Annual Cost per Household of Achieving Net-Zero 2050 in the U.S.[1]

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Executive Summary

There is an extensive literature regarding estimation if the “social cost of carbon.” In principle, this is an estimation of the environmental damage associated with carbon emissions to the atmosphere, not an estimate of the benefits of abating these emissions. There are substantially fewer estimates of the cost of abatement, and apparently no estimates of the cost of abatement at the household level, where all costs are ultimately manifest. In January 2021, President Biden announced that it would be Administration policy to achieve Net Zero 2050 — the reduction to zero of carbon emissions net of those which cannot be abated at any known price. This announcement directed all federal agencies to take action and did not include any estimates of the cost of achieving this policy objective. The rhetoric surrounding the policy announcement displays little or no interest in what it would cost.

This paper provides a plausible lower-bound estimate of the cost of achieving Net Zero 2050 in the U.S. It is a lower bound because it assumes Net Zero 2050 is achieved via a uniform carbon tax on energy-related CO2 emissions. Such a tax does not exist and appears unlikely to be enacted by Congress. Nonetheless, a uniform carbon tax would be the least-cost means of achieving Net Zero 2050, and much less expensive than continuing to pursue it through regulations promulgated under the authority of various federal statutes.

Cost is reported at the household-level, in both dollars and percentage of median household income, disaggregated by State. Two scenarios are examined: (A) annual household-level cost is the quotient of tax revenues collected from each State’s energy-related CO2 emissions divided by the number of households in the State; and (B) annual household-level cost is the quotient of tax revenues collected nationally and divided by the number of households in the nation. These scenarios purposefully ignore the uncountable complexities that could be included in tax design for the purpose of rewarding favored geographies and interest groups, which necessarily would result in punishing others.

Four alternative carbon tax rates are considered, ranging from $100/metric ton to $700/metric ton. The paper is agnostic concerning which of these values is correct. It is noted, however, that Net Zero 2050 advocates portray climate change as an “existential” “crisis” deserving an “emergency” response. Therefore, tax rates at the upper end of this range are not unreasonable. And tax rates at the lower end have been criticized as likely to be ineffective.

Looking across States under Scenario A, the household-level burden, assuming Net Zero 2050 can be achieved at $100/metric ton, ranges from $974 per year (District of Columbia) to $25,338 per year (Wyoming), with a State median of $4,165 per year. Expressed as percent of median household income, this range is 1.1% to 39%, At $700/metric ton, the range is $6,817 per year to $177,368 per year, with a State median of $29,157 per year.

Under Scenario B, the highly disproportionate household-level costs on households residing in carbon-based energy-exporting States is substantially reduced, with households in carbon-based energy importing States picking up the slack. All U.S. households are

assumed to pay $4,231 per year at $100/metric ton and the range is $29,619 per year at $700/metric ton. Because household income differs substantially by State, this uniform carbon tax would have disproportionate interstate impacts. At $100/metric ton, the range is 4.7% of median household income (District of Columbia) to 9.1% of median household income (Mississippi). At $700/metric ton, the range is 7.4% to 64% of median household income.

I. Introduction

Climate change in general and Net Zero 2050 in particular now occupy center stage in domestic and international environmental policy fora. Moreover, a Google Scholar search yields 146,000 apparently unique scientific references published in 2022 alone. A small fraction of these publications is concerned with the cost of mitigation, and fewer still provide useful insight concerning the costs households can expect to bear. This paper provides default cost estimates for U.S. households. It relies on respected third-party estimates of the transformative economic changes that are expected to be required, with shadow prices for carbon under alternative implementation scenarios. Finally, it takes as given the economic principle that all costs which cannot be exported are ultimately borne by households, even if the distribution of costs among households varies or is today unknown.

The remainder of this Section briefly describes Net Zero 2050 and the alternative means available to the U.S. (or other national governments) to achieve it. Most of these means, such as myriad examples of command-and-control regulation, would not be transparent because their opportunity costs are poorly understood by experts and the public alike. Several nontraditional forms of indirect regulation also have been proposed or implemented, such as financial regulations, and environmental, social, and governance (ESG) policies the effects of which would be mediated through financial markets. Estimating the costs of these nontraditional regulatory approaches is especially difficult.

The most transparent (and economically cost-effective) means of achieving Net Zero 2050 is through a direct tax on the emission of carbon dioxide and other greenhouse gases. Because a carbon tax is uniquely transparent and would be more cost-effective than any other policy approach, it provides a credible lower-bound cost estimate. When divided by the number of households in any jurisdiction, the resulting quotient is the (minimum) cost per household. Though there are many ways to implement a carbon tax in the U.S., two simple alternatives are considered: (1) a carbon tax based on energy-related CO2 emissions by State, and (2) a tax based on national energy-related CO2 emissions. Under Tax 1, households in each State would share equally the aggregate tax on in-State CO2 emissions; under Tax 2, households in the U.S, would share equally the aggregate tax on nationwide CO2 emissions. Both are oversimplifications. For example, the actual burden of a carbon tax, even if levied directly on households, would not be borne equally across households. Also, Tax 1 would be transferred to households in other States to the extent that factors of production (e.g., stock ownership) and distribution (e.g., suppliers and customers) are located elsewhere. Similarly, the burden of Tax 2 would be redistributed unequally across States. Intensive modeling is required to tease out these second-order effects, and it is more important at this stage to provide broad indicators.

Finally, there is an infinite number of carbon tax designs from which legislators could choose, not just the two considered here. Any actual carbon tax is virtually certain to have complex design features intended to shift burdens away from protected interests.

A. Net Zero 2050

Global energy-related CO2 emissions are forecast to rise from 39,259 million metric tons in 2022 to 42,839 million metric tons in 2050. The U.S. share is projected to decrease from 13.3% (2022) to 11.2% (2050).[2] Net-Zero 2050 is a plan to reduce these emissions to zero, taking account of the fact that some emissions cannot be prevented at any known cost. Net Zero 2050 would require that the quantity of emissions that cannot be eliminated be stored instead of released, this resulting in *net* zero emissions.

This is a highly ambitious goal agreed upon in 2016 in the Paris Agreement.[3] In 2021, President Joseph R. Biden Jr. committed to reduce net greenhouse gas (GHG) emissions by 50-52% below 2005 levels by 2030 (United Nations Framework Convention on Climate Change 2021). In this "base" year, GHG emissions are estimated to have been 6,645 million metric tons (U.S. Environmental Protection Agency 2022). Thus, the Administration's commitment is to eliminate 3,232 million metric tons by 2030 and all 6,645 million metric tons by 2050.[4]

The magnitude of this policy goal is hard to overstate. Its advocates characterize it as

B. Alternative ways to achieve Net Zero 2050

There are two primary ways to achieve this goal: (1) leverage market forces by establishing either a cap-and-trade system or a carbon tax, or (2) expand reliance on traditional command-and-control regulations such as those promulgated by U.S. EPA under

[2] U.S. Energy Information Administration (2022b).

[3] United Nations Framework Convention on Climate Change (2016). Art. 2, Sec. 1(a) sets forth the goal of limiting the increase of global temperature to 1.5°C above its pre-industrial level. Art. 4, Sec. 1 sets forth the implementation goal "to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century." The year 2050 is the beginning of that range (2099 also qualifies as within the range) and, while not explicitly mentioned, is usually expressed as the stated goal.

[4] Because the U.S. Senate has not ratified an applicable treaty, and the U.S. Congress has not enacted any legislation establishing Net Zero 2050 as U.S. policy, the Administration's commitments are its own. They are not legally binding and may be rescinded at any time.

the Clean Air Act, regulations issued under other statutory authorities,[5] and nongovernmental entities attempting to advance Net Zero 2050 through coordinated private sector action.[6] Many of these actions face legal challenges, including disputes about whether federal agencies have requisite statutory authority and whether coordinated action by asset managers is compliant with antitrust law. I

The costs of these actions are much less transparent than Clean Air Act regulation, in large part because their authors generally conduct no benefit-cost analysis. For purposes of this paper, all that matters is that they are (or would be) considerably less cost-effective than a simple carbon tax. For that reason, the carbon tax provides a credible lower bound for the cost of Net Zero 2050.

1. Market-based regulation

Under a cap-and-trade scheme, Congress would establish a fixed number of emission permits and let markets set the price. Generally, more than *de minimis* quantities CO2 could not be emitted without a permit. They would reduce their own emissions to the extent they could at a cost below the market-clearing permit price and earn permits to the extent they reduced more emissions than permits allowed. They would buy permits to cover emissions that cost more to reduce than the permit price. Permits would be bought and sold in government run or sponsored markets.

Under a carbon tax, Congress would legislatively levy a tax on each unit (e.g., metric ton) of CO2 emissions. Emitters would pay a tax equal to the product of the tax rate and the quantity of their emissions. No permits would be required, so the government would not establish or sponsor markets for permits to be bought and sold. Under broad conditions, a cap-and-trade scheme and a carbon tax are indistinguishable.[7]

It is commonly assumed that firms but not households are "emitters." This is false. Every household emits CO2 — primarily in the form of motor vehicle tailpipe emissions and as a byproduct of energy combustion for residential heating, cooling, refrigeration, cooking, and lighting; and secondarily with respect to its other consumption choices that include carbon-based energy as an input. If Congress were to enact a carbon tax, it could tax each metric ton of CO2 emitted regardless of source, or it could tax each metric ton of potential CO2 emissions, thereby focusing the apparent burden on firms. (As discussed in Section II.B below, imposing a carbon tax on firms alone would not shield households from bearing the tax because costs initially borne by firms wind up being borne by households.)

2. Traditional command-and-control regulation

U.S. EPA has been responsible for regulating air pollutants since its establishment in 1970. It has been regulating CO2 and other greenhouse gases since 2009.[8] A key input to

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[5] See, e.g., certain appliance standards (U.S. Department of Energy 2021a, 2021b), data collection potentially leading to a ban on residential gas ranges (Consumer Product Safety Commission 2023), and proposed CO2 disclosure mandates on publicly traded firms (Securities and Exchange Commission 2022).

[6] See, e.g., the Net Zero Asset Managers initiative (2022a, 2022c, 2022b) and (Glasgow Financial Alliance for Net Zero 2023).

[7] Nichols (1984).

[8] U.S. Environmental Protection Agency (2009).

the Agency's climate change regulations is its determination of the "social cost of carbon" (SCC). Under traditional regulation, a credible estimate of the SCC is needed to estimate the climate benefits of regulations, and estimates of benefits and costs are required pursuant to a longstanding presidential directive.[9] If properly calculated, the optimal SCC and the optimal carbon tax are equal.[10]

In 2010, an Obama Administration interagency working group established SCC values ranging from $21-$65/metric ton (emitted in 2010) to $45-$136/metric ton (emitted in 2050)[11] The estimated SCC increases over time to reflect the belief that the marginal damage to the climate caused by CO2 is rising with global temperatures.

The Obama Administration revised the SCC in 2016 to $31-$86/metric ton (emitted in 2010) to $69-$212/metric ton (emitted in 2050).[12] A Biden Administration interagency working group updated the 2016 SCC to a range of $14-$152/metric ton (emitted in 2020) to $32-$260/metric ton (emitted in 2050).[13] The Biden IWG was directed to revise the SCC by January 2022, but as of this writing it has not done so. Draft guidance to agencies has been published for public comment but has not been finalized,[14] and U.S. EPA has proposed or promulgated regulations that rely on SCC values greater than those in the Biden IWG 2021 guidance [cite].

Federal agencies use the SCC for estimating the benefits of regulations that reduce CO2 emissions. Regulations costing less than the SCC are presumed to have net benefits.[15] Congress also might delegate this legislative act to the Executive branch. Whether that would pass constitutional muster is beyond the scope of this analysis.

3. Nontraditional regulation by government agencies

The Securities and Exchange Commission has recently proposed a regulation to impose certain climate-related disclosures by publicly traded firms, most notable estimates of CO2 emissions by firms from suppliers and customers ("Scope 3").[16] Obtaining the former requires them to obtain from other firms, including firms that are not publicly traded. Obtained such information from customers the latter may be impossible, at least if the SEC expects the data obtained to be reliable.

Section 5(b) of Executive Order 14,030 directed the Federal Acquisition Regulatory Council to impose similar reporting burdens on federal contractors. In response, the major federal acquisition agencies issued a proposed common regulation affecting as estimated

[9] Clinton (1993).

[10] Stern and Stiglitz (2021, at 1).

[11] Interagency Working Group on Social Cost of Carbon (2010).

[12] Interagency Working Group on Social Cost of Carbon (2016).

[13] Interagency Working Group on Social Cost of Greenhouse Gases (2021).

[14] Council on Environmental Quality (2023),

[15] Aldy et al. (2022).

[16] Securities and Exchange Commission (2022).

4,413 entities that received $7.5 million or more in federal contract dollars.[17] To date, no final agency action has been taken.

These regulations are best understood as a form of traditional but highly indirect and untargeted command-and-control regulation. Benefits and costs are unknown. Pursuant to Executive Order 12,866, the proposed Federal acquisition regulation is required to, but does not, include a Regulatory Impact Analysis with credible benefit and cost estimates. SEC is exempt from Executive Order 12,866, and its proposed rule includes no credible benefit or cost estimates.

The Paperwork Reduction Act (PRA)[18] applies to both regulations and can, under certain circumstances, be a useful source of cost information. The proposed FAR regulation includes burden estimates (4,812 entities with average paperwork burden of 254 burden hours to prepare and disclose Scope 1 and 2 emission estimates; 793 entities with average paperwork burden of 4,117 burden hours).[19] SEC estimated average paperwork burden of more than $10 billion in annual paperwork burden.[20]

The Office of Management and Budget (OMB) has the statutory authority to disapprove agency Information Collection Requests (ICRs) that, in OMB's view, do not comply with the PRA. This authority is rarely exercised, however. During the period 1994-2022, OMB disapproved 0.05% of the 123,927 Information Collection Requests it reviewed.[21] From this statistic alone it is beyond question that OMB liberally exercises its administrative discretion to permit agencies to publish noncredible paperwork burden estimates and allow agencies to not respond in good faith to public comments alleging that agency burden estimates are unrealistically low. For this reason, paperwork burden estimates are not reliable even if they are authoritative.

4. *Nontraditional regulation by nongovernmental entities*

The United Nations has established a Principles for Responsible Investment (PRI) program intended to conform international investment with Net Zero 2050.[22] PRI is affiliated with the Glasgow Financial Alliance for Net Zero (GFANZ), a UN program launched in 2021 "in partnership with the UNFCCC Race to Zero campaign."

Net Zero Asset Managers Alliance (NZAM), which as of June 30, 2023, reports that its "[m]ore than 315 asset managers" manage "USD 59 trillion in assets.[23] Most major asset managers that service U.S. households, whether directly through brokerage and retirement

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[17] Department of Defense, General Services Administration, and National Aeronautics and Space Administration (2022, at 68313).

[18] Paperwork Reduction Act of 1995 (Pub. L 104-13) (1995), and its implementing regulations (Office of Management and Budget 1995).

[19] Department of Defense, General Services Administration, and National Aeronautics and Space Administration (2022, at 68326-68327).

[20] Securities and Exchange Commission (2022, at 21461 [PRA Table 4]).

[21] Calculations by the author based on data reported at reginfo.gov. During the period 1981-1993, OMB disapproved only 1.9% of the ICRs it reviewed.

[22] United Nations Environment Program Principles for Responsible Investment (2022).

[23] Net Zero Asset Managers Initiative (2022c).

accounts or indirectly through government and private sector pension funds, are NZAM signatories. Being a signatory commits an asset management firm to:

- "Work in partnership with asset owner clients on decarbonisation goals, consistent with an ambition to reach net zero emissions by 2050 or sooner across all assets under management ('AUM');
- "Set an interim target for the proportion of assets to be managed in line with the attainment of net zero emissions by 2050 or sooner; and
- "Review our interim target at least every five years, with a view to ratcheting up the proportion of AUM covered until 100% of assets are included"[24]

Currently, NZAM signatories may not be accountable to their investors or trust beneficiaries to whom they owe fiduciary duties, nor are they clearly accountable to the governments of the jurisdictions in which their investors live. Signatories' actions include, among other things, voting by proxy the shares owned by investors and beneficiaries, and conducting thousands of "engagements" in which they pressure company executives and boards to support Net Zero 2050 or risk hostile shareholder actions.[25]

Absent legislative authority (or regulatory authority, if the SEC regulation mentioned in subsection I.B.3 above is finalized and survives legal challenge), actions taken by individual asset managers that subordinate beneficiary interests to other objectives (such as Net Zero 2050) may be breaching their fiduciary duties to investors under federal and State law.[26] Collaborations like NZAM also may violate U.S. antitrust law if they are concerted action in restraint of trade.[27]

The household-level burdens of Zero 2050 using these indirect means have not been estimated. Moreover, the lack of transparency in asset management engagement makes estimation exceedingly difficult, if not impossible. Nonetheless, it is reasonable and appropriate to assume that the cost of Net Zero 2050 would be considerably greater if achieved through such nontraditional means rather than via a direct carbon tax. Whereas a carbon tax has key economic efficiency attributes, nontraditional approaches, especially when accompanied by coercion, do not.

Environmental, Social, and Governance (ESG) investing and Net Zero 2050 enjoy substantial public support. However, this appears to be because household-level costs are hidden from view. A recent poll estimated that support in the U.K. ranged from 47% to 68%, depending on the activity. This declined substantially, however, when respondents were "presented with the possible lifestyle and financial cost implications [qualitatively characterized] for them personally."[28] Public support appears to depend on the assumption that cost would be minor or others would pay. is plausible, therefore, if not likely that

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[24] Net Zero Asset Managers Initiative (2022b).

[25] BlackRock (2021).

[26] Cameron, Iaccarino, and Richards (2022).

[27] Brnovich et al. (2022) (State attorneys general alleging potential antitrust violations). *See also* Miazad (2022) (concerns expressed by a Net Zero 2050 advocate about asset managers' vulnerability to antitrust enforcement).

[28] IPSOS (2021).

public support would evaporate if the public understood the cost in practical, quantitative terms.

C. How market-based and traditional regulation differ

Market-based approaches offer three important potential advantages over traditional regulation. First, they can achieve any policy goal at much less expense than command-and-control regulation. The reasons are simple. No government agency can possibly know everything it needs to minimize cost. At best, an agency can know only part of what market actors know, and they can only learn this by demanding that market actors belatedly reveal the information. This is something market actors are loath to do because much of their knowledge consists of trade secrets.

In contrast, existing law (primarily the Clean Air Act) does not require (or in many cases, even allow) U.S. EPA to issue economically efficient regulations. The Agency is constrained to act within the four corners of constitutionally permissible congressionally delegated authority. The Clean Air Act was not written with either climate change or economic efficiency in mind. That means achieving Net Zero 2050 through command-and-control regulation using the Clean Air Act will have costs substantially greater than a carbon tax.

Second, a market-based approach would allow the climate-related elements of traditional command-and-control regime to be terminated. Indeed, the efficiency of a market-based approach cannot be achieved by layering it on top of the existing command-and-control regulatory regime. Thus, it is assumed that if Congress enacts a carbon tax, it explicitly rescinds any direct or indirect authority for U.S. EPA — or any other Federal or State agency — to issue climate regulations. If a carbon tax were enacted without these provisions, it could not achieve Net Zero 2050 cost-effectively. The tax would have to be set at a level above the SCC to achieve the same results as a carbon tax alone would accomplish on its own.

Third, a market-based approach would make the cost of achieving Net Zero 2050 highly transparent. Whereas the cost of traditional regulation is difficult to estimate and easy to obfuscate, the cost of a market-based system would be visible via the market-clearing permit price or the tax rate.

These advantages are highly unlikely ever to be realized, however, so the household-level cost estimates reported here are unrealistically low. These estimates depend on a carbon tax that Congress has had many opportunities to enact but has declined to do so. The most recent such opportunity was in the FY 2022 budget reconciliation bill, which includes hundreds of billions of dollars in climate change-related subsidies.[29] Subsidies are inherently inefficient because, among other things, they are poorly targeted and susceptible to debilitating leakage from rentseeking and corruption. Thus, the most likely scenario is the U.S. continues to rely on traditional command-and-control regulations despite their well-known and pervasive economic inefficiency. And that means household-level costs would be much higher than the estimates reported here.

[29] H.R. 5376 (Pub, L. 117-169, (*Inflation Reduction Act of 2022*).

D. Net Zero 2050 is driven by cost-effectiveness, not benefit-cost analysis

It is important to note that the SCC (or carbon tax rate) would not be determined based on traditional benefit-cost criteria, in which costs are subtracted from benefits to obtain the net improvement in human welfare. Net Zero 2050 is different because the benefits are assumed to exceed costs no matter how high the costs might be. In the words of Lord Nicholas Stern and Nobel prize awardee Joseph Stiglitz, "now that a target has been adopted by the Biden administration, the appropriate notion of the carbon price is one that would guide decisions to achieve the target."[30] Neither the policy nor the date it is achieved are open to debate. Indeed, they further assert that there is a global consensus supporting their view:

> [T]he international community arrived at the consensus that temperature changes should be limited to 1.5°C to 2°C because they believed higher temperature increases posed unacceptable risks that could be avoided at an acceptable cost.[31]
>
> …
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> The international community has balanced the risks of increased climate change with the reasonable costs of containing it, and has agreed on keeping temperature change to well below 2°C. Having made that commitment, the task at hand is how to efficiently implement it, which includes a derivation of the SCC that reflects the targets that have been set.[32]

For serious Net Zero 2050 advocates, the best possible outcome would be achieving it at the lowest possible cost. It follows that if any proffered SCC is too low to justify regulations deemed by the Biden administration necessary to achieve Net Zero 2050, the SCC must be increased to whatever value is required to ensure that benefits at least exceed costs. As for the methods used by the Biden IWG to estimate the SCC, Stern and Stiglitz (2021) characterize these methods as "flawed" and "cannot be relied upon to produce reliable estimates of the SCC that are in line with international temperature targets or domestic emissions targets."[33]

Because of the way Net Zero 2050 is portrayed, the best way to approximate its household-level burden is to assume that the SCC (or carbon tax rate) must be set as high as necessary to ensure that it is achieved. This has the advantage of making household-level burden highly transparent. Decision-makers in each household can envision paying this amount as if it were a tax due every April 15.

II. Key Elements of the Analysis

[30] Stern and Stiglitz (2021, at 2).

[31] Stern et al. (2022, at 6).

[32] Stern et al. (2022, at 2). They posit no role for Congress in setting climate policy.

[33] Stern et al. (2022, at 1).

A. Data

Annual U.S. aggregate and State carbon tax revenue is calculated by multiplying each of four alternative carbon tax rates by CO2 emissions in 2019.[34] Other State-level energy data also were obtained from the Department of Energy's State database.[35] Numbers of persons,[36] households,[37] average household size,[38] and median income[39] for the US and each State in 2020 were obtained from the U.S. Census Bureau.

Estimates of the social cost of carbon (SCC) come from Obama and Biden Administration interagency working groups,[40] the international consulting firm McKinsey & Company,[41] international insurance colossus Swiss Re Institute,[42] and the Network for Greening the Financial System (NGFS).[43]

B. Virtually all costs are borne by households

Taxes and regulatory burdens are not borne solely by the party on whom they are imposed. Rather, they are passed on to households in a complex web of relationships related to households' consumption and employment choices, taxes, and direct or indirect stock ownership. (An estimated 58% of all U.S. households bear part of the cost of the corporate income tax via direct or indirect stock ownership.[44]) The fraction of a carbon tax not borne by stockholders is passed on to customers (in the form of higher prices), suppliers (in the form of reduced payments for inputs), and employees (in the form of lower wages). These are not different households, but rather different roles households play in the economy. In the aggregate, escaping the cost of Net Zero 2050 requires that cost be exported to other countries, other current U.S. households (via government-mandated transfer payments), or future U.S. households (via government expenditures financed by debt).

Indeed, the most popular method of escaping household costs is to shift them to future households. For FY 2022, the latest year for which data are available, the federal

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[34] U.S. Energy Information Administration (2022d). CO2 emissions in 2020 and 2021 were not used because they were seriously diminished, in an unsustainable way, by government responses to COVID-19. Data for 2022 are not yet available, making 2019 the most representative recent year.

[35] U.S. Energy Information Administration (2022c).

[36] U.S. Census Bureau (2022a).

[37] U.S. Census Bureau (2022b).

[38] U.S. Census Bureau (2022b).

[39] U.S. Census Bureau (2022d).

[40] Interagency Working Group on Social Cost of Carbon (2010, 2016); Interagency Working Group on Social Cost of Greenhouse Gases (2021).

[41] McKinsey & Company (2022).

[42] Swiss Re Institute (2022).

[43] Network for Greening the Financial System (2021b, 2021a, 2022a). NGFS is "a group of Central Banks and Supervisors willing, on a voluntary basis, to share best practices and contribute to the development of environmental and climate risk management in the financial sector and to mobilize mainstream finance to support the transition to a sustainable economy" (Network for Greening the Financial System 2019).

[44] *See* Saad and Jones (2022).

government budget deficit was $1.4 trillion[45] on a budget of $6.8 trillion,[46] thereby shifting more than one-fifth of current outlays to future generations. From FY 2009 to FY 2022, total federal debt increased from $12.3 trillion to $31.4 trillion.[47] To be sure, shifting costs to future generations may be ethically justifiable insofar as future generations are expected to reap the benefits of costly actions taken today in hopes of reducing climate impacts tomorrow. Current deficit financing does not qualify, however, because it shifts the burden of current *consumption* to future generations.[48]

To say that virtually all costs of Net Zero 2050 will be borne by households does not imply that costs will be the same for all households. Costs will vary across households in complex ways. Describing the cost distribution is critically important but beyond the scope of this initial analysis, the purpose of which is to characterize household-level impacts in rough terms.

Therefore, the most complete picture that can be obtained today of the lower-bound cost of achieving Net Zero 2050 is revealed by estimating average household burden regardless of its actual incidence. This captures all five roles that households play in the economy: shareholders, suppliers (including bondholders, who supply debt financing), customers, workers, and taxpayers. And the most transparent way to reveal the lower-bound average household burden is to report it as if it were directly levied on households as an annual carbon tax.

Households are likely to have already borne some of these costs indirectly through rising prices for energy, and goods and services for which energy is a significant input. While rising prices have been blamed on supply chain issues, energy is a key component of modern supply chains.

In the short run households can avoid bearing only the capital component of household cost, by disinvesting in firms with large direct or indirect carbon "footprints" that cannot be easily reduced. Only in the long run can households reduce their own carbon "footprints," and this will require radically changing their consumption choices, including where they live and work. These long-run changes will be costly and must be added to long-run residual carbon tax payments to derive total long-run household costs. To a significant, household opportunity cost will include accepting a mandated reduced quality of life—a cost difficult to quantify and monetize, but nevertheless, quite real.

Meanwhile, none of the major Net Zero 2050 modeling teams has addressed the question of how its extraordinary cost would be paid, or by whom. NGFS says "the role of governments is crucial in ensuring a just transition and cushioning the impact of

[45] Federal Reserve Bank of St. Louis (2023c).

[46] Federal Reserve Bank of St. Louis (2023b).

[47] Federal Reserve Bank of St. Louis (2023a).

[48] An obvious exception occurred in 2022 via the Inflation Reduction Act of 2022 (Pub. L. 117-16), which appropriated hundreds of billions in federal subsidies on technologies and activities intended to reduce future climate impacts. Because these expenditures were debt-financed, their opportunity costs will be borne mostly by future households.

decarbonization on the most vulnerable groups in society,"[49] but offers no insight concerning what it means for the transition to be "just," how governments would accomplish it if they wanted to, or why it is reasonable to expect that they would. McKinsey, which relies on NGFS's scenarios to derive its $275 trillion global cost estimate for the *transition* to Net Zero 2050 (i.e., excluding the cost of sustaining it thereafter), discusses a subset of obviously relevant questions about who pays but says its results "do not factor in these considerations."[50] The Swiss Re Institute synthesizes over a dozen external estimates (including McKinsey's) to obtain its estimated $290 trillion "investment gap,"[51] but instead of confronting the question of who would pay, claims that there would be "huge benefits" amounting to 90-140% of costs,[52] presumably making the question irrelevant. Finally, none of the modeling teams has given any public attention to the cost of rentseeking—resources consumed for the purpose of capturing benefits and shifting costs to others.

C. Household-level burden is the most informative estimate of the cost of Net Zero 2050

This paper reports plausible estimates of the average direct and indirect household-level burdens of a carbon tax, using several alternative tax rates, irrespective of whether the tax is levied directly (via an explicit carbon tax) or indirectly (via regulation supported by the SCC). It is generally agreed that a uniform tax per unit of CO2 is the least costly means of achieving any desired reduction in emissions, including the 100% reduction demanded by Net Zero 2050. Market actors (including household decision-makers) have the best available information concerning the marginal cost of reducing these emissions. A carbon tax gives them a powerful incentive to efficiently use this information. They will try to eliminate any CO2 emissions that can be abated at a cost less than the tax rate. At the same time, it is important to note that all other means of achieving Net Zero 2050 would be more expensive than a carbon tax. Thus, the household-level burdens reported here are lower bounds, and quite possibly, very much lower than all other Net Zero 2050 implementation paths.

D. Alternative values for the SCC (or carbon tax)

The Obama administration estimated multiple SCCs, with its preferred value dependent on the year in which CO2 emissions were abated. When updated to 2020 dollars, this range is $56/metric ton for 2025 emissions to $85/metric ton for 2050 emissions. A higher range was obtained using statistical methods to account for the unlikely probability that damages from CO2 could turn out to be greater than currently expected. That higher range SCC was $169/metric ton for 2025 emissions to $260/metric ton for 2050 emissions.[53]

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[49] Network for Greening the Financial System (2022b, at 3).

[50] McKinsey & Company (2022, at 6).

[51] Swiss Re Institute (2022, Table 3).

[52] Swiss Re Institute (2022, at 21).

[53] Interagency Working Group on Social Cost of Carbon (2016); Interagency Working Group on Social Cost of Greenhouse Gases (2021).

Alternative SCC estimates can be derived from net zero analyses sponsored by NGFS.[54] Two scenarios are relevant here. The first is an "orderly" scenario that would achieve Net Zero 2050 "through stringent climate policies and innovation." The second is a "disorderly" scenario that would achieve Net Zero 2050 but "with higher costs due to divergent policies introduced across sectors."[55] The "orderly" scenario predicts shadow carbon prices (i.e., implicit SCCs) ranging from $180/metric ton (2025 emissions) to about $450/metric ton (2050 emissions). The "disorderly" scenario predicts shadow carbon prices ranging from about $200/metric ton (2025 emissions) to about $700/metric ton (2050 emissions).[56]

The analysis here uses four alternative values: first, a pair of values ($100/metric ton and $300/metric ton) derived from the Administration's authoritative reports; and second, a pair of carbon shadow prices obtained from NGFS ($450 and $750/metric ton). Each alternative SCC can be criticized. For example, highly influential nongovernment economists who favor Net Zero 2050 say the Administration's lower range SCCs (i.e., ~$100/metric ton) "are too low to be consistent with the aim of reaching net zero by 2050," which they regard as a consensus international agreement beyond legitimate debate.[57] The Administration's upper-bound range (~$300/mt) reflects higher than expected marginal damages from CO2, but like the lower-bound it does not capture the higher cost of command-and-control regulation, the purpose for which it was devised. The NGFS "orderly" scenario ($450/metric ton) is suspect because it includes highly restrictive conditions that do not reflect sociopolitical realities both across and within nations. Finally, the NGFS's "disorderly" scenario ($700/metric ton) is criticized as inefficient and undesirable,[58] but not for being unrealistic.

Analysts and Net Zero advocates may disagree concerning which estimate is most accurate, but there appears to be no dissent from the proposition that higher SCCs are more likely to achieve Net Zero 2050. Moreover, advocates also insist that the transition to Net Zero 2050 must be "immediate,"[59] "coordinated,"[60] "more sudden than expected,"[61]

CAVEATS

While the SCC is informed by economic estimates of the marginal damage from CO2 emissions, its value critically depends on several key assumptions, most

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[54] Network for Greening the Financial System (2021a). McKinsey & Company (2022) relies on the NGFS "orderly" transition scenario to derive its global cost estimate for Net Zero 2050 of $275 trillion ($9.2 trillion per year on average) through 2050.

[55] Network for Greening the Financial System (2021b).

[56] Network for Greening the Financial System (2022a, slide 9).

[57] Stern et al. (2022). They do not specify how high they believe the SCC must be to achieve Net Zero 2050.

[58] Boissinot et al. (2022).

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[60] Boissinot et al. (2022).

[61] Network for Greening the Financial System (2022b, at 3).

notably the discount rate. The discount rate matters because the costs of mitigation are borne now, and any benefits are realized many decades hence.

Objectively defined, the discount rate captures how much it is worth to postpone current consumption. Consider a simple illustration. Assume that a particular CO2-reducing action would provide $1,000 in benefits in 2073 — 50 years from now. If the discount rate is set at 0%, the value of this benefit is the same today as it would be in 2073 — $1,000. But households never value current and future consumption the same. Discounting at 7%, the $1,000 benefit delivered in 2073 is worth $33.95 today. Put another way, a household that discounts future consumption at 7% would be willing to pay $33.95 today to receive (or enable the household's children or grandchildren to receive) a $1,000 payment in 2073.

The choice of discount rate for calculating the SCC matters because the lower the rate, the higher will be the calculated SCC. The Obama administration used a discount rate of 3% to calculate the SCC. When updated to 2020 dollars, the range of SCC estimates was $56/metric ton for 2025 CO2 emissions to $85/metric ton for 2050 CO2 emissions. A higher range was obtained using, for example, the 95th percentile (i.e., the reasonable worst case): a range of $169/metric ton for 2025 CO2 emissions to $260/metric ton for 2050 emissions.[62] Recently, the Office of Management and Budget formally proposed to use 1% for climate change-related regulations.[63]

Highly influential nongovernment economists who favor Net Zero 2050 as a policy goal argue for rates of 2%,[64] 1%, or even 0%.[65] They say that SCC values based on discount rates of 3% or higher "are too low to be consistent with the aim of reaching net zero by 2050."[66]

These discount rates do not reflect household preferences; indeed, OMB's recent proposal explicitly denies that household preferences are relevant. Nonetheless, household preferences surely matter for estimating the household-level burden of Net Zero 2050. Few households discount future consumption at 3%; none discount at 0%.

No household costs. Implicit household discount rates have been estimated for various energy conservation investments, such as air conditioners[67] and weatherstripping,[68] in which the same household that bears up-front capital costs also captures future benefits in the form of reduced operating costs. Quite reasonably, household decision-makers are uncertain about future benefits, and

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[62] Interagency Working Group on Social Cost of Carbon (2016); Interagency Working Group on Social Cost of Greenhouse Gases (2021).

[63] Office of Management and Budget (2023a, 2023b).

[64] Greenstone and Stock (2021).

[65] Stern et al. (2022).

[66] Stern et al. (2022).

[67] Hausman (1979).

[68] Hartman and Doane (1986).

their implicit discount rates reflect this uncertainty. Uncertainty would be much greater in the climate change context because future benefits are delayed many decades (instead of only months or years in the examples studied), and benefits are less certain to actually materialize. Nevertheless, implicit discount rates derived from these empirical studies are instructive because the average discount rate estimated—26%—is much higher than the discount rate used by government decision-makers on their behalf.

For low- and middle-income households, which often borrow at double-digit interest rates to pay for unexpected consumption (such as medical bills or sudden increases in the price of energy), implicit discount rates would be much greater.

Section III calculates the minimum annual average household burden of a carbon tax design in which each State is responsible for covering all energy-related CO2 emitted within its borders. Section IV provides the comparative calculation in which every U.S. household was assigned the same burden. Both approaches are intentionally simple and, importantly, require no household-specific information except taxpayer identity, which with fairly minor errors could be obtained from IRS income tax filings. Many other approaches are, of course, feasible and potentially worthy of analysis. However, they could require a great deal of household-specific data that may be difficult or impossible to obtain. Also, as tax design gets more complicated, administrative costs and errors both rise, along with deadweight losses due to rentseeking, which can be expected to be truly unprecedented.

III. Scenario A: Annual Burden of Net Zero 2050 per Household Assuming its Share is Proportional to Its State's Energy-related CO2 Emissions

In this Section, it is assumed that each State's share of the national carbon tax burden is proportional to the State's energy-related CO2 emissions, and that each household's share is the same as every other household in that State. This is largely the path of the suite of current and expected future command-and-control regulations promulgated under the Clean Air Act, which target stationary sources and motor vehicle manufacturing. Federal and State regulation using other authorities are inherently less well-targeted, and thus more expensive.

Here, the distinguishing feature is that Net Zero 2050 is assumed to be achieved at the lowest possible cost—i.e., through the lowest uniform carbon tax that can achieve it instead of command-and-control regulation. If a uniform carbon tax is not enacted, or to the extent that Net Zero 2050 is achieved either through a nonuniform carbon tax, command-and-control regulations, or a mix of carbon taxes and command-and-control regulation, the actual cost of achieving Net Zero 2050 will be much higher.

Twenty-eight States and the District of Columbia, representing 68% of the population, are net importers of carbon-based energy. They clearly would prefer this allocation formula because their share of the national burden would be disproportionately low. It would be unsurprising if their Members of Congress steadfastly supported a carbon tax designed this way. Further, 56 Senators serve these States. Thus, if the enactment of a carbon tax designed this way required only majority support in the Upper House, it could pass handily. Unsurprisingly, the 22 States that export carbon-based energy to other States would intensely dislike this tax regime and vigorously oppose it. Their Senate minority would be sufficient to prevent a cloture vote, thereby blocking passage. Of course, the Senate could abandon the filibuster or enact this carbon tax as part of a budget reconciliation bill exempt from the filibuster.[69] If Congress were to enact a carbon tax of this design, carbon-based energy exporting States could shift burdens back onto carbon-based energy importing States. This is discussed in Subsection III.C below.

A. Annual Carbon Tax per Household, by State

Figure 1 displays the average annual cost of Net Zero 2050 in dollars per household for each State if it can be achieved for $100/metric ton CO2. Jurisdictions are arrayed alphabetically on the horizontal axis, with gridlines separating each group of five. For 32 States and the District of Columbia, shown in green, the cost of Net Zero 2050 is less than $5,000 per year. For seven States, shown in blue, the burden of Net Zero 2050 is between $5,000 and $10,000 per year. The burden is between $10,000 and $15,000 per year for two States, shown in yellow, and exceeds $25,000 per year for one State—Wyoming. For the median jurisdiction, the average annual burden is $4,165. The jurisdiction with the lowest annual average household-level burden is the District of Columbia: $974.

Cost is linear with the minimum carbon tax rate necessary to achieve Net Zero 2050. Thus, trebling cost to $300/metric ton results in a threefold increase in the annual average household-level burden. In all 50 States (but not the District of Columbia), this burden would exceed $5,000 per year. For nine States, shown in orange, burden would exceed $20,000 per year, and for three States it would exceed $30,000 per year. In five States, the annual average household burden per year would exceed $50,000, with Wyoming ($76,000) being the worst case.

Figure 2 displays results if Net Zero 2050 costs $700/metric to CO2 to achieve. For all 50 States (but not the District of Columbia), Net Zero 2050 costs more than $10,000 per household per year. For only 10 States (and the District of Columbia) is the average household burden less than $20,000 per year, and for 25 States, shown in yellow, it is between $20,000 and $40,000 per year. The average household burden exceeds $40,000 per year for 13 States, and for two States it exceeds $100,000—North Dakota ($124,682) and Wyoming ($177,368).

B. Annual Carbon Tax per Household as a Percent of Annual Household Income

To put these burdens in perspective, they can be expressed as fractions of median household income, which varies by State. This is shown in Figure 3 for the case in which Net Zero 2050 is achieved at a cost of $100/metric ton CO2. In 12 States (and the District of Columbia), shown in green, the burden of Net Zero 2050 is less than 5% of median household income. But the average burden is between 5% and 10% of median household income in 22 States, and between 10% and 15% in 11 States, shown in yellow. In four States, shown in red, the average burden exceeds 20% of median household income—Louisiana (22%), West Virginia (24%), North Dakota (27%), and Wyoming (39%).

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[69] A carbon tax designed this way could have been included in the 2022 budget reconciliation bill (Pub. L 117-169).

Figure 4 shows the average annual household burden if achieving Net Zero 2050 costs $700/metric ton CO2. This burden is less than (but approaches) 50% of median household income. (It's lowest in the District of Columbia: 7.5%). In 14 States, shown in yellow, the burden of Net Zero 2050 is between 50% and 100% of median household income, and it exceeds 150% of median household income in four States, shown in red: Louisiana (153%), West Virginia (170%), North Dakota (191%), and Wyoming (272%).

States may be acutely interested in how they fare relative to others. Figure 5 answers that question by displaying the fraction of median household income extracted by Net Zero 2050 as a multiple of the fraction extracted from households in the District of Columbia, the jurisdiction with the lowest household-level burden. (The multiple is the same irrespective of the cost of achieving Net Zero 2050.)

For 32 States, the average household burden of achieving Net Zero 2050 is less than five times the average household burden in the District of Columbia. (The smallest multiple, 2,34, is found in Massachusetts.) For 13 States, the average household burden is between five and 10 times the burden in the District. And it exceeds 10 times the burden in the District in five States: Alaska (14x), Louisiana (11x), North Dakota (18x), West Virginia (12x), and Wyoming (26x).

C. <u>Carbon-based energy exporting states could shift part of the burden to Carbon-based energy importing states</u>

1. All States would rationally seek to shift burdens to other States

As noted above, there are many ways to allocate the burden of the SCC or carbon tax. This paper considers only two alternatives: (1) allocating household burden by differences in State-level CO2 emissions, or (2) allocating household burden equally across all U.S. households. This difference alone is sufficient to divide the States into sharply divided camps. States that import carbon-based energy would prefer that costs be allocated based on State CO2 emissions.

All States (except AK and HI) and the District of Columbia are either net electricity importers or exporters.[70] Under the design analyzed in this Section, States that export electricity to other States would have to subsidize the electricity consumption of importing States. Electricity-exporting States would say this design is unfair, but as noted at the beginning of this Section, importing States would have the votes unless the Senate filibuster is preserved. And it's likely that importing States also would have the votes to impose a carbon tax regime even more disadvantageous to exporting States. For their part, exporting States clearly would prefer to shift as much as possible of the burden of Net Zero 2050 to others.

2. States that produce carbon-based energy could easily shift burdens to States that import carbon-based energy

Assuming that importing States win the legislative battle, exporting States would still be able to shift some (and potentially a lot) of the burden of Net Zero 2050 to electricity-importing States. They could do this by imposing their own tax on in-State

[70] U.S. Energy Information Administration (2022e).

electricity generation and fully rebating the proceeds to State residents. This would hold their own residents harmless, at least on average, while forcing energy-importing States to pay the tax.[71]

Electricity-importing States could not as easily shift burdens to electricity-exporting States. They could not tax electricity generated out of state without unconstitutionally restraining interstate trade. Even if they could impose such a tax, much of the tax would be borne by their own residents, the intended beneficiaries. (Electricity-importing States would have to be more creative to figure out how to shift burdens to electricity-exporting States, but there is no question that they would be highly motivated to do so.)

IV. Scenario B: Annual Burden of Net Zero 2050 per Household Assuming its Share is the Same as all other Households Nationwide

An obvious alternative tax allocation scheme is to impose the same tax on every U.S. household regardless of residence. As noted above, States that import carbon-based energy are likely to perceive this as unfair.

A. Annual Carbon Tax per Household

For this alternative, the annual burden of Net Zero 2050 per household is defined as the product of total U.S. CO2 emissions and the tax rate, divided by the number of U.S. households. Because the state of origin of CO2 emissions would be ignored, it would be the same for all U.S. households:

- $4,231 at $100/metric ton CO2
- $12,694 at $300/metric ton CO2
- $19,041 at $450/metric ton CO2
- $29,619 at $700/metric ton CO2

B. Annual Carbon Tax per Household as a Percent of Annual Household Income

Median household income varies across States, so the effective household-level burden would vary across States even if the carbon tax was constant. Figure 6 displays for Scenario B the fraction of annual household income extracted by Net Zero 2050 if it can be achieved for $100/metric ton.

Figure 6 shows for Scenario B how the burden of achieving Net Zero 2050 varies by jurisdiction, assuming that it costs $100/metric ton. Data are expressed as percent of the jurisdiction's median household income. For all States and the District of Columbia, Net Zero 2050 would extract more than 4% of median household income. For 14 States and the District of Columbia, shown in yellow, the income fraction is between 4% and 6%. The income fraction is between 6% and 8% for 29 States, shown in orange, and between 8% and 10% for seven States, shown in red: Alabama (8.1%), Arkansas (8.6%), Kentucky

[71] The five States that exported the most electricity in 2020 were Pennsylvania (714 tBTUs), Alabama (420 tBTUs), Illinois (3,231 tBTUs), Wyoming (261 tBTUs), and Washington (258 tBTUs). The five States that imported the most electricity were California (757 tBTUs), Massachusetts (333 tBTUs), Ohio (289 tBTUs), Georgia (243 tBTUs), and Maryland (242 tBTUs). See U.S. Energy Information Administration (2022c).

(8.1%), Louisiana (8.3%), Mississippi (9.1%), New Mexico (8.3%), and West Virginia (8.8%).

Figure 7 shows the burden of achieving Net Zero 2050 if it costs $700/metric ton to achieve. For all States and the District of Columbia, Net Zero 2050 would extract more than 30% of median household income. For 12 States, shown in yellow, Net Zero 2050 would extract 30-40% of median household income. For 19 States, shown in orange, Net Zero 2050 would extract 40-50% of median household income. And for 18 States, it would extract at least 50%.

The design in Scenario A resulted in some States having highly disproportionate annual household-level burdens resulting from interstate differences in median household income and CO2 emissions. The design in Scenario B reflects only interstate income differences. Much, but not all, of the interstate disproportionality in burden is attenuated in Scenario B. Twenty-two States would be better off under this scenario than under Scenario A. However, 28 States and the District of Columbia would be worse off. Among States better off, average gains per household range from $52/household in Pennsylvania to $21,107 in Wyoming; the average gain is $5,237. Among States worse off, average losses per household range from $62/household in Ohio to $3,258/household in the District of Columbia; the average loss is $1,107.

C. Percent of Mean Household Income for Quintiles, and Top 5 of Household Income

Median income is a useful indicator but it does not reveal how the burden of Net Zero 2050 would vary by household income. One would intuitively expect low- and middle-income households to face disproportionately large burdens. This intuition is correct. To see why, note that the Census Bureau divides income distributions into quintiles ("fifths", 0-20%, 20-40%, 40-60%, 60-80%, and 80-100%) and calculates the average income for each quintile. It also reports average income for the top 5% of households.[72]

Figure 8 shows the percentage of U.S. median household income extracted by Net Zero 2050 under each alternative cost of achieving it. For the lowest quintile, Net Zero 2050 would extract between 29% (at $100/mt) and 204% (at $700/mt) of median household income. These fractions are not quite as large for the second quintile, ranging from 10% (at $100/mt) to 72% (at $700/mt). Even for the third quintile, which contains median household income for the U.S. population, Net Zero 2050 extracts less than 50% in all four alternative unit costs. Only for the Top 5% of the income distribution is the fraction of income plausibly acceptable, ranging from 0.9% (at $100/mt) to 6.5% (at $700/mt).

Figure 7 leads to an obvious question: How can the poor (quintile 1) and working class (quintile 2) pay their proportionate share of the cost of Net Zero 2050? The obvious answer is because they cannot pay these amounts, they wouldn't. The highest-income households would have to pay for them as well. To get a handle on the scope of this additional burden on high-income households, Census's income figures first must be adjusted for taxes (disproportionately paid by high-income households) and transfer payments (disproportionately received by low-income households. Figure 9 shows the

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[72] Census's income definition generally ignores taxes and transfers.

shows the percentage of U.S. median household income extracted by Net Zero 2050 under each alternative cost of achieving it after income is adjusted for taxes and transfers.[73] For the poor (quintile 1), the average household burden is reduced from the range 29-204% to the range 9-60%. And the average household burden for the working class (quintile 2) declines from 10-72% to 8-55%.

But the poor and working class almost certainly cannot pay these lower amounts, either. As a thought experiment, consider the case in which households in the top quintile are taxed to cover the costs that otherwise would be assessed on the bottom quintile. (That is, households in the bottom quintile would pay nothing.) Because the number of households in each quintile is the same, the burden per household in the top quintile would simply double, both in dollars and in percent of household income. For the top quintile, their burden per household would double from the range $4,231-29,619 to the range $8,463-59,239. And the fraction of their income extracted to pay for Net Zero 2050 also would double, from the range 1.7-11.7% to the range 3.4-23.4%. While these may seem to be extraordinary amounts, they are at least feasible, whereas the income shares otherwise dur from the lowest quintile are either mathematically or politically infeasible.

D. Other allocation formulae

Many other variables could be meaningful (or just useful) to individual States. For example, some States might argue that the carbon tax burden should account for States' relative poverty rates,[74] or they might want to leverage the Administration's stated concerns about racial equity.[75] For every State, there is a way to minimize its residents' household-level burden. Of course, whatever any group of States gains by shifting burdens to other States, those other States lose by having burdens shifted onto them.

In short, every carbon tax regime is a zero-sum game with winners and losers. The same is true of course for command-and-control regulation, the only other alternative available. States can be expected to do everything within their power protect the interests of their residents, whether the battlefield is the design of a carbon tax or the design of a climate regulation.

V. Avoiding Dramatically Increased and Politically Unpopular Net Zero 2050 Burdens

A. The extraordinary magnitude of Net Zero 2050 burdens

Collecting carbon taxes on all energy-related U.S. CO2 emissions would generate revenue ranging from $515 billion (at $100/mt) to $3,611 billion (at $700/mt). If a carbon tax were levied on top of existing taxes, that would increase static federal revenues by 13%

[73] Tax and transfer payment adjustments come from Gramm, Ekelund, and Early (2022). Income inequality is significantly reduced by these adjustments.

[74] U.S. Census Bureau (2022c). Any reliance on poverty rates likely would trigger pushback based on the Census Bureau's incomplete calculation of income. See, e.g., Gramm and Early (2022).

[75] See, e.g., Biden Jr. (2021a) and Biden Jr. (2021b).

to 90%.[76] This would have devastatingly contractionary effects on the U.S. economy and impose incalculable harm on low- and middle-income households. (Using the SCC as the basis for command-and-control regulation would hide or disguise these contractionary effects, not make them go away.)

Congress might try to prevent these outcomes by enacting a "revenue-neutral" carbon tax — that is, one that offsets carbon tax revenues dollar-for-dollar with reductions in other taxes. Revenue neutrality would keep the aggregate tax burden constant, thus avoiding catastrophic macroeconomic outcomes. However, it would not prevent catastrophic effects on low- and middle-income households without massive additional income redistribution, and it is far from clear that upper-income households would tolerate the dramatically increased effective tax rates they would have to bear.

B. A revenue-neutral carbon tax is theoretically superior but practically infeasible

For several reasons, a revenue-neutral carbon tax is highly unlikely to be enacted or sustained in practice. First, design tradeoffs apply to all taxes, whether they are explicit or implicit. States and households vary on myriad dimensions, and there is no universally acceptable method for allocating the burden of Net Zero 2050 or distributing compensating tax relief. Tax designs and command-and-control regulations are both determined by politics, not tenured economics professors. The federal income tax is already the most progressive among all developed economies, and low-income households generally pay little or no income taxes. Nonetheless, tax rebates would have to be structured so that low- and middle-income households received substantially greater refunds — that is, the already highly progressive U.S. federal income tax would have to become extraordinarily more so. This would be complicated and likely riven with unexpected consequences. Many low- and middle-income households would fall through the cracks, and many high-income households would engage succeed in legally evading the new tax.

Second, even if today's Congress could agree on a revenue-neutral carbon tax design, tomorrow's Congress could change it, or even repeal it. No Congress can statutorily bind a successor. It's likely that Congress would succumb to the temptation to breach any statutory requirement for revenue-neutrality. Congress could vote to collect more revenue from a carbon tax than is required, skimp on promised tax reductions and rebates, allocate rebates to favored interest groups, or spend it on district-specific purposes, or some combination thereof. Congress has ample experience under the Budget Impoundment and Control Act offsetting actual new spending with speculative or imaginary budget cuts such that purported spending reductions inevitably turn into spending increases. This experience likely would guide its deliberations, resulting in a tax regime substantially different from the simple versions analyzed here. And it supports the inference that revenue neutrality could not be assured without a carefully crafted constitutional amendment.

Third, any system of taxing CO2 emissions within the Nation's boundaries must ensure that imports do not escape taxation. This is especially important for imports from

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[76] USASpending.gov (2022) reports total federal government revenue for 2021 was $4.05 trillion.

nations such as China that would be effectively exempt from both a carbon tax and conventional command-and-control regulation. Taxing carbon only within the Nation's borders would result in more goods and services production being offshored to these noncompliant jurisdictions, profoundly enriching them, punishing U.S. producers and consumers, and making voters angry.

Ensuring equitable tax treatment of imports requires "border adjustment taxes."[77] Unfortunately, these taxes are highly complex, data intensive, fraught with irreducible error and uncertainty, and subject to the usual special interest pleading and opaque foreign affairs considerations.

VI. How Households Would Respond to Increased Prices

Households generally respond to price increases by replacing their purchases of newly higher-priced goods and services with goods and services with unchanged or reduced prices. For example, it is commonplace to observe that when the price of one fruit (say, blackberries) rises in price, households reduce their consumption of blackberries and buy more of a substitute (say, strawberries). This does not fully eliminate the adverse effect of higher blackberry prices, but it substantially reduces it if blackberries and strawberries are close substitutes.

Carbon taxes and regulations based on the SCC both raise the price of carbon-based energy, and households respond slowly to energy price increases because there are no good substitutes. A carbon tax directly increases the cost of many things — heating, cooling, and lighting a home; traveling to work; shopping; attending school; and obtaining medical care, to consider just a few examples. In the short run, it is hard to buy a lot less energy when the price goes up. When faced with new energy costs consuming 10% or 25% of their income each year, households would have no choice but to severely reduce their consumption of other goods and services they value highly, such as groceries, clothing, medical care, education, and travel. And a carbon tax indirectly increases the cost of these other goods and services, as well. Their prices also would rise to include a significant portion of Net Zero 2050 taxes or regulatory costs. It cannot be escaped just by reducing energy consumption at the margin.

Indeed, there would be few ways to escape. The only reliable long-term path forward is to adopt a Spartan lifestyle: wear sweaters and coats to keep warm indoors in the winter; open windows or sleep on the porch to keep cool in the summer; move from a country or suburban house to a small urban apartment; sell the family car and walk or bicycle for transportation. These changes are not bugs but intended features of the radical economic transformation that may climate change advocates seek.[78]

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[77] Nordhaus (2020).

[78] See, e.g., Schwab and Malleret (2020) and McKinsey & Company (2022), which (at 58) expresses the same view in more temperate language that disguises the cost ("a universal transformation of energy and land-use systems").

VII. Net Zero 2050 Would Be Much More Expensive than its Advocates Acknowledge

The household-level burden estimates reported here may seem large, but they aren't if one recognizes the scope and scale of Net Zero 2050 and the haste with which it would have to be achieved. And there are many reasons why advocates likely have underestimated the true cost of Net Zero 2050.

Subsection A briefly discusses several assumptions embedded in Net Zero 2050 transition modeling that appear to materially understate likely costs. Subsection B discusses reasons why it's likely that the Administration's SCC also has been underestimated.

A. Unrealistic assumptions in Net Zero 2050 transition scenarios

1. Renewables will cost more than forecast

Net Zero 2050 transition scenarios include unrealistic cost forecasts. For example, the International Energy Agency (IEA) assumes:

- The capital cost of solar photovoltaic electricity generation will decline 63%, from $1,140/kilowatt (kW) in 2020 to 420/kW in 2050.[79]
- The capital cost of U.S. offshore wind electricity will decline 63%, from $4,040/kW in 2020 to $1,480/kW in 2050.[80]

Among other things, these unit cost declines are inconsistent with limitations in the supply of essential minerals. This includes both conventional minerals (e.g., aluminum, chromium, cobalt, copper, lithium, nickel, platinum, and zinc) and rare earth elements (REEs) (e.g., neodymium). The top three nations producing lithium, cobalt, and REEs control three-fourths of global supply, with China dominating. China also dominates world production of nickel.[81] IEA alludes to the obvious national security concerns but does not analyze them or include their management as a cost of Net Zero 2050.[82]

IEA characterizes the estimated sevenfold increase in demand not as the cost driver it is, but as "substantial new opportunities for mining companies."[83] These opportunities will not be in the U.S., where it is virtually impossible to secure the permits for a new mine. Thus, even if greater supplies are forthcoming, it remains likely that supply will be under the control of a small number of nations capable of exercising economic and political power.

2. Essential future technologies are assumed to be invented and be inexpensive

[79] International Energy Agency (2021b, Table B.1).

[80] International Energy Agency (2021b, Table B.1).

[81] International Energy Agency (2021c, 32).

[82] International Energy Agency (2021b, 23).

[83] International Energy Agency (2021b, 17).

Net Zero 2050 transition scenarios include numerous assumptions about future technology. For example, an extensive system of batteries is needed to store the electricity produced by the greatly expanded supply of wind and solar photovoltaics, and to produce the hydrogen needed to supply fuel cells. IEA assumes that these technologies will be invented, and that they will be less expensive than current technology. IEA assumes:

- The capital cost of batteries will decline 50-58%, from $130-155/kWh in 2020 to $55-80/kWh in 2050.[84]
- The capital cost of low-temperature electrolyzers used to make hydrogen will decline 70-76%, from $835-$1,300/kWh in 2020 to $200-390/kWh in 2050.[85]

Because some CO2 would still be emitted in 2050, achieving Net Zero 2050 also requires that CO2 be captured and indefinitely stored, and that the cost of doing so will be lower than today. IEA assumes:

- The capital cost of natural gas carbon capture will decline 19%, from $1,155-$2,010/kWh in 2020 to $935-$1,625/kWh in 2050.[86]

Each of these forecasts appears highly optimistic and is obviously overly precise; uncertainties well exceed the ± $2.50/kWh estimates. If future technologies are invented, they may be more costly because they must push difficult engineering boundaries and be quickly scalable to the scope of the demand. A considerable amount of technological uncertainty is not reducible, especially in a crisis policy environment.

Technologies that appear promising when modeled may fail when implemented or scaled. These costs would be stranded. Private investors can be expected to be apprehensive about bearing these risks, so the government may have to directly fund the R&D or backstop private investments with loan guarantees and ironclad intellectual property rights.

3. The cost of overcoming potentially devastating grid reliability problems is excluded

As the fraction of asynchronous electric power produced by intermittent renewables rises, the electric grid becomes increasingly fragile. Grid reliability is a known and serious problem that has grown as this fraction has increased. Net Zero 2050 calls for renewables to comprise between 67%[87] and virtually 100%[88] of electricity supply, thus exacerbating existing grid reliability issues to an unknown dimension. Grid reliability would be made worse if funds usually spent on conventional electric power system maintenance are diverted to building out renewables capacity. In practical terms, grid instability means frequent, large-scale blackouts.

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[84] International Energy Agency (2021b, Table B.2).

[85] International Energy Agency (2021b, Table B.2).

[86] International Energy Agency (2021b, Table B.2).

[87] International Energy Agency (2022, Table A.1).

[88] McKinsey & Company (2022).

Net Zero 2050 transition scenarios acknowledge these issues but do not include them as costs[89] despite the known scale of the technical problem.[90] Instead, it is assumed that grid reliability issues will be solved by unknown future technology, the cost of which is assumed to be low, or even negligible.

4. Unemployment costs are excluded

Net Zero 2050 transition scenarios forecast substantial unemployment, but they do not include these effects as costs. Rather, they assume virtually costless substitution of new jobs for old. Unemployment is characterized as an "opportunity" to invest in green technology.[91] This practice follows long-discredited reasoning that broken windows are a social good because they increase employment among glaziers.[92]

Much of the unemployment from the transition to Net Zero 2050 would be permanent. Among Western nations, this would put substantial burdens on social safety nets. Where workers can be retrained, effective programs are expensive. It is unclear whether Western political systems can withstand this disruption. In less-developed countries, where social safety nets are rudimentary or nonexistent, unemployment caused by the Net Zero 2050 transition should be expected to result in existential social and political crises. (These costs are mentioned in passing in Net Zero 2050 transition scenarios but not quantified.)

5. Opportunity costs are excluded

Net Zero 2050 transition cost estimates are based on expenditures,[93] not on what economists call "opportunity cost" — the value of goods and services that must be sacrificed.[94] In regulatory impact analysis, opportunity costs are notoriously difficult to comprehensively estimate. A key reason why is regulatory costs usually are assumed to be borne by firms, contrary to Section II.B above, and household-level effects generally are not

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[89] See, e.g., McKinsey & Company (2022, 116). ("[C]ontinued technological and market innovation would be needed to manage grid intermittency and ensure reliability").

1. [90] *International Energy Agency (2021b, 176) ("Maintaining electricity security also requires a range of measures to ensure flexibility, adequacy and reliability at all times. Enhanced electricity system flexibility is of particular importance as the share of variable renewables in the generation mix rises. As a consequence, electricity system flexibility quadruples globally in the [Net Zero 2050 scenario] in parallel with a more than two-and-a half-fold increase in electricity supply.")*

[91] See, e.g., International Energy Agency (2021b), Network for Greening the Financial System (2022a), and McKinsey & Company (2022).

[92] Bastiat (1850).

[93] See, e.g., International Energy Agency (2021b).

[94] See, e.g., Mishan (1976), Office of Management and Budget (2003), U.S. Environmental Protection Agency (2014), Boardman et al. (2017), and Dudley et al. (2017).

estimated. In addition, opportunity costs will be different across households for a host of reasons including divergent tastes and varying income.

Examples of opportunity costs abound. For example, all Net Zero 2050 scenarios envision very large increases in the number of wind generation units and fields of solar photovoltaic panels. The IEA predicts that worldwide solar electrical capacity will increase from 737 gigawatts (GW) in 2020 to 14,458 GW in 2050 — a compound average annual growth rate of 21%.[95] Each megawatt of rated capacity (MW, 1/1000 GW) requires about 15 acres of land. Therefore, if the IEA's prediction supply of solar photovoltaic is true, about 206 million acres (326,563 square miles) would be required, and even more to the extent that the marginal utility of land declines as more productive sites are exhausted. The opportunity cost of converting that land to solar photovoltaic farms is the value it produces in its current uses.

6. Cost estimates assume frictionless policymaking in democratic societies

Net Zero 2050 scenarios (like the NGFS "orderly" scenario) assume that the transition is led and implemented by a technocratic elite insulated from democratic politics, policies, and procedures, and immune to the temptations of corruption. This is not realistic. Considering just domestic challenges, whether Net Zero 2050 is implemented by explicitly legislating a carbon tax or by continued command-and-control regulation, it will be subject to an array of compromises, all of which will increase cost. Indeed, the more difficult it is to achieve legislative consensus, the more significant and expensive these compromises will be. For now, the most likely U.S. scenario is the government muddles through using existing statutory authorities, none of which was designed for climate change.

Independent of the compromises required in a democratic society, substantial (and perhaps unprecedented) opportunities for corruption, fraud, and rentseeking will drive up costs. (Rentseeking is the expenditure of resources to reallocate costs and benefits without producing anything of value. It is a deadweight loss.)

These domestic challenges are not unique to the U.S. Every nation will face them.

7. Current SCC estimates are based on efficient global central planning

Every Net Zero 2050 transition scenario requires implementation to be performed by selfless, gifted, and possibly omniscient global central planners supported by unprecedented power.[96] This has never occurred in human history. Lesser exercises in central planning have not been successful. The costs of global central planning are extraordinarily difficult to estimate, but no less real and likely to be exceedingly large.

In addition to constraints inherent to democratic societies, achieving global Net Zero 2050 as envisioned by its advocates requires all nations to fully participate in enforceable global central planning.[97] Nations that have tried central planning on much small scales

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[95] International Energy Agency (2021b, Table: Electricity: World).

[96] McKinsey & Company (2022).

[97] See, e.g., Network for Greening the Financial System (2021b, 2021a, 2022a), International Energy Agency (2021b, 2021a), and McKinsey & Company (2022).

have failed, and nothing in the Paris Agreement commits any nation to submit to globally centralized control even if they agreed to meet Net Zero 2050 targets (which has not happened yet). Some nations are unlikely to ever agree to bear the costs that the Net Zero 2050 scenarios implicitly assign to them. Achieving Net Zero 2050 would require other nations to bear these costs, most notably the U.S — and that means U.S. households.

B. Unrealistic assumptions about the SCC

1. Current SCC estimates depend on models that assume economic efficiency

Economic efficiency is a convenient heuristic, but it is generally used as a baseline from which real-world costs can be estimated. To approximate the effect of certain economic inefficiencies, the SCC can be increased by an appropriate multiplier. Household-level burden estimates reported here can be modified accordingly. Incorporating these adjustments would increase the household-level burden accordingly.

2. Current SCC estimates assume trivial administrative costs

The administrative costs of both command-and-control regulation and its market-based alternatives are not trivial. As for the administrative costs of a global central planning regime, which all Net Zero 2050 scenarios assume, these costs are unknown and, frankly, unknowable.

These costs can be approximated by increasing the SCC or carbon tax used in the analysis, with the difference attributable to administrative costs. Household-level burdens would be proportionately higher. Thus, whether administrative costs are small (e.g., 25%) or large (e.g., 200%), the analysis can be modified to explicitly incorporate these costs as if they were a surcharge to the analyzed SCC or carbon tax rate.

3. Current SCC estimates assume global benefits that cannot materialize unless U.S. households pay the costs of reducing CO2 emissions by other key nations

Major CO2 emitters include India and China, which in 2019 were responsible for 9,877 mt and 2,310 mt CO2 emissions, respectively, or 29% and 7% of world emissions. The SCC is derived from models that assume these nations and others "do their part" by mitigating their national emissions.

For example, a key Net Zero 2050 scenario assumes that CO2 emissions from coal-fired power plants in China will decline 85% between 2020 and 2050.[98] This seems unlikely at best, and China has made no such commitment. China's energy-related CO2 emissions have significantly increased — 750 million metric tons from 2019-2021 — enough to fully offset all reductions achieved in the rest of the world.[99] (This period understates the trend because it includes output reductions due to governmental responses to COVID-19, and China's response was extraordinarily strict.)

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[98] International Energy Agency (2021b, 44).

[99] U.S. Energy Information Administration (2022a, 8).

The SCC is based on global benefits assuming that other nations reduce their emissions as expected by the models used to estimate the SCC. If these nations cannot be reasonably expected to achieve the reductions assumed by the models, achieving Net Zero 2050 would require U.S. households to cover the costs of non-U.S. emission reductions. This would raise the minimum SCC by an unknown amount.

Even this adjustment likely would not be enough. While emission reductions would be much less expensive to achieve in other nations (especially China and India), ensuring that these reductions actually occur if U.S. households paid for them would be exceedingly difficult.

Even under the hypothetical perfection assumed by the various Net Zero 2050 scenarios, it is not clear that the highest of the tax rates analyzed here would be sufficient. Each of the assumptions in subsection A above should be reconsidered by Net Zero 2050 transition modelers and their effects on the SCC be estimated.

C. Other unrealistic circumstances

It is conventional practice to conduct demonstration projects to validate key theories and ensure that new technologies are feasible. Such projects are routine for transformative proposals that have modest scope and scale.

Net Zero 2050 is very different. Scope and scale are unprecedented. Key international entities that support Net Zero 2050 have acknowledged this, but none have called for first conducting demonstration projects.[100] In short, the Net Zero 2050 transition is an experiment that would be undertaken in an environmental of maximum technological uncertainty and unlimited social, political, economic, and financial risk.

Like the direct costs of Net Zero 2050, the costs of these risks will be borne by households. Because these costs have not been seriously discussed in the prevailing literature, much less estimated, how much they will increase household-level burden beyond the estimates in this analysis can only be guessed.

Should any element of the Net Zero 2050 transition prove to be technologically infeasible, this will not necessarily reduce household-level burden. Costs will be borne even if they do not produce benefits. That, in turn, will compel additional, unexpected regulations, systematically higher direct carbon taxes, or abject failure.

VIII. Conclusion

Net Zero 2050 has broad support among U.S. government and academic elites but the extent of public support is unknown. A key reason is elites supporting Net Zero 2050 have not communicated in practical terms how much it would cost U.S. households. The public does not understand this because, despite huge investments in climate change research and exploding media coverage of Net Zero 2050, the likely cost of this policy is

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[100] See, e.g., Schwab and Malleret (2020), World Economic Forum (2021), Network for Greening the Financial System (2021b, 2021a, 2022a), International Energy Agency (2021b), and McKinsey & Company (2022).

highly opaque. This may be a desirable feature of the policy debate for the elites. Drawing attention to cost diminishes public support for action unless the public can be persuaded that costs will be paid by others. Costs can be described as borne by others, but such public communications are highly misleading. No matter who initially bears the cost, sooner or later cost will find its way into the household economy.

This paper shows that under a range of plausible assumptions concerning the unit cost of achieving Net Zero 2050, the total cost is staggeringly large. Even in Scenario B, at the lowest unit cost examined ($100/metric ton), Net Zero 2050 can be expected to extract more than 4% of median household income everywhere, and more than 6% in 36 States. If Net Zero 2050 costs $700/metric ton to achieve, U.S, households would expect to lose at least 30% of their household income, and in some States more than 60%. In Scenario A, the household-level burden goes sky high in several States—more than 20% of household income in four States if Net Zero 2050 costs $100/metric ton to achieve, and more than 25% of household income in 36 States if Net Zero 2050 costs $700/metric ton to achieve.

For the poor and working class, paying these costs is financially infeasible. If forced to pay it, they would endure abject poverty never before experienced in the U.S. They must be substantially (if not fully) subsidized, and that requires shifting the cost burden to high-income households. These households would see large increases in their effective tax rate, from the current 30% to 50%, or more. And there are knock-on effects from these subsidies: those subsidized would have little or no incentive to reduce their direct and indirect CO2 emissions, making the achievement of Net Zero 2050 even more elusive.

Finally, the cost of Net Zero 2050 does not go away if the policy is not achieved and its presumptive benefits do not materialize. This could happen simply if other major CO2 emitters, most notably China and India, decline to participate. Costs are borne early; benefits are captured later, and in the case of climate change mitigation, many decades later. By the time benefits are realized, costs will have been borne and cannot be recovered. To the extent that these costs significantly reduce the U.S. standard of living, that change will be permanent.

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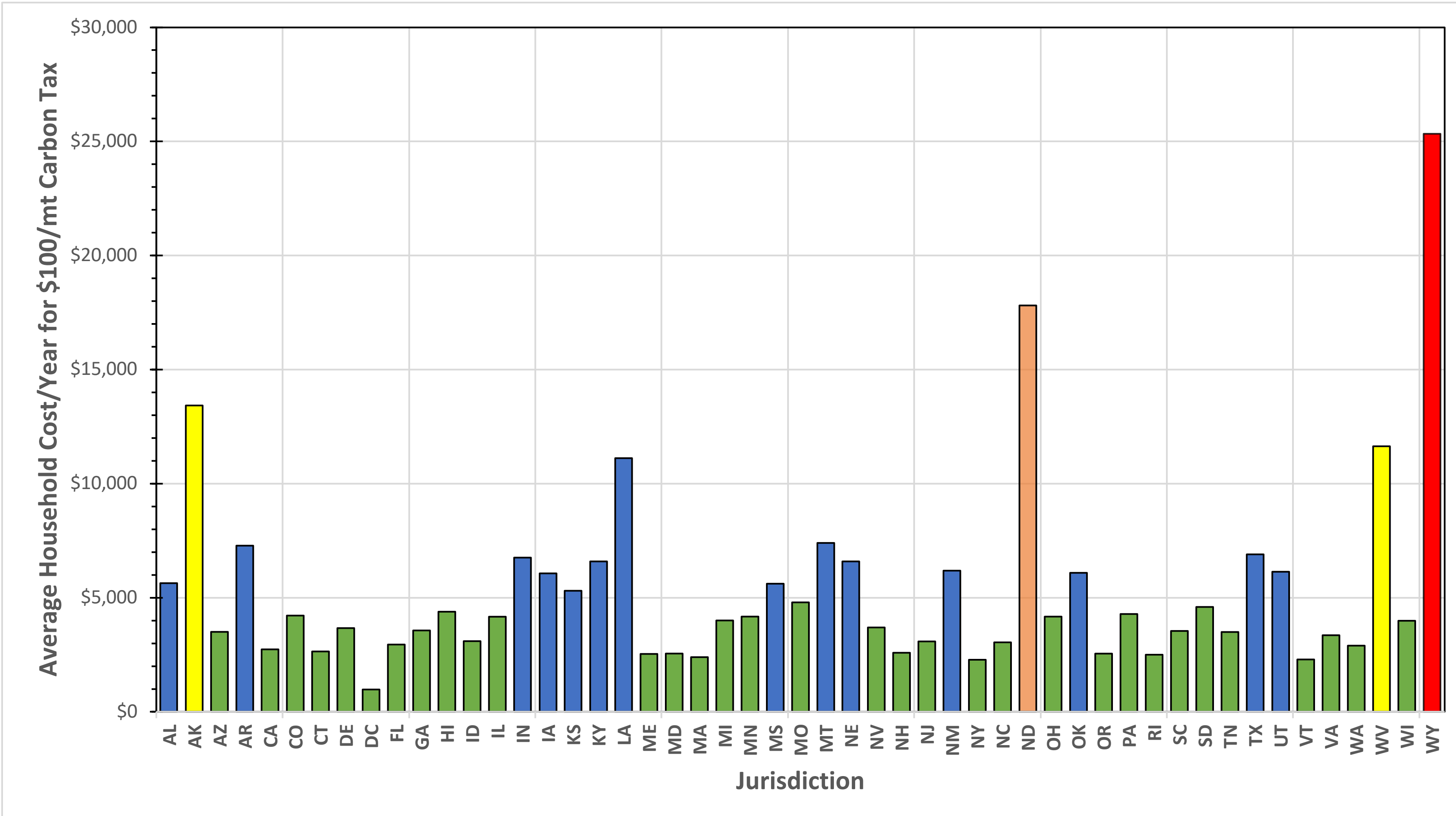

Figure 1: Average Annual Household Cost of Net Zero 2050 at $100/mt, Scenario A

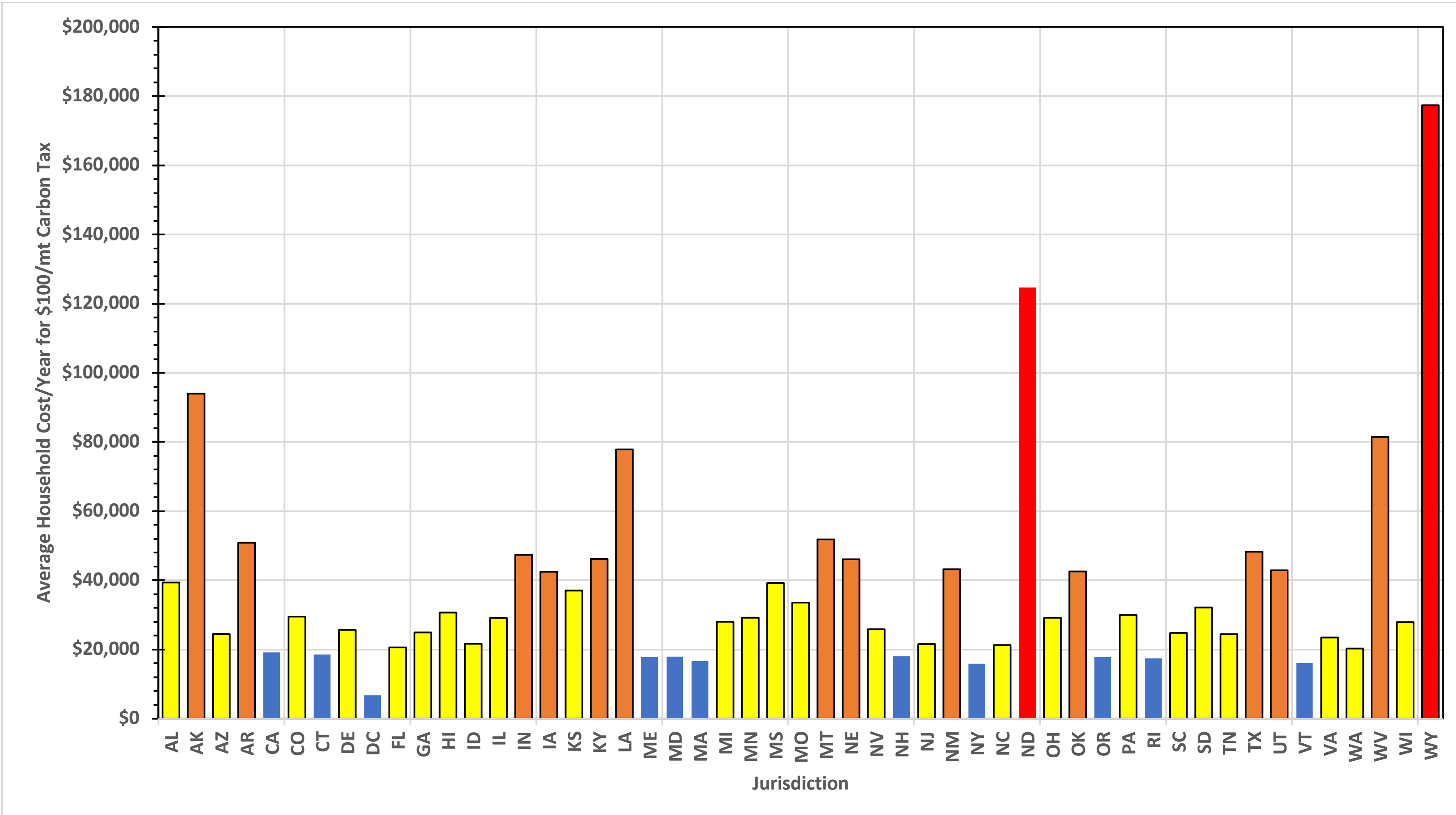

Figure 2: Average Annual Household Cost of Net Zero 2050 at $700/mt, Scenario A

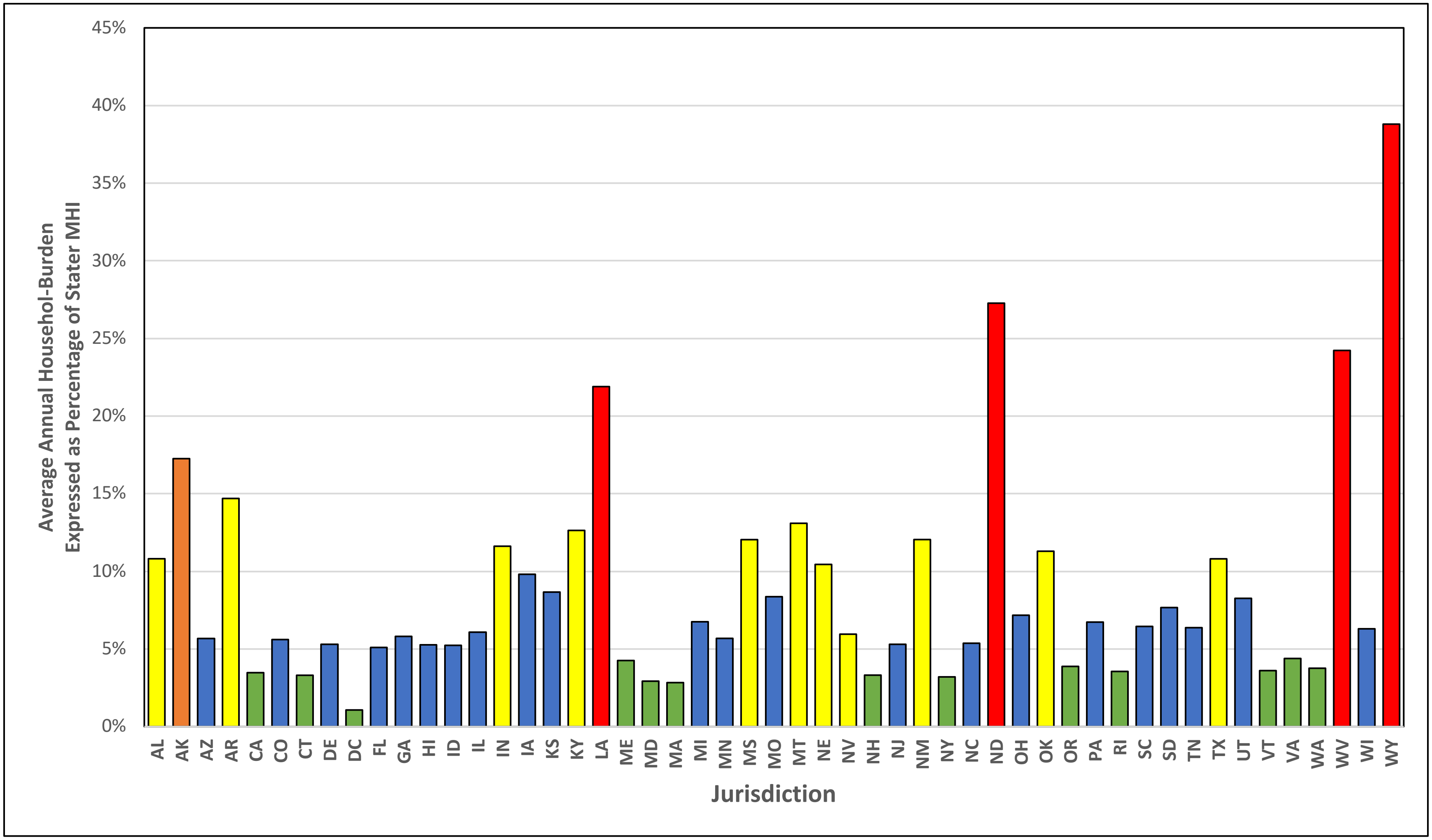

Figure 3: Average Annual Household Cost of Net Zero 2050 at $100/mt Expressed as Percent of Median Household Income, Scenario A

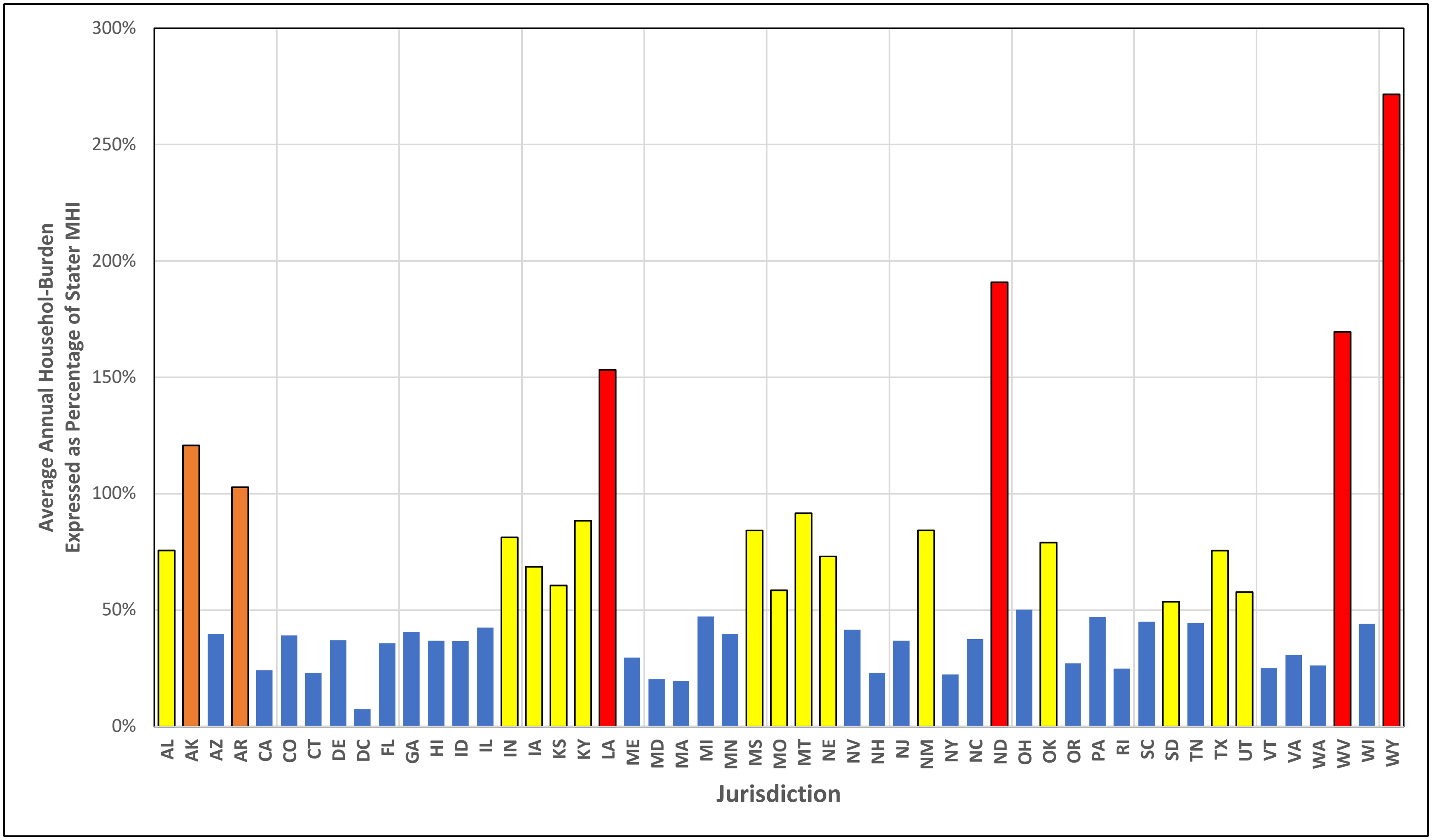

Figure 4: Average Annual Household Cost of Net Zero 2050 at $700/mt Expressed as Percent of Median Household Income, Scenario A

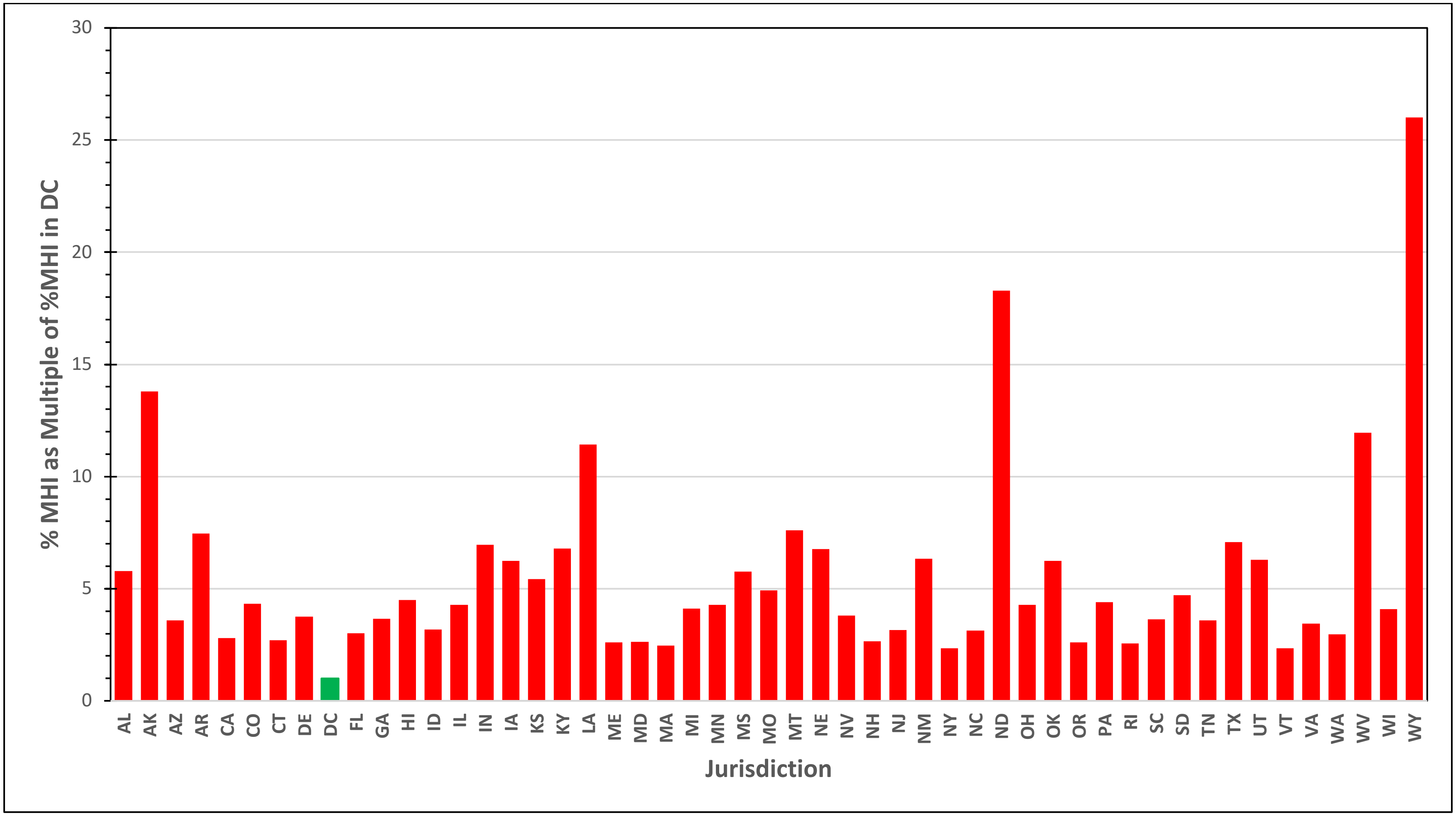

Figure 5: Burden of Net Zero 2050 Expressed as the Multiple Median Household Income Divided by Median Household Income for the District of Columbia, Scenario A

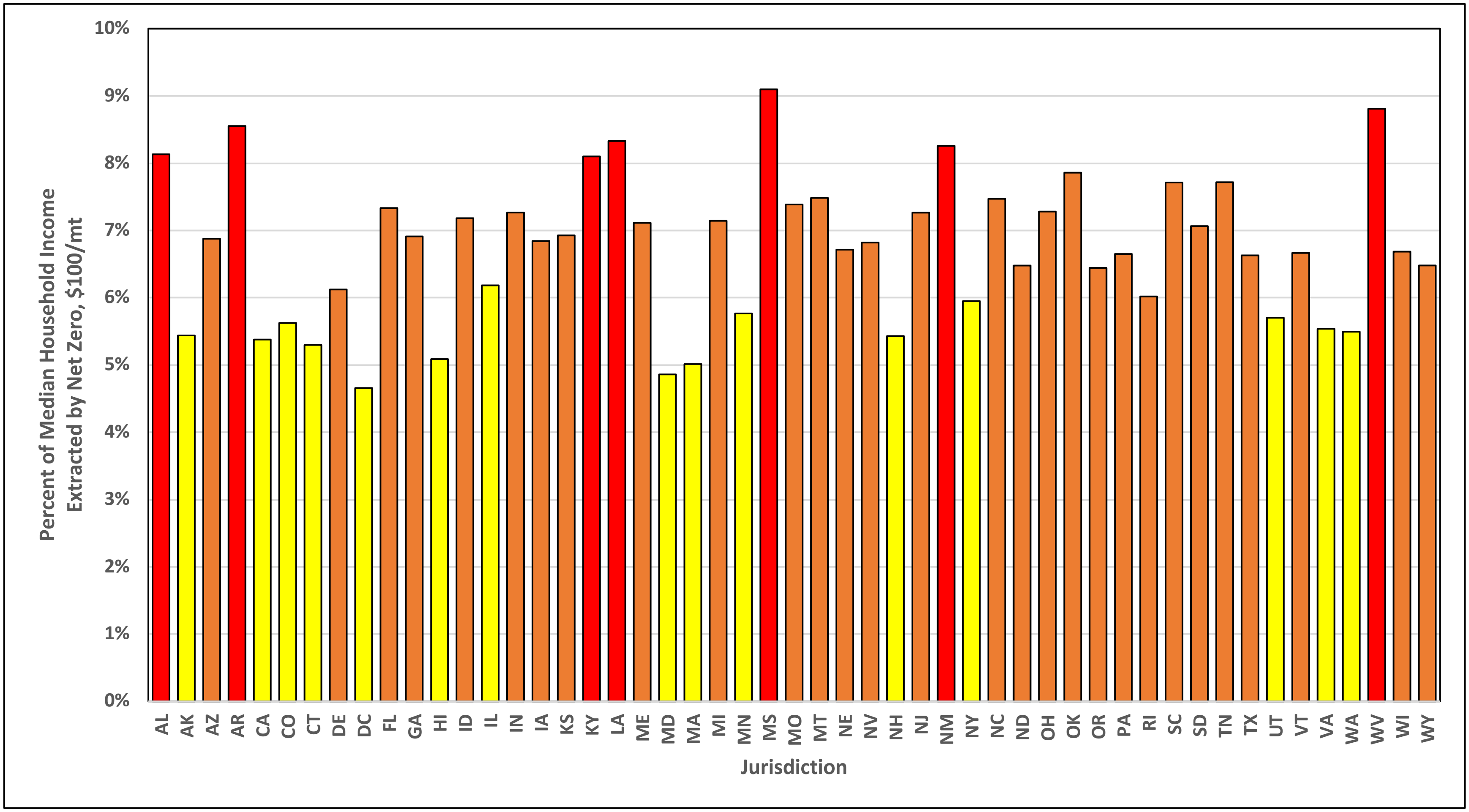

Figure 6: Average Annual Household Cost of Net Zero 2050 at $100/mt Expressed as Percent of Median Household Income, Scenario B

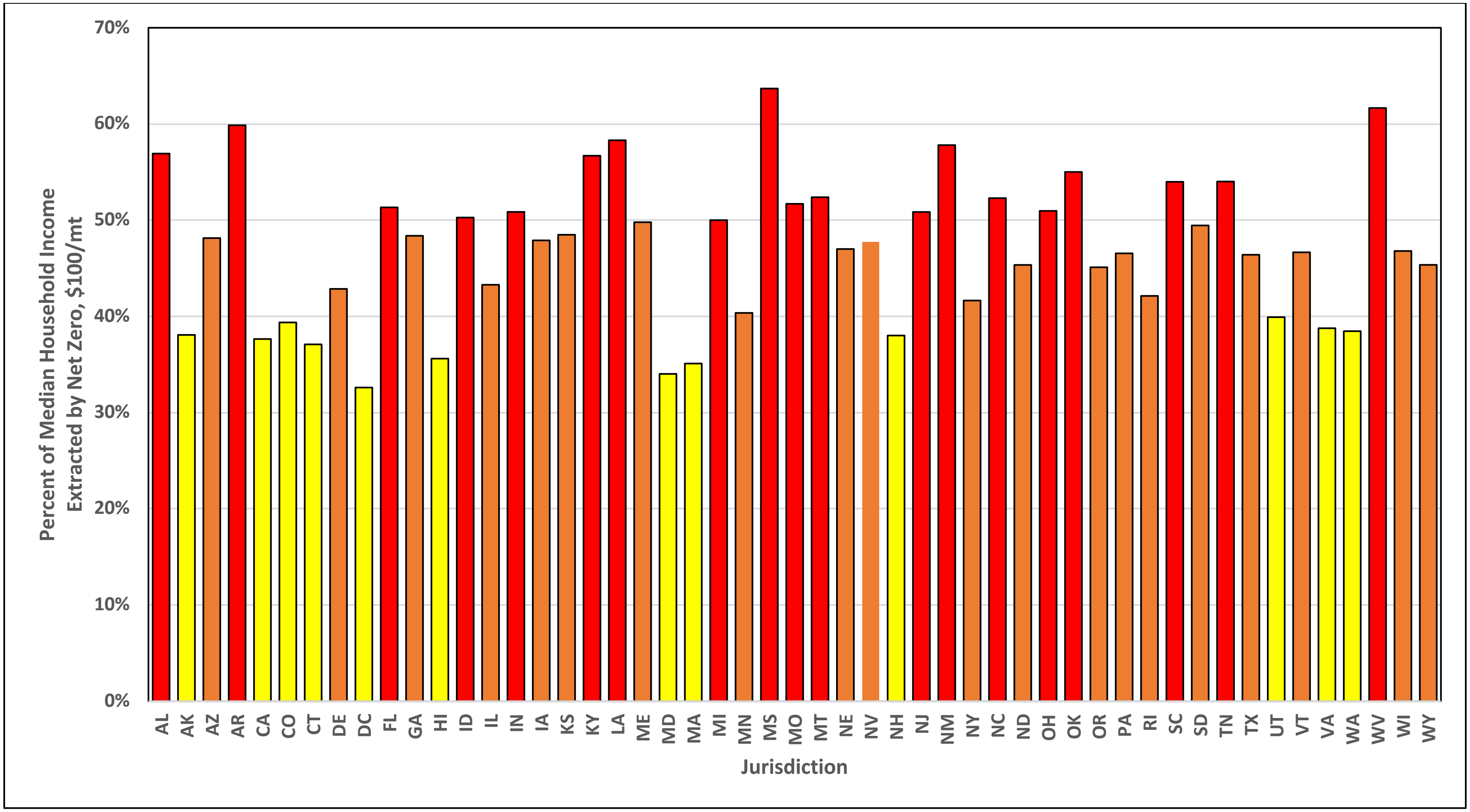

Figure 7: Average Annual Household Cost of Net Zero 2050 at $700/mt Expressed as Percent of Median Household Income, Scenario B

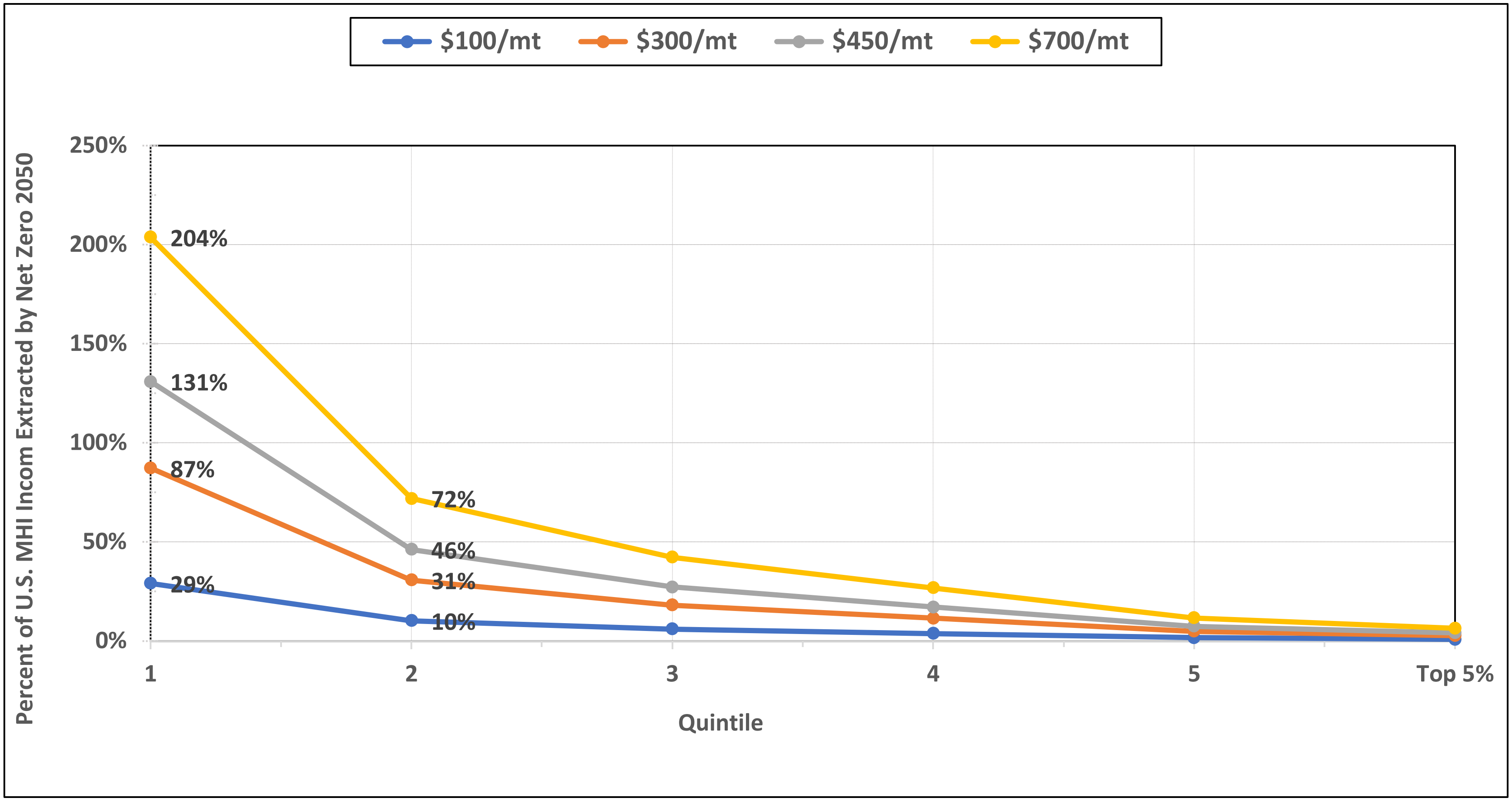

Figure 8: Average Percent of U.S. Median Household Census Income Extracted by Net Zero 2050, Scenario B

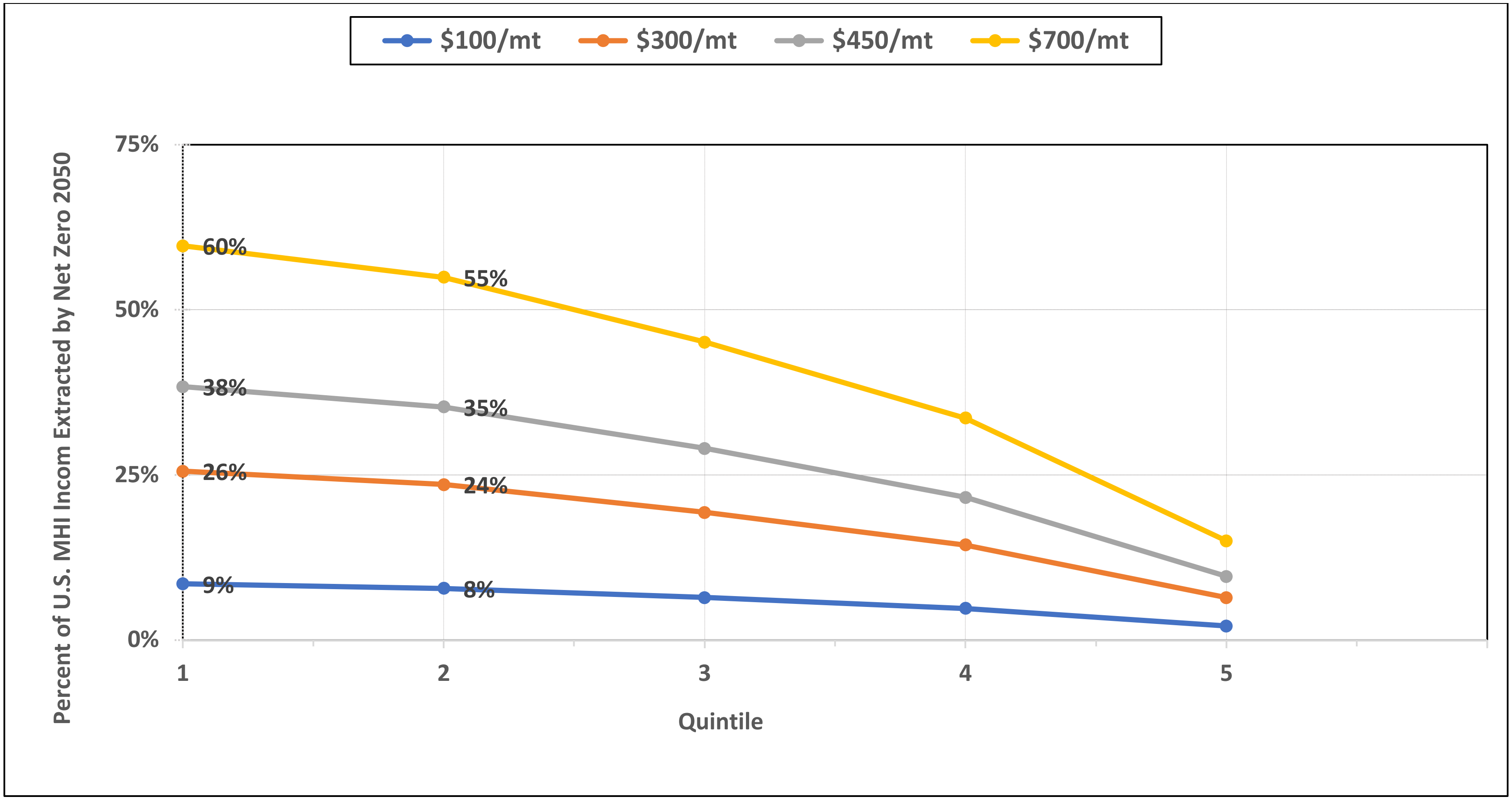

Figure 9: Average Percent of U.S. Median Household After-Tax and After-transfer Income Extracted by Net Zero 2050 Scenario B