the BBBA were available (Rapid Energy Policy Evaluation and Analysis Toolkit, 2022). We used these model results to explore the potential contributions of household actions to calculated emission reductions. Although the IIJA has few provisions that address household behavior (Supplementary Table 1), it constituted an additional baseline when compared to the Frozen Policy scenario for analyzing the impact of household emissions. Further, the BBBA is the IRA's predecessor, with highly similar policy sections and a relatively small difference between allocated funds (14.6% difference, Supplementary Table 1).~~

~~To analyze the impact of~~REPEAT estimates of emissions under the Current Policies Scenario (IRA and IIJA) were made available to the public in July of 2023. The IIJA and IRA are represented using a trio of scenarios, which represent different estimates for the effectiveness of implementing the programs under 'Conservative', 'Mid-Range', and 'Optimistic' assumptions (Supplementary

Table 1). In addition to historic scenarios such as Frozen Policy, which represents the policies in place when President Biden was inaugurated in January 2021, and the IIJA alone, scenarios such as the Net-Zero Pathway Benchmark, a yardstick assessment tool created by REPEAT to measure US progress, are estimated (Jenkins et al., 2023). We used these publicly-available model results to explore the potential contributions of household actions to calculated emission reductions.

To analyze the future impacts of energy and climate policies (e.g., Frozen ~~Policies and the IIJA as compared to the BBBA over time,~~ Policy and the trio of scenarios associated with Current Policy), we used REPEAT's estimated emissions ~~data~~ by fuel type and energy use for the residential and transportation sectors ~~were used (Rapid Energy Policy Evaluation and Analysis Toolkit, 2022).~~, except for various oil products, such as heating oil, gasoline fuel, and diesel fuel, as we explain below (REPEAT 2023). We used the emissions intensity of ~~gasoline and diesel fuel was~~ coal and natural gas provided by REPEAT. Further, because the REPEAT analysis aggregates emissions from ~~REPEAT. In contrast,~~ all oil products into one category, we calculated disaggregated emissions for gasoline and diesel fuel, and home heating oil, by multiplying the REPEAT estimates of energy consumption for gasoline, diesel fuel, and home heating oil by carbon emissions factors for each fuels as reported by the EPA (US Energy Information Administration, 2023). Lastly, because data on emissions from electricity generation was not available, we converted the emissions intensity associated with electricity generation ~~was converted~~ from quadrillion BTU to Million Metric Tons (MMT) using the Environmental Protection Agency's (EPA) Greenhouse Gas Equivalencies Calculator ~~to convert from quadrillion BTU to Million Metric Tons (MMT) (US EPA, 2015).~~(US EPA, 2015), based on the mix of fuels used for generation according to the REPEAT analysis for the different scenarios. Using these values, we summarized energy use and associated emissions for household actions ~~were estimated by~~for each policy scenario, using ~~the BBBA~~Frozen Policy as a ~~reference.~~baseline. All data analyses were conducted using R (v. 4.3.1)(R Core Team 2023).

We concluded that actions proposed in the ~~BBBA could result in significant reductions in~~Mid-Range Current Policies Scenario could considerably lower total emissions, up to ~~1,487~~1008 MMT of CO_2 could be reduced annually when compared to Frozen Policy ~~and up to 1,349 MMT of CO2 annually when compared to the IIJA~~ (Figure 2).



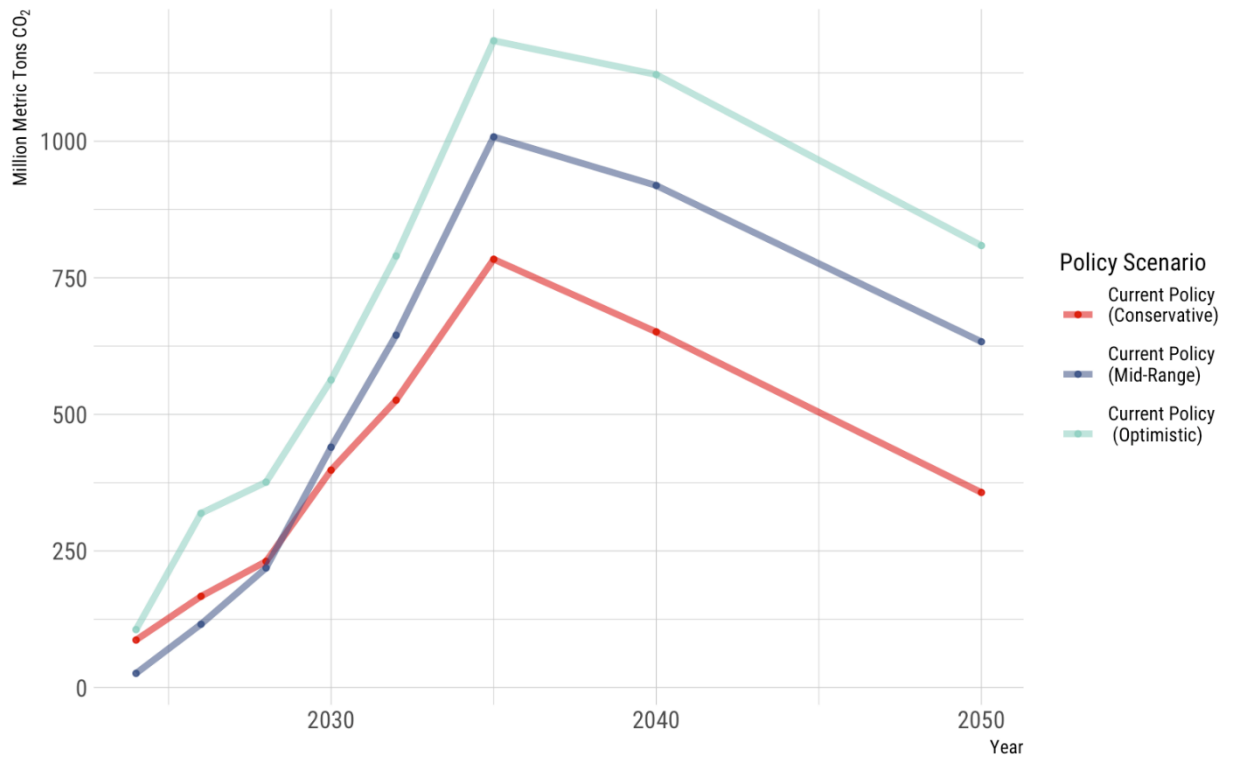
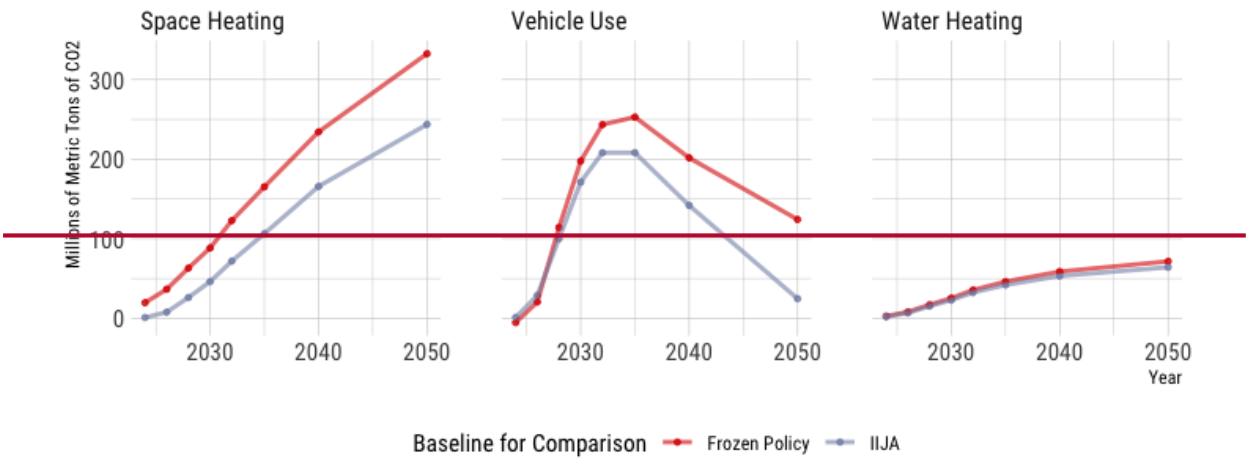


Figure 2. Total emissions reductions estimated under the ~~BBBA, when compared~~trio of Current Policy Scenarios from 2024 to 2050, using Frozen Policy ~~and the IIJA~~as a baseline.

To assess the role of household actions in the IRA, we disaggregated the effects of those actions on household energy consumption by fuel from the impacts of actions outside the household's purview on the carbon intensity of those fuels. For instance, if utility companies shift the mix of electrical generation away from fossil fuels and toward renewable or nuclear energy sources, the emissions reduction associated with household electricity consumption would not be due to household actions. We performed this disaggregation by recalculating three baseline scenarios, each corresponding to the household energy consumption under the frozen policy scenario, but using greenhouse gas emissions coefficients for each energy source that correspond to current policies, under conservative, mid-range, and optimistic assumptions. We then calculated the emissions reduction associated with household energy consumption changing to the current-policy

scenario from the corresponding baseline. By taking emissions factors from the current policy for both the baseline and current-policy scenarios, we were able to calculate the effect of changing household energy demand and fuel mix separately from changes in energy supply, infrastructure, and carbon intensity that are beyond the household's control.

When considering household actions proposed in the ~~BBBA~~Current Policy Scenarios, we concluded that provisions supporting residential space and water heating in the Mid-Range Policy Scenario could result in emissions reductions of up to ~~404~~261.6 MMT of CO_2 annually (~~332.5~~199 and ~~71.5~~62.6 MMT of CO_2, respectively), as compared to Frozen Policy. Further, provisions supporting changes to light-duty trucks and autos could result in emissions reductions of up to ~~253 MMT~~191 MMT in the Mid-Range Current Policy Scenario as compared to Frozen Policy (Figure 3).



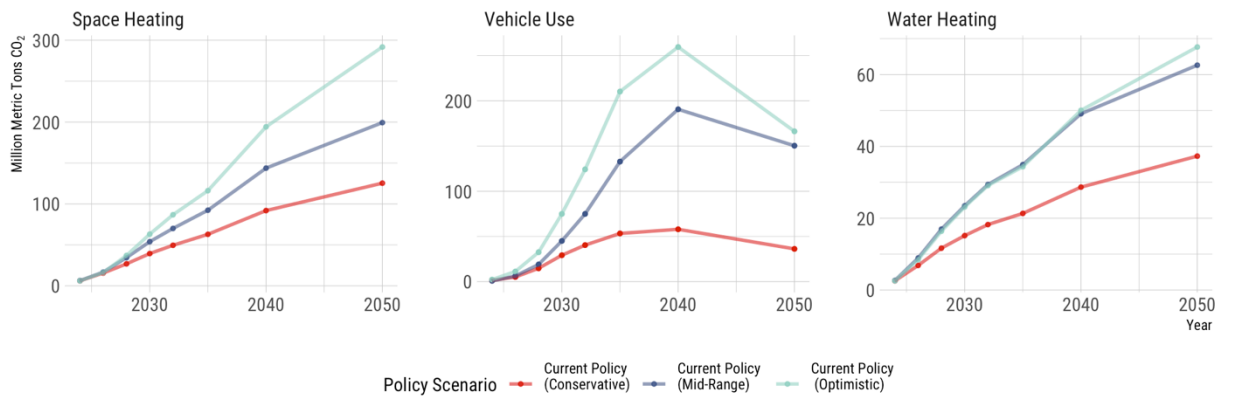
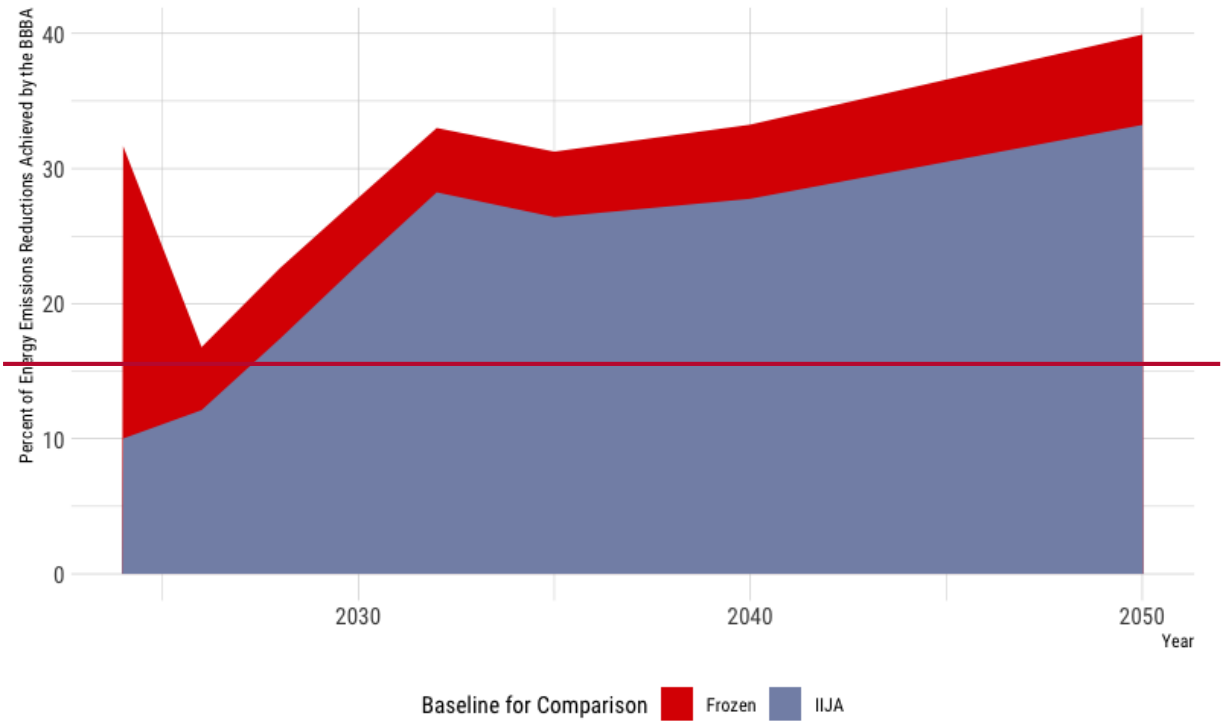


Figure 3. Total emissions reductions estimated under the ~~BBBA~~trio of current policy scenarios for household actions such as a) vehicle use, b) residential heating, and c) residential water heating as compared to Frozen Policy ~~and the IIJA~~.

~~Finally, the analysis based on the REPEAT model suggested that the proposed provisions in the BBBA addressing household actions produced up to 39.9% of the total annual emissions reductions attributable to the BBBA as compared to household actions under Frozen Policy (range = 16.8% to 39.9%). The analysis also suggested that the BBBA provisions regarding household actions produced up to 33.2% greater annual emissions reductions than produced by household provisions in the IIJA (range = 10.0% to 33.2%). On average, household actions proposed under the BBBA could save 25.9% of annual emissions in the United States between 2024 and 2050 (Figure 4).~~



Finally, we calculated the cumulative emissions reductions due to household actions from 2024-2050 and compared them to the total cumulative emissions reductions reported by the REPEAT project. This suggests that under the Mid-Range and Optimistic current policy scenarios, 40% of the expected cumulative emissions reductions through 2050 under IRA and IIJA will be due to household actions (Figure 4).

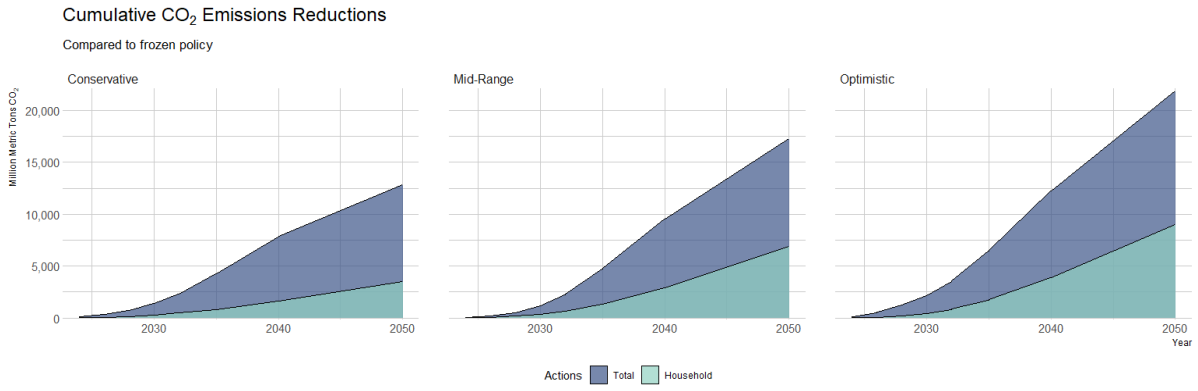


Figure 4. ~~Percent of~~Household Action and Total emissions reductions ~~estimated under proposed provisions in the BBBA addressing household actions such as vehicle use, residential heating, and residential water heating,~~for the Trio of Current Policy Scenarios as compared to ~~household actions under~~ the Frozen Policy ~~and IIJA scenarios~~Scenario.

4. Conclusions and Policy Implications

Our results ~~suggested~~suggest that household actions ~~are~~play a substantial ~~focus of~~role in the IRA and IIJA. The IRA ~~includes eight~~and IIJA include a combined eleven sections that directly incentivize these actions, including the uptake of efficient heat pumps, water heaters, and personal electric vehicles, and these types of household actions account for roughly $38.8 billion or 11.7% of the climate and energy funds in the IRA~~.~~ and $4.3 billion or 5.7% of clean energy and power funds in the IIJA. Although our budgetary analysis considers appropriated funds, it is essential to note that uncapped tax credits associated with clean energy and efficiency incentives represent more than two-thirds of the climate and energy provisions in the IRA and are challenging to model (Bistline et al., 2023).

The relatively small financial subsidies in the IRA ~~also~~and IIJA as compared to subsidies for non-household actions could produce a disproportionately large share of the estimated emissions reductions from ~~the IRA~~these laws. Based on models of the ~~IRA's predecessor, the BBBA~~Mid-Range Current Policy Scenario, we estimated that ~~up to 39.9~~40% of annual estimated emissions reductions ~~were~~could be attributable to household actions. In short, roughly 12% of the ~~total~~ climate and energy spending in the IRA ~~is~~ and 5.7% of clean energy and power funds in the IIJA are focused on household actions, ~~and that 12%~~which may ~~yield up to~~produce 40% of ~~its~~the total cumulative emissions reductions through 2050.

The household actions subsidized by the IRA and IIJA are only a ~~baseline~~beginning, and the recent legislative embrace of these types of actions may continue or increase. The large and growing role of household actions thus suggests the need to increase the research base and agency expertise

on household policies and programs. (Stern et al., 2023). An important aspect of this research and agency expertise is a better understanding of the behavioral plasticity of households, which may differ substantially from that of the traditional industrial targets of environmental laws and policies. Integrating behavioral plasticity into policy modeling estimates and program design will be critical for exploiting the opportunity to harness household actions in climate change mitigation.

To augment future policy models and programmatic interventions, we also suggest the following implementation strategies for the IIJA and IRA, aligned with the policy design principles enumerated in Stern et al's *Design Principles for Carbon Emissions Reduction Programs* al. (2010): 1) Ensure household programs prioritize impactful action. and Vandenbergh et al. (2010): 1) Ensure household programs prioritize impactful action. For example, while re-insulating one's home may effectively curb emissions (technical potential), individuals may be more likely to take advantage of smaller projects, such as replacing windows or doors (behavioral plasticity). Designing programs to balance technical potential and behavioral plasticity will help ensure rapid and widespread emissions reductions (Dietz et al., 2009). 2) Provide significant financial incentives. While the IRA offers many financial incentives in its provisions, programmatic design should focus on lowering the barriers to accessing those funds. For example, if eligibility requirements are unclear for the used clean vehicle credit program, household decision-makers may be disincentivized to take advantage of credits. 3) Strongly market the program. Although media campaigns can be effective, research suggests that local context matters in home energy efficiency programs and community-based programs can be more effective (Reames, 2016).Although media campaigns can be effective, research suggests that local context matters in home energy efficiency programs and community-based programs can be more effective (T. Reames, 2016). 4) Provide valid information from credible sources at the points of decision. For example, if HVAC contractors are equipped with credit options in the IRA, they can advise their customers on savings options at the time of replacement. 5) Keep it simple.

Programs are more likely to be successful if they minimize the burden on the consumer. Thus, lessening the paperwork, timelines, and organizational navigation associated with the ~~IRA's household provisions may significantly increase uptake.~~IIJA and IRA's household provisions may significantly increase uptake. A recent example of this is the US Department of the Treasury's rule proposal, intended to provide immediate rebates for the IRA's EV tax incentives at the point of sale (US Department of the Treasury, 2023). 6) Provide quality assurance. Household decision-makers should be confident that their decision to take advantage of the IIJA and IRA's incentives will be worth the additional time spent identifying qualified car salespeople, eligible appliances, and certified contractors.

Household behavior is also significantly tied to a ~~household's~~household's level of agency. For example, replacing an old water heating system with a new heat pump water heater in a single-family home represents an action that many households have the agency to address. In contrast, the same replacement in a multi-family dwelling is likely to be limited by external constraints or coordination requirements associated with a renter's or unit owner's agency. Behavioral wedge actions are also likely to vary by community and household-level structural inequities. For example, low-income homeowners requiring health and safety upgrades will likely be ~~deferred~~deterred from participating in low-income weatherization assistance programs until costly repairs are made (Tonn et al., 2015). At the same time, high-socioeconomic status households are responsible for far more consumption-based CO_2 emissions than their low-income counterparts, presenting a significant potential for emissions reductions (Nielsen et al., 2021). Thus, targeting higher-income households and addressing structural inequities concomitantly should be prioritized for IIJA and IRA program design.

Household action not only presents ~~viable new pathways~~important pathway for emissions reductions, but also provides opportunities to increase efficiency and reduce the inequitable energy burdens of low-income households. The growing focus on household action thus can promote both climate change mitigation and energy justice.

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Appendix

	Infrastructure Investment and Jobs Act November 6, 2021		**Inflation Reduction Act,** July 27, 2022			
Action Type	**Section**	**REPEAT Modeled Funds**	**Section**	**REPEAT Modeled Scenarios**		
				Conservative	**Mid-Range**	**Optimistic**
Residential HVAC/ Building Shell	40502-- Energy efficiency revolving loan fund capitalization grant program	$0.25	60103-- GHG Reduction Fund	$13.3 modeled funds, assuming total loan volume is $40 and 10% program effectiveness	$20 modeled funds, assuming total loan volume is $60 and 20% program effectiveness	$33.3 modeled funds, assuming total loan volume is $100 and 40% program effectiveness
	40551-- Weatherization assistance program	$3.5	60201-- Environmental and Climate Justice Block Grants	$1.5 modeled funds, assuming 10% program effectiveness	$1.5 modeled funds, assuming 20% program effectiveness	$1.5 modeled funds, assuming 40% program effectiveness
	40552-- Energy Efficiency and Conservation Block Grant Program	$0.55	50121-- Home Energy Performance-Based, Whole House Rebates	$4.3 modeled funds, assuming 10% program effectiveness	$4.3 modeled funds, assuming 20% program effectiveness	$4.3 modeled funds, assuming 40% program effectiveness
			50122-- High-efficiency electric home rebate program	$2.25 modeled funds, assuming 10% program effectiveness	$2.25 modeled funds, assuming 20% program effectiveness	$2.25 modeled funds, assuming 400% program effectiveness
			13301-- Extension, increase, and modification of nonbusiness energy property credit (25C)	N/A		
			13304-- Extension, increase, and modification of new energy efficient home credit (45L)	N/A		
Water Heating			50122	$2.25 modeled funds, assuming 10% program effectiveness	$2.25 modeled funds, assuming 20% program effectiveness	$2.25 modeled funds, assuming 400% program effectiveness
			13301	N/A		
Light Duty Vehicles			13401-- Clean Vehicle Credit	N/A		
			13402-- Credit for previously-owned clean vehicles	N/A		
		Total Funds: $4.3 Billion		**Total Funds:** $23.6 Billion	$30.3 Billion	$43.6 Billion

Supplementary Table 1. Policy comparison for the ~~BBBA,~~ the IIJA~~;~~ and the IRA, including household action type, section, and funds and scenarios as modeled ~~funds~~ by REPEAT

~~**Supplementary Table 2.** Differences in funds dedicated to household actions between the IRA's two versions (August 02, 2022 and August 06, 2022).~~

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

CRediT Authorship Statement:

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