CLOSING THE EMISSIONS GAP BETWEEN THE IRA AND 2030 U.S. NDC: POLICIES TO MEET THE MOMENT

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EXECUTIVE SUMMARY

The United States committed to cutting its greenhouse gas (GHG) emissions to 50 to 52 percent below 2005 levels by 2030 as part of its updated Nationally Determined Contribution (NDC) under the Paris Climate Agreement. In 2020, U.S. carbon dioxide equivalent (CO_2e) emissions were 21 percent below 2005 levels. The U.S. made significant progress toward its NDC in 2022 by passing the Inflation Reduction Act (IRA), which is expected to cut emissions to 37 to 43 percent below 2005 levels in 2030.

But even with this historic legislation, significant additional economywide reductions are required to close the emissions gap between the IRA and the 2030 NDC. The technical characteristics of burning fossil fuels across our economy suggest the power sector needs to move fastest to decarbonize by 2030, but that each of the other major demand sectors—transportation, buildings, and industry—also must accelerate their emissions reductions pace.

The lifetime of most end-use equipment like cars, furnaces, and boilers is 10 to 20 years, meaning the speed those stocks can be decarbonized is limited to their natural replacement rate—an effect referred to as stock turnover.[i]

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By contrast, although the power sector relies on large capital-intensive assets, it is subject to a high degree of competition and regulatory oversight, empowering a faster clean transition. While these dynamics suggest the power sector must lead the way toward that commitment, all sectors require robust additional policy to achieve the NDC.

This report uses the Energy Policy Simulator (EPS) to outline policies capable of achieving the U.S. NDC, building on the IRA's major climate provisions. The open-source and peer-reviewed EPS climate policy model estimates climate and energy policy impacts using publicly available data. While there are multiple pathways to meet the NDC, we rely on our judgement to determine the right policy mix, focusing on existing legislative or regulatory pathways while avoiding policies that have historically faced considerable pushback, like carbon pricing.

The table below summarizes our recommended policies to achieve the NDC, covering each of the major emitting energy sectors.

Electricity	Industry	Transportation	Buildings
• New, Stronger Federal Regulations on Existing Coal Power Plants • New, Stronger Federal Regulations on New Natural Gas and Coal Power Plants • New, Stronger Federal and State Standards on Clean Electricity Generation • Federal and State Reforms to Near-Term Transmission System Barriers to Renewable Energy Deployment	• Stronger Federal Energy Efficiency Standards • New Financial Incentives and Emissions Standards for Industrial Heating • Stronger Federal Standards on High Global Warming Potential Refrigerants • Stronger Federal Fugitive Methane Emissions Standards • New Federal Fugitive Nitrous Dioxide Emission Standards	• Stronger Federal and State Tailpipe and Fuel Economy Standards • Charging Infrastructure Investment • New Standards on EV Supply Chains	• New, Stronger Federal and State Appliance Standards • New, Stronger State and Local Building Code Adoption and Enforcement

Table 1: Policies to Meet U.S. NDC in 2030

In addition to reducing GHG emissions to 50 percent below 2005 levels in 2030, the policies listed above generate enormous economic and health benefits. In 2030 in addition to the benefits from the IRA, this NDC policy pathway will create an additional 2.7 million jobs, grow GDP an additional $700 billion (1.7 percent), and avoid 3,900 more premature deaths through lower air pollution, which is more heavily concentrated in communities of color. Households can also expect to save $110 per year on their energy spending, an additional $80 per year on top of savings from the IRA.

IRA provisions could also create international tailwinds for clean energy technologies. We estimate the IRA could reduce global costs 3.8 percent for solar PV, and 2.6 percent for wind technologies by 2030. These cost reductions could yield at least $11 billion per year in savings by 2030.

Using the U.S. Environmental Protection Agency's (EPA) newly released social cost of carbon, the IRA coupled with the NDC policies outlined here could avoid a cumulative $1.7 trillion in damages between 2023 and 2030.

The IRA's climate investments will make significant progress toward the 2030 NDC but the federal government, along with state and local governments, must adopt additional policies to put the U.S. on a path to achieving its climate targets.

INTRODUCTION

The U.S. updated its NDC in 2021, committing to reduce GHG emissions to 50 to 52 percent below 2005 levels by 2030, with a goal of reaching net-zero emissions by 2050. Based on the EPA's GHG inventory, net 2005 emissions were 6,645 million metric tons (MMT) CO_2e, meaning the U.S. would need to reduce emissions to 3,323 MMT CO_2e or lower in 2030 to meet the NDC. The latest official GHG data finds that in 2020, U.S. emissions were 5,222 MMT CO_2e, or 21 percent below 2005 levels. However, 2020 emissions were lower than expected due to COVID-19. Official GHG data for 2021 will likely show increased emissions based on U.S. Energy Information Administration estimates of CO_2 emissions from energy consumption for 2021, which reflect a 7 percent increase relative to 2020 levels.

Either way, the U.S. must significantly reduce emissions relative to historical levels to hit its NDC.

The U.S. made significant progress toward achieving the required reductions in 2021 and 2022. The Infrastructure Investment and Jobs Act (IIJA), the CHIPS and Science Act, and most importantly, the IRA will significantly cut U.S. emissions, putting the NDC within reach. Prior to IRA passage, the U.S. was on track to reduce 2030 emissions to 25 percent of 2005 levels. With the IRA's enactment, the U.S. is on track to reduce 2030 emissions to 37 to 43 percent below 2005 levels, based on earlier Energy Innovation Policy and Technology LLC® modeling.[1]

Put another way, relative to pre-IRA projections of 2030 emissions, the IRA achieves 48 to 72 percent of the emissions reductions required for the NDC target.

Though the IRA can significantly reduce emissions, additional reductions are required by 2030 to meet the U.S. NDC, even under the most optimistic scenarios. Furthermore, IRA reductions are not guaranteed given the nature of the legislation's reliance on incentives and tax credits, as well as considerable remaining barriers to clean energy deployment like transmission and interconnection bottlenecks. If market forces don't play out as expected and market barriers aren't resolved, IRA emissions reductions could be smaller than projected.

These findings underscore the need for additional policy to ensure IRA provisions are fully implemented and close the 2030 emissions gap between IRA and the NDC. This research note identifies a potential policy pathway to achieve the U.S. NDC using the EPS, relying on our judgement of the most viable policies.

PATHWAYS TO ACHIEVE THE 2030 U.S. NDC

Sectoral Considerations

Important technical and policy considerations can help identify potential pathways to meeting the 2030 target.

To start, the stock turnover dynamic limits certain sectors' speed of emissions reductions. Stock turnover refers to the dynamic wherein only a portion of the stock of equipment—for example, passenger cars or building furnaces—is replaced each year. Because policies tend to target new equipment sales, and equipment can take many years to reach the end of its useful life, the stock turnover dynamic means certain sectors could take decades to decarbonize, even with strong policies targeting new sales. For example, building furnaces tend to last 15 to 20 years, meaning a sales standard implemented today requiring all new furnaces to be zero emissions wouldn't fully decarbonize the building furnace stock for up to 20 years.

Of the economy's major emitting sectors, buildings, transportation, and industry are all subject to the stock turnover dynamic because of each sector's technology investment cycles. For instance, a typical passenger car is on the road for 12 years and a typical industrial boiler lifetime is 20 to 30 years. As a result, emissions reductions from these sectors are likely to be limited by 2030. Industrial process emissions are an exception, where small changes in practices that are not heavily reliant on expensive capital equipment can yield significant emissions reductions. One example of this is reducing methane emissions through better monitoring and leak protection.

The stock turnover dynamic leads to several important conclusions:

- Sectors characterized by slow stock turnover (i.e., buildings, industry, and transportation) are unlikely to deliver large emissions reductions by 2030.
- These same sectors need strong policies to be implemented as soon as possible to ensure sufficient time to fully decarbonize before 2050.

- These sectors therefore appear to be only small contributors to 2030 reductions but are important to reaching the 2050 net-zero emissions target.
- Sectors that are less prone to stock turnover are more likely to decarbonize faster.

Three factors suggest the electricity sector is the linchpin to economywide decarbonization and that it will be the fastest decarbonizing sector, even though it is comprised of large, expensive assets.

First, the electricity sector is the primary economic sector that is not prone to the capital cycles of other sectors, because it comprises a mix of private and regulated entities competing to provide electricity. Although the electricity sector is composed of large, capital-intensive power plants with long lifecycles, robust competition leads to new plants routinely entering the market. Power plant owners will build new facilities if economic incentives are sufficiently large and they are allowed to connect to the grid, and these facilities will compete with existing facilities. State regulation of utilities puts an emphasis (at least in theory) on keeping rates affordable and building new assets to meet system needs while lowering costs.

Second, most clean electricity generation technologies are already cheaper to build and run than fossil alternatives, i.e., the unsubsidized levelized cost of most new clean electricity sources is already lower today than for either natural gas or coal power plants. IRA incentives make this economic equation even more favorable for clean electricity. This dynamic is increasingly true for consumer technologies, such as electric vehicles (EVs), but is not yet true for many electrification technologies needed to decarbonize buildings or industry. Given the lower levelized cost of clean electricity, coupled with the lower generation cost and resulting market prices, decarbonizing the power sector can yield immediate economic benefits.

Third, the primary path to decarbonizing most end uses is electrification. This includes battery electric vehicles (BEVs), building and industrial heat pumps, and electrified industrial processes. The opportunity to outsource emissions from other sectors of the economy to the electricity sector via electrification underscores the importance of rapidly decarbonizing the electricity sector.

Modeling an NDC Pathway

This paper outlines a policy- and technology-feasible pathway to close the emissions gap from forecast U.S. emissions reductions under existing policies to achieve the 2030 U.S. NDC of 50 to 52 percent emissions below 2005 levels.

The policies in this NDC pathway were selected based on available technology options and our judgement regarding the potential for policies to be adopted. Where it is politically viable or where statutory authority already exists, we prioritize well-designed federal policy over state policy to better scale reductions. We rule out politically unviable policies like a national, economy-wide carbon price.

To align with the official U.S. NDC, our modeling uses 100-year global warming potential (GWP) values following the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4 GWP-100) and relies on officially reported data on energy consumption and emissions, net of land-use change. Though the U.S. officially reports in AR4 GWP-100, subsequent IPCC reports have updated GWP-100 values, which notably have a higher value for methane (CH_4). As a result of relying on these data sources and conversions, our modeling results may particularly understate methane emissions and reductions.

We evaluated three U.S. emissions scenarios using a customized version 3.4.4 of the U.S. EPS: the Business-As-Usual (BAU), Inflation Reduction Act (IRA), and Nationally Determined Contribution (NDC) scenarios. The BAU Scenario reflects all federal and state policy and regulations enacted prior to IRA passage. The IRA Scenario reflects the estimated IRA impact on energy and emissions, using the Moderate IRA Scenario from earlier modeling by Energy Innovation®.[ii,2]

The NDC Scenario reflects a policy pathway to achieve the NDC.

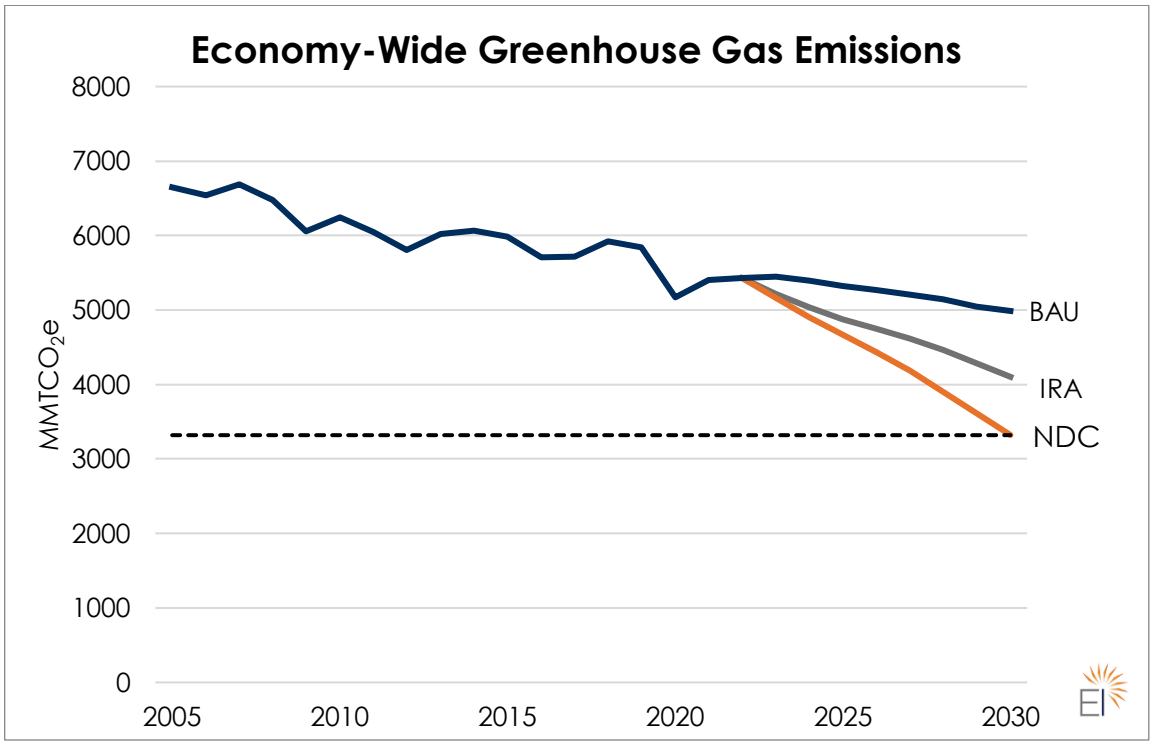

Figure 1: Economy-wide GHG emissions by scenario

[ii] Note that the modeling of the IRA Scenario here may differ slightly from earlier modeling based on updates to the way we modeled the IRA and structural updates to the EPS since the release of our original research.

This report focuses on technical pathways to achieve the NDC and the policies that can be used to achieve those pathways. It therefore provides a policy roadmap for decision-makers working to determine how the U.S. can achieve its 2030 goals.

ELECTRICITY

The electricity sector includes utility-scale electricity production from large power plants and distributed generation like rooftop solar. It is the third-largest source of U.S. emissions after industry and transportation, emitting roughly 1,550 MMT of CO_2e in 2021, or about 28 percent of net GHG emissions.[3]

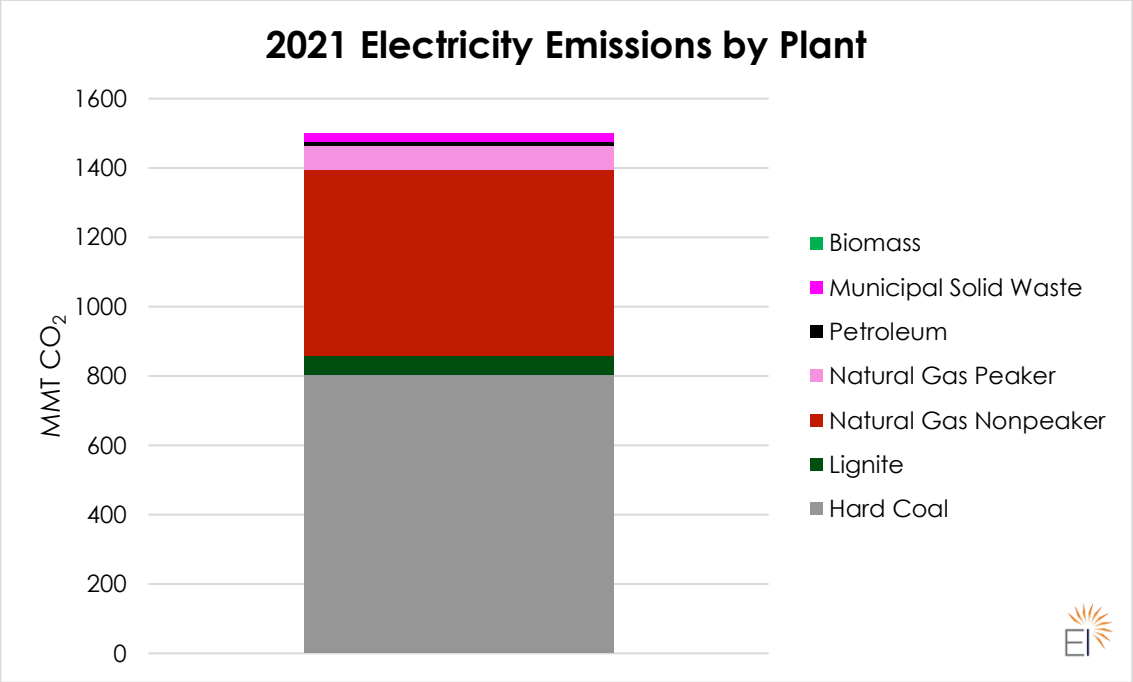

Figure 2: 2021 GHG Electricity Emissions by Plant Type

Electricity sector emissions decreased 24 percent[4] in the past decade as natural gas prices remained low (until recently), while falling prices, federal support, and state requirements for solar photovoltaics (PV), wind, and batteries have catalyzed deployment of these technologies. Increasingly stringent pollution standards for coal plants, coupled with cheaper technology options, have led to significant coal retirements and lower output from existing coal plants.

The electricity sector is the linchpin to achieving the U.S. 2030 NDC because mature, cost-effective technologies can rapidly decarbonize electricity generation, which other sectors must rely upon for emissions reductions through electrification. For these reasons, the electricity sector should be first

and fastest to decarbonize both in terms of what is technically achievable and in terms of policy needs.

The IRA includes many provisions to accelerate clean electricity deployment including tax credits, funding programs, and low-cost loans, all of which are discussed in the next section. By 2030, the IRA could push the power sector to more than 80 percent clean electricity and eliminate most of today's unabated coal emissions, but the IRA does not guarantee this progress.

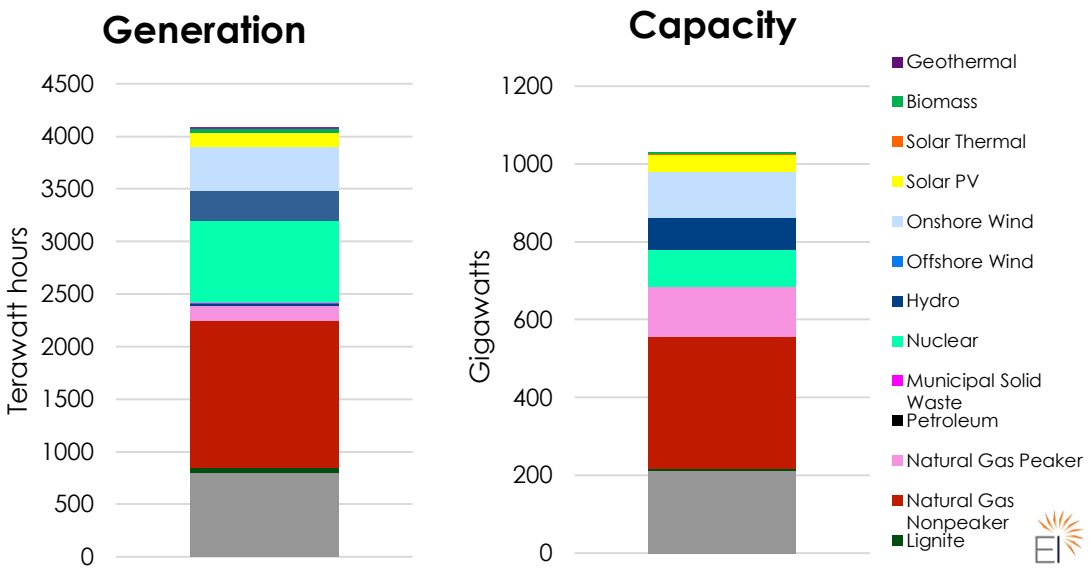

Figure 3: 2021 Electricity Generation and Capacity by Plant Type

IRA provisions make clean electricity and supporting infrastructure more financially attractive, but the rapid infrastructure buildout needed to replace aging fossil power plants faces significant institutional barriers and near-term supply-chain constraints. The IRA also includes large incentives to invest in unproven carbon capture technologies for coal-fired power plants that could preserve these plants without significant carbon and air pollution reductions.[5]

Absent additional policies, the U.S. is unlikely to achieve 80 percent clean electricity by 2030 and eliminate unabated coal generation – two outcomes that are necessary to hit the NDC. Key policies include EPA pollution standards for new and existing power plants, new state or federal clean electricity procurement requirements, and improved transmission development and interconnection processes. Each is crucial for success – to hit the NDC we must both maximize clean energy development and minimize the emissions from the remaining fossil fleet. However, much also relies on state action, starting especially with public utility commissions, which regulate utility investments in new infrastructure. These quasi-judicial regulatory bodies can steer utilities toward a coal-free 80 percent clean electricity system, drag their feet, or wait for utilities to act, creating uncertainty. While the following package of policies represents the main tenets of

electricity sector reforms needed to meet to NDC, every state must also act to hold utilities accountable, particularly given the cost savings potential generated by the IRA.

IRA Policies Targeting Electricity Emissions

The IRA includes tax incentives and significant funding to deploy clean electricity and reduce emissions. Provisions include investment and production tax credits (which become technology neutral in later years), a tax credit for existing nuclear power plants, a new U.S. Department of Energy (DOE) loan program (Section 1706), and funding for rural utility energy transitions. The tax credits also have bonus provisions that increase their value if certain project conditions are met, such as paying prevailing wages, meeting minimum domestic content requirements, and siting within certain communities.

The 45Y clean energy production and 48E clean energy investment tax credits are designed to be technology neutral by allowing any zero-emitting resource to qualify. The value of the tax credits is significant: as much as $31 per megawatt-hour (for ten years) or 50 percent of capital costs if projects can meet the IRA's credit requirements. The tax credits are also transferrable, meaning developers will not be hampered by the need to find tax equity partners, who would typically take a significant cut of the tax credit value.

Adding the new 45U tax credit for existing nuclear power plants provides a significant incentive to help retain the existing nuclear fleet. The 45U credit, especially when coupled with IIJA incentives, should forestall future nuclear retirements at least until the credits expire in 2032.

A new program with $9.7 billion in funding for rural cooperatives to decarbonize could result in the retirement of nearly 20 gigawatts (GW) of coal plants, as our earlier IRA modeling outlined.

Finally, the new 1706 DOE loan program offers up to $250 billion in loan guarantees to help retire and retrofit existing fossil fuel infrastructure, including replacing fossil plants with clean energy. Considerable uncertainty exists around how this program will be implemented, which makes it challenging to model potential impacts, but if utilities leverage the funding to replace coal plants with clean energy, the impact could be significant.

Altogether, these provisions could result in significant power sector decarbonization. Earlier Energy Innovation® modeling found IRA provisions could increase the 2030 share of clean electricity from 49 percent (pre-IRA) to 72 to 85 percent. This range reflects uncertainty regarding tax credit values and the efficacy of programs accompanying the tax credits, such as the 1706 loan program. It does not account for other important barriers, such as challenges with transmission build-out and delays for new project grid interconnections. In all but the most optimistic IRA scenario, significant coal generation remains while the electricity sector falls short of 80 percent clean electricity by 2030.

In summary, the IRA locks in the affordability of a rapid clean electricity transition but does not guarantee the requisite clean energy infrastructure will get built. Additional policies, however,

could eliminate unabated coal emissions and ensure the power sector scales fast enough to reach 80 percent clean by 2030.

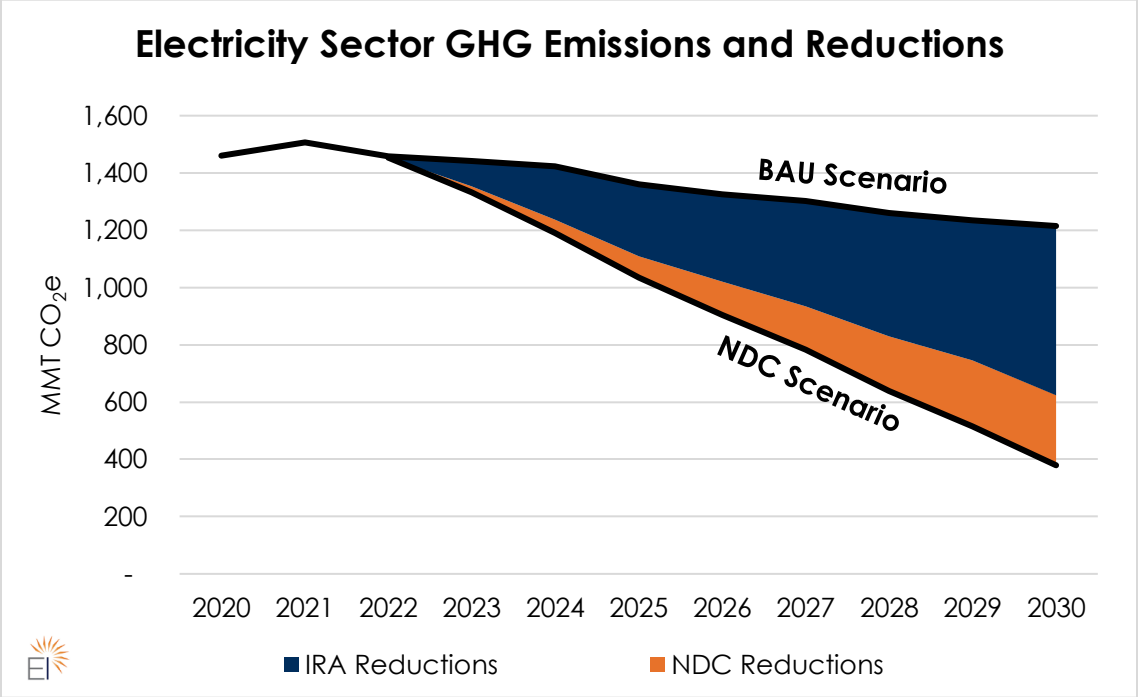

Figure 4: Reductions in electricity sector emissions in the IRA and NDC scenarios relative to BAU

Additional Policies to Reach the 2030 NDC Target

Several federal and state policies can achieve the power sector decarbonization needed to meet the 2030 U.S. NDC.

New and Stronger Federal Regulations on Existing Coal Power Plants

Reducing unabated coal power generation to zero by 2030 is necessary to meet the U.S. NDC. Even if the U.S. achieves 80 percent clean electricity by 2030, we will fall short of our NDC target if the remaining fossil mix includes unabated coal generation because coal power emits nearly twice as much CO_2 as gas. Several policies together can help achieve this goal.

The best option would be a federal clean electricity standard (CES), which failed to pass in the latest budget reconciliation process. Even without a federal CES, the IRA will reduce coal generation through economic investment in cheaper clean energy along with new financial support for coal replacement. However, it is unclear which utilities and state regulators will take advantage of new

federal tax incentives, loans, and grants to retire and replace coal-fired power plants; likewise, the amount of coal that will retire is uncertain.

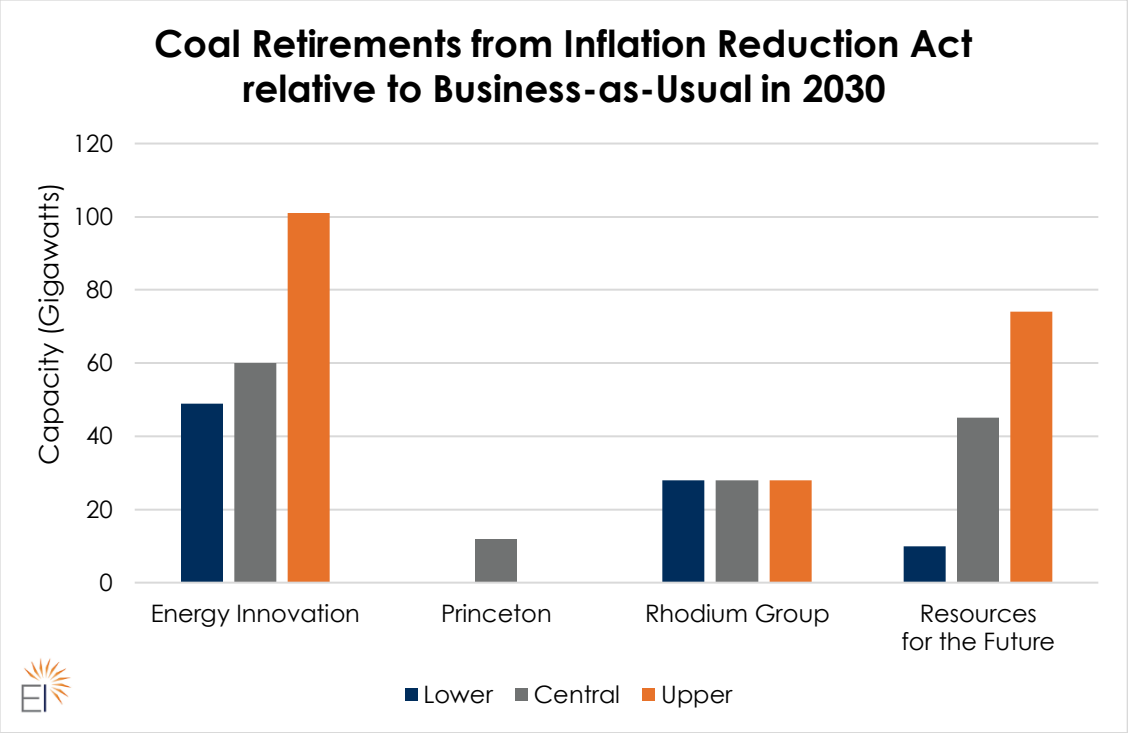

Figure 5: Coal retirements from the IRA in different studies

Additional EPA air and water pollution standards can reduce coal emissions by targeting their CO_2 emissions and non-CO_2 health impacts, including a new standard for existing coal-fired power plant CO_2 emissions under Clean Air Act Section 111(d) and various updates to public health and water quality standards that require new pollution controls on coal-fired power plants.[6] Updated health-based pollution standards would markedly improve public health, with the co-benefit of reducing coal's climate impacts and reducing customer costs. When considered alongside IRA provisions, additional federal climate and air pollution regulations would likely lead to significant coal retirement and associated emissions reductions.

But federal pollution standards and the IRA alone will not reduce unabated coal generation to zero. State public utility commissions, municipalities, federal power administrations, cooperative utilities, and investor-owned utilities must also act. Though IRA and federal regulations provide clear economic justification for retiring coal, state regulators and utilities also must recognize and implement these changes under their mandate to offer just and reasonable electricity rates, often in the absence of competition. Without a federal carbon pollution standard or CES, significant uncertainty will linger around the indirect efficacy of policies.

The NDC Scenario assumes new federal regulations on the coal fleet result in retirement or retrofit of 100 percent of the coal fleet by 2030, with no coal CO_2 emissions by 2030.

New and Stronger Federal Regulations on New Natural Gas and Coal Power Plants

Section 111(b) of the Clean Air Act is another key policy to reduce emissions by tightening CO_2 emissions standards for new power plants , thus barring new unabated coal and gas generation. In June 2022, the U.S. Supreme Court ruled in *West Virginia v. EPA* that the term "best system of emission reduction," under the Clean Air Act does not include generation shifting from existing fossil to new clean energy resources. However, this ruling did not undermine EPA's fundamental authority to regulate CO_2 emissions from power plants under Clean Air Act Section 111. Moreover, language included in the IRA amended the Clean Air Act to define CO_2 emissions from burning fossil fuels as an "air pollutant."[7] The amendments significantly bolster EPA's ability to regulate CO_2 from fuel combustion.

These developments leave the door open for the federal government to regulate CO_2 emissions from power plants. In April 2022, EPA released a white paper calling for industry input on the best system of emissions reduction for new gas-fired power plants.[8] However, as the white paper and record of comments demonstrates, no consensus exists on whether measures beyond efficiency improvements such as carbon capture, use of the NET Power Cycle, and hydrogen blending are feasible in the near term.[9] That said, the new IRA incentives for carbon capture (45Q) greatly strengthen the economic case for requiring carbon capture and sequestration (CCS) for new gas power plants.

The NDC Scenario includes federal regulations requiring all new coal and natural gas plants be equipped with CCS beyond those plants already under construction.

New and Stronger Federal and State Standards on Clean Electricity Generation

Standards requiring utilities to reduce emissions or reach higher carbon-free electricity shares are also essential to achieving the U.S. NDC, and IRA incentives make faster electricity sector decarbonization a no-regrets policy for consumers.

The NDC Scenario includes a nationwide 80 percent CES by 2030, though in practice this would fall either to Congress, which failed to adopt a CES as part of budget reconciliation, or more likely to state legislatures, utility regulators, and electric utilities.

State legislators can strengthen or introduce a CES, which typically refers to a technology-neutral standard requiring utilities to serve customers with a certain percentage of "clean" zero- or low-carbon resources, such as wind, solar, and nuclear electricity, and in some cases coal or natural gas fitted with carbon capture, as well as other technologies.[10] This well-established policy framework

reduces pollution, promotes new investment, and generally insulates customers from volatile fossil fuel prices.

States should pass CES legislation balancing affordability, feasibility, and investment opportunity, targeting 80 percent carbon-free electricity by 2030. To date, 16 states have legislation committing to 100 percent clean electricity sales by 2050 or sooner,[11] but most of this legislation lacks interim 2030 targets. In total, existing state renewable portfolio standard commitments by 2030 would only increase the share of renewable generation 7 percent by 2030,[iii] whereas an 80 percent CES implies a 40 percent increase. A handful of states, including California and Maine, have clean electricity requirements by 2030 on pace for a national 80 percent CES by 2030, while other jurisdictions, including Rhode Island and Washington, D.C., have required utilities to achieve 100 percent clean electricity by the early 2030s. The IRA provides an opportunity to accelerate state goals, which together represent roughly one-third of retail sales, without increasing costs.

But to reach the 80 percent by 2030 goal without congressional action, additional high-emitting states including Arizona, Florida, Georgia, Indiana, Michigan, Ohio, Pennsylvania, and Texas must also act, either through binding legislation or economic regulation of monopoly utilities.

The NDC Scenario includes President Biden's target of 30 GW offshore wind capacity by 2030 as part of achieving 80 percent clean electricity in 2030.

In aggregate, as of May 31, 2022, state legislative commitments call for deploying at least 39,322 megawatts of offshore wind capacity by 2040.[12] Utilities have signed contracts for 18 GW worth of offshore wind to operate before 2030. Collaboration between the federal government and states, including transmission development, accelerated leasing, coordinated permitting and environmental assessment, and supply chain and port investments can help achieve these targets.

Federal and State Reforms to Near-Term Transmission System Barriers to Renewable Energy Deployment

Modeling of the IRA's impact assumes developers can access the transmission necessary to achieve a rapid renewable energy and energy storage build-out. While the IIJA and IRA both provide new incentives for critical transmission lines, the transmission interconnection and planning processes need a major overhaul to resolve long-standing deployment issues.

The Federal Energy Regulatory Commission is actively exploring solutions in its Interconnection Notice of Proposed Rulemaking,[13] and this process could meaningfully address clogged

[iii] This calculation is based on renewable portfolio standard data collected by Lawrence Berkeley National Lab in 2021 and does not include recent legislation passed in Illinois that required utilities to achieve 40 percent clean electricity by 2030 or North Carolina legislation requiring 70 percent electricity emissions reductions from large utilities by 2030. See generally, "Renewable Portfolio Standards Resources," Berkeley Lab Electricity Markets & Policy, https://emp.lbl.gov/projects/renewables-portfolio.

interconnection queues.[14] States can also address interconnection and transmission, both through public utility commission oversight and state energy office planning.[15] For example, states, utilities, and grid operators can study the potential for locating renewables and storage around closing coal plants to use existing interconnection capacity and leverage those investments to bolster local jobs and tax revenues in coal-dependent communities. Utilities, regulators, state agencies, and grid operators can jointly explore grid-enhancing technologies, which can increase grid capacity and be installed much more quickly on the existing transmission system than conventional transmission capacity,[16] including by leveraging IIJA funds.[17]

The NDC Scenario assumes roughly a 30 percent increase in transmission capacity by 2030, as well as total battery storage of nearly 65 GW and roughly 100 GW of demand response by 2030, because of transmission and market policy reform.

Together, the policies outlined above could eliminate unabated coal emissions by 2030, put the power sector on a path to reach 80 percent clean by 2030, and resolve some of the most important barriers to clean energy deployment, aligning U.S. electricity sector decarbonization with the 2030 NDC.

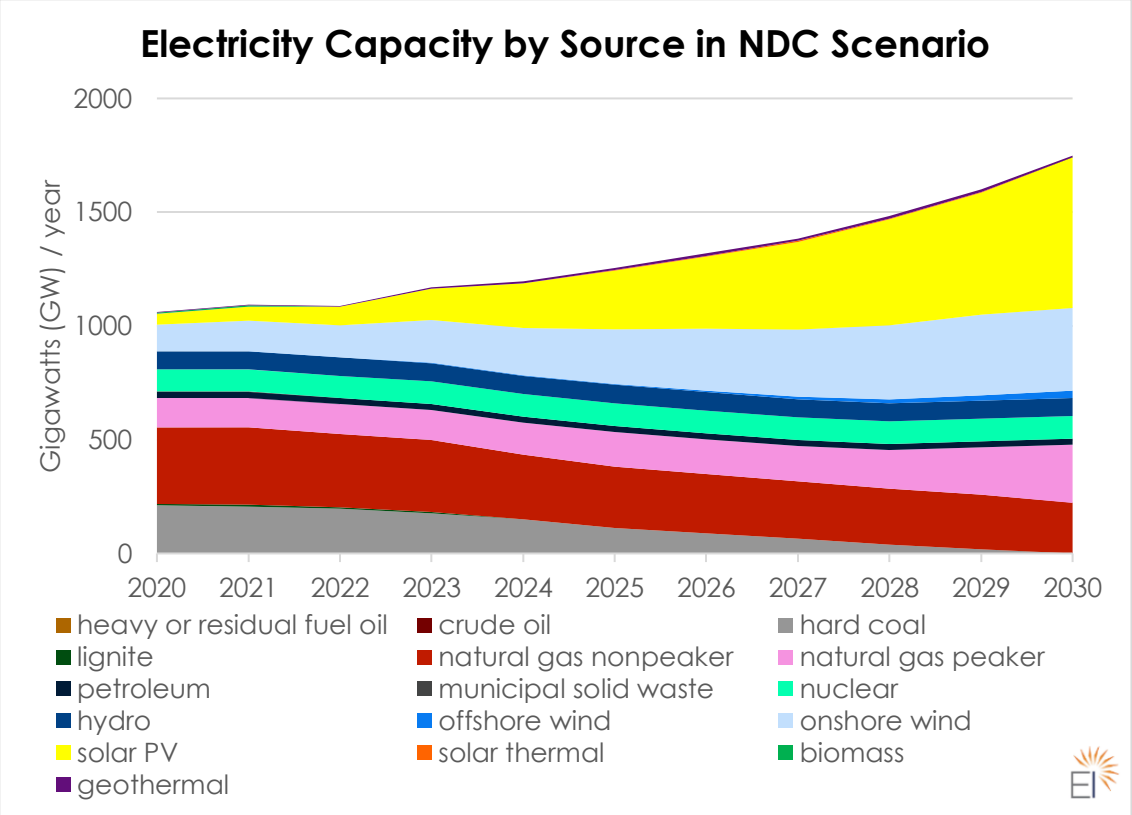

Figure 6: Electricity capacity in the NDC Scenario by plant type

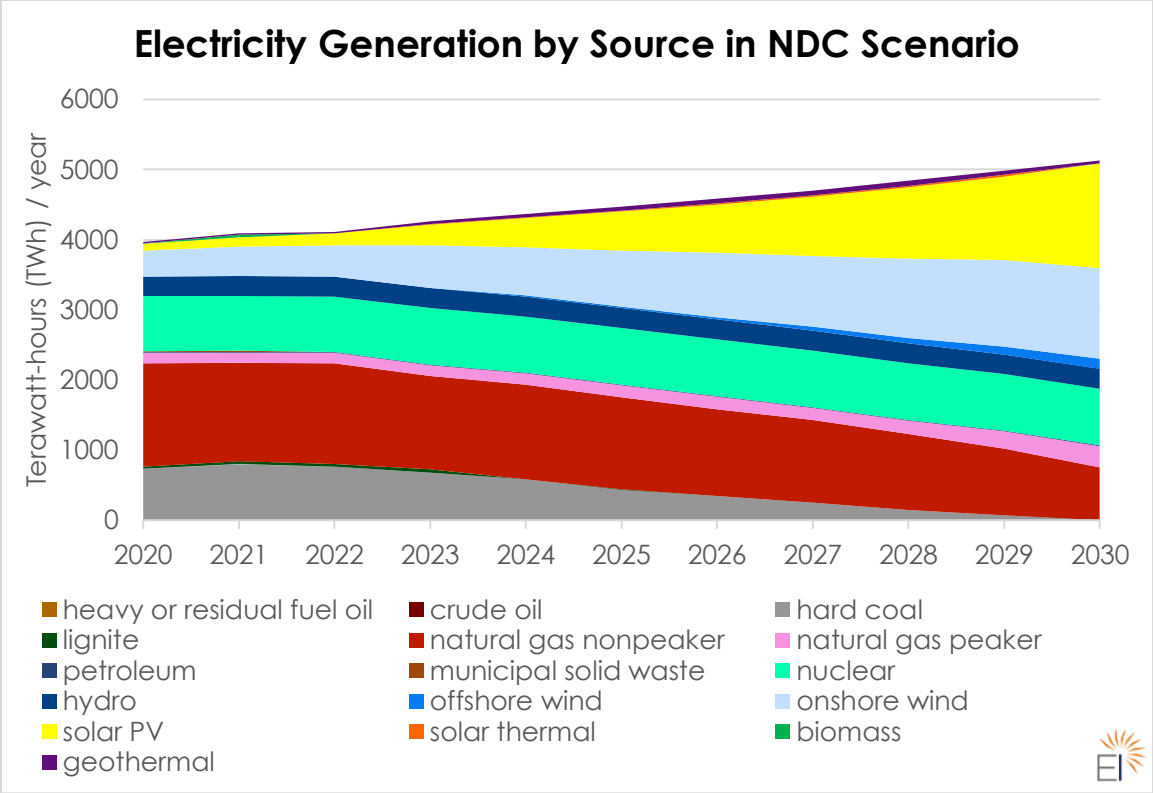

Figure 7: Electricity generation in the NDC Scenario by plant type

INDUSTRY

The industry sector includes all manufacturing activities, construction, and fossil fuel extraction and processing. In 2020, industry directly emitted around 1,660 MMT CO_2e, roughly 30 percent of total U.S. emissions in that year. Given the size of industrial emissions as a share of total U.S. emissions, industry decarbonization is critical to meeting the U.S. NDC target.

Industrial emissions take two forms: energy-related emissions and process emissions. Energy-related emissions come from burning fuels for energy, of which 84 percent is used to provide heat for manufacturing steps such as melting metals and driving chemical reactions. Energy-related GHG emissions are almost exclusively CO_2.

Process emissions are GHGs emitted from industrial activities other than fuel combustion. Examples include breaking down limestone to create cement, methane leaked from oil and gas operations, nitrous oxide (N_2O) formed during the manufacture of nitric and adipic acid, and production and use of fluorinated gases (F-gases) used as refrigerants, propellants, and electrical

insulators, among other things. Energy-related industrial GHG emissions make up 50 percent of total industrial emissions, while process emissions make up the other 50 percent.

The IRA includes provisions targeting industrial emissions, but the law will not significantly lower overall industry sector emissions. Prior Energy Innovation® modeling found that the IRA will only reduce industrial emissions 6 percent by 2030. Reducing industry emissions in line with the NDC will thus require significant additional policy.

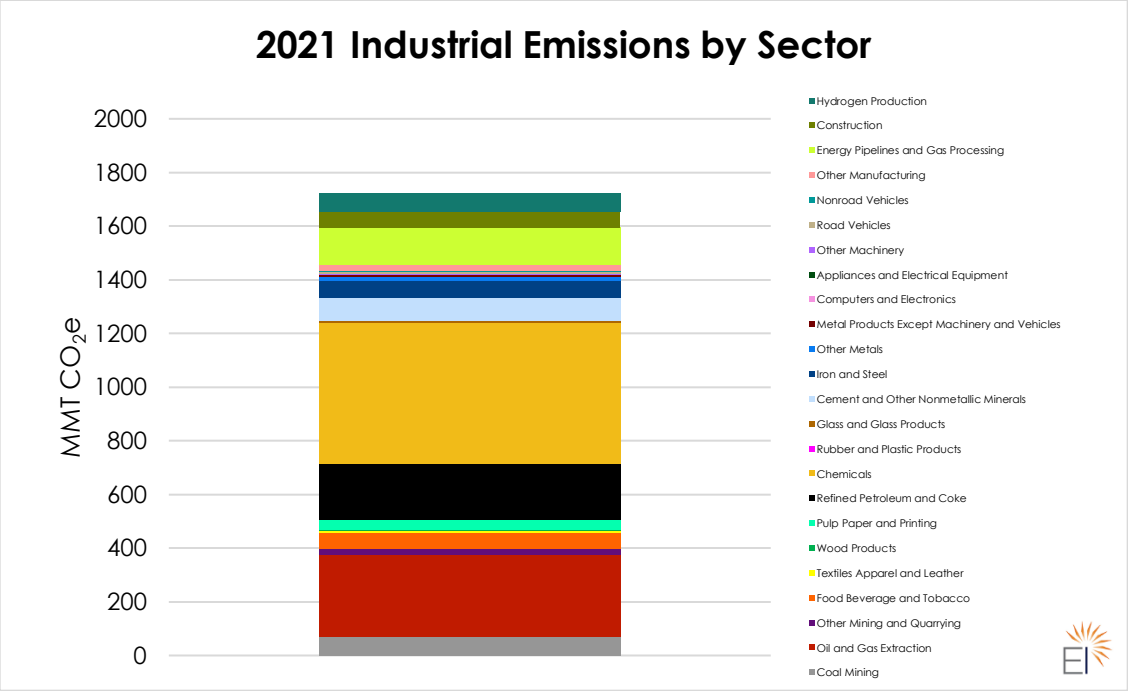

Figure 8: 2021 industrial GHG emissions by sector

IRA Policies Targeting Industrial Emissions

The IRA includes several policies to reduce industrial GHG emissions. Two of these provisions are particularly significant.

Energy Innovation® IRA modeling finds the 45V Clean Hydrogen Production Credit could abate around 45 MMT CO_2e of emissions in 2030. Hydrogen is used extensively in certain industries (such as to produce ammonia for fertilizer and to make other chemicals). In our modeling of the IRA, we assumed that the hydrogen tax credit could result in green hydrogen (i.e., hydrogen produced from electrolysis using 100 percent clean electricity) replacing gray hydrogen (i.e., hydrogen made from steam methane reforming without carbon capture) in these applications but would not create additional demand for hydrogen by 2030.

The 45Q Credit for Carbon Oxide Sequestration provides a generous tax credit for CCS, creating an incentive for industries to capture and store CO_2 underground. Carbon capture projects are capital intensive and take a long time to scale up. Earlier analysis from Energy Innovation® finds industrial CCS projects could abate 95 MMT CO_2 of emissions per year in 2030, inclusive of increased CCS from the IRA.[iv] Our IRA modeling assumes all CCS is within the industrial sector.

Other industry-related IRA provisions include a fee encouraging oil and gas facilities to reduce methane leaks, development of environmental product declarations disclosing the emissions associated with the making of construction materials such as concrete, procurement of low-carbon construction materials in federal buildings and transportation projects, and funding for industrial firms to upgrade to clean technology via changes to the 48C Manufacturing Tax Credit (Section 13501) and the Advanced Industrial Facilities Deployment Program (Section 50161).

Altogether, the IRA reduces industrial emissions by 93 MMT CO_2e in 2030, which is less than what is required to achieve the U.S. NDC. Additional policies can cut industrial emissions to achieve the necessary 2030 reductions.

Additional Policies to Reach the 2030 NDC Target

Stronger Federal Energy Efficiency Standards

Energy efficiency standards already exist for many types of industrial equipment and DOE can set stronger standards to achieve larger energy reductions. Efficiency standards reduce the cost of a transition to clean industry by reducing the quantity of clean energy that must be supplied.

The NDC Scenario includes gradually tightening standards such that industrial equipment uses 4 percent less energy in 2030 per unit of output (steel, glass, etc.), on the path to 14 percent in 2050, based on available industrial efficiency potential data.

Energy efficiency standards are also useful because they can push industry toward electrification, given that electricity is generally more efficient at delivering heat to a material or product being processed compared to combustible fuels. However, DOE's existing efficiency standards are set separately for each fuel type (for instance, different efficiency standards apply to gas-burning versus oil-fired industrial boilers) and are set to be technologically feasible and economically justified for each fuel source.

In the future, standards should be both technology neutral and fuel neutral, so that weak standards for fossil-burning equipment don't undermine the incentive to switch to electrical heating technologies. While DOE appears to be legislatively mandated to establish fuel-specific standards

[iv] The CCS deployment data for earlier IRA modeling are drawn from Rhodium's modeling of the IRA but assume no deployment of direct air capture. For more information, see: https://rhg.com/research/climate-clean-energy-inflation-reduction-act/.

for consumer products under 42 U.S.C. § 6295(q)(1), this limitation does not apply to industrial equipment. DOE should establish fuel- and technology-neutral standards for industrial equipment to reduce emissions.

New Financial Incentives and Emissions Standards for Industrial Heating

Heat creation for industrial processes is the sector's primary emissions source. Not all heat demand is the same, however, with different manufacturing processes requiring different temperatures and methods of heat delivery. To meet the 2030 U.S. NDC and ultimately achieve net-zero emissions by 2050, industrial heat production must be decarbonized.

Today, most low-temperature industrial heat (meaning heat at temperatures up to 165 degrees Celsius) is produced by burning fossil fuels, but this heat could easily and cost effectively be provided by industrial heat pumps. Heat pumps are significantly more efficient than other heating technologies because they move existing heat (like a refrigerator or air conditioner) rather than converting input energy into heat.

Medium- and high-temperature industrial heat must also be decarbonized to achieve the U.S.'s 2050 decarbonization goals. Heat at these temperatures can be provided through electrified technologies such as induction and electric arc furnaces, plasma torches, electric resistance heaters, infrared heaters, and lasers. Where direct electrification is difficult (for instance, in making primary steel), green hydrogen can both provide energy and serve as a chemical reactant. However, decarbonizing these processes can move at a slower pace than for low-temperature heat, where heat pumps provide an excellent, commercially available option.

Financial incentives, efficiency standards, and emissions standards for industrial heating can all help achieve industrial heat decarbonization. Financial incentives could include clean public procurement programs (mandates that publicly funded projects be built with low-carbon materials), grants, and tax credits. Federal or state governments can also include lending mechanisms such as loan loss reserves or loan guarantees to help deploy more capital-intensive equipment. Support for research and development (R&D) is another important financial incentive.

The IRA's $27 billion for national and state-level green banks could be used as additional financial assistance to encourage accelerated adoption of industrial heat pumps. This funding could provide low-cost financing for industry to replace fossil fuel heating with electrified heating.

EPA has authority to set emissions standards under the Clean Air Act and currently regulates industrial emissions of a variety of pollutants through programs such as New Source Performance Standards, National Emissions Standards for Hazardous Air Pollutants, and Control Techniques Guidelines. EPA attempted to establish mandatory CO_2 emissions standards for industry, but this was put on hold following an unfavorable 2014 Supreme Court ruling.

This 2014 ruling and the 2022 *West Virginia* ruling mentioned above seemingly constrain the EPA's powers regarding which facilities are subject to CO_2 regulation and prevent the EPA from requiring fuel switching as the sole compliance option. Still, the EPA may be able to craft industrial GHG standards that comply with these rulings, particularly for non-CO_2 gases such as fugitive methane or process N_2O emissions, where affordable emissions control technologies exist (for instance, thermal or catalytic destruction of N_2O adds very little cost to adipic and nitric acid manufacturing). Furthermore, it remains to be seen how IRA amendments to the Clean Air Act classifying CO_2 as an air pollutant change the EPA's ability to regulate CO_2 from industrial sources. The 45Q tax credit also makes industrial CCS as a compliance option much more financially attractive, offering more compliance options.

To incentivize a shift to electrified heating technologies, EPA would need to establish technology-neutral emissions limitations with a range of compliance options (CCS, hydrogen combustion, direct electrification, etc.), but might ultimately need new legislative authority to overcome the 2014 and 2022 Supreme Court decisions.

In aggregate, the NDC Scenario assumes that a combination of incentives, emissions standards, and efficiency standards can drive industrial heat decarbonization through heat pump adoption, with 29 percent of low-temperature heat electrified by 2030 on the pathway to 100 percent by 2050, but does not include medium- and high-temperature heat decarbonization by 2030.

Stronger Federal Standards on Use of High Global Warming Potential Refrigerants

Stronger standards for high-GWP refrigerants, or fluorinated gases (F-gases), can further lower emissions associated with these gases, which are thousands of times more potent than CO_2. Stronger federal EPA and state standards should require destruction of F-gases formed as a byproduct of other industrial processes, as well as collecting and recycling or destroying F-gases in equipment that has reached its end of life, in addition to further substitution of F-gases with low-GWP alternatives. Some of these measures were agreed to as part of the Kigali Amendment to the Montreal Protocol, along with the American Innovation and Manufacturing Act of 2020 (and are included in the BAU Scenario).

The NDC Scenario implements additional F-gas mitigation measures, reaching the maximum potential identified by the EPA by 2035.

Stronger Federal Fugitive Methane Emissions Standards

Strong fugitive methane emissions standards are required to significantly reduce these emissions by 2030. EPA is currently considering rules for existing oil and gas facilities, and several states, including Colorado and New Mexico have implemented strict standards that will dramatically lower emissions. However, even EPA's latest proposed rules leave additional tons on the table in 2030.

By 2030, the NDC Scenario achieves 100 percent of the potential to capture or destroy fugitive methane emissions, reflecting best practices identified by the EPA and including measures such as proper casing and sealing of oil and gas wells, monitoring and fixing leaks from pipes and machinery, among others.

It is worth noting that EPA's estimate for methane emissions, mitigation measures, and potential has historically been very conservative, so emissions and reductions could be significantly greater.

New Federal Fugitive Nitrous Dioxide Emission Standards

Nitrous oxide is a powerful GHG with a GWP of 298 (using AR4 GWP-100 values). Most N_2O emissions are from the agriculture sector and fossil fuel combustion, however some industrial processes produce N_2O as a byproduct, particularly from producing acids such as nitric acid and adipic acid. Current practice allows for these byproduct gases to be vented to the atmosphere, but EPA or state standards could require combustion of these gases, mostly eliminating them.

The NDC Scenario assumes 28 percent of the potential to destroy these gases from the manufacturing sector by 2030 as identified by EPA, on the way to 100 percent by 2050.

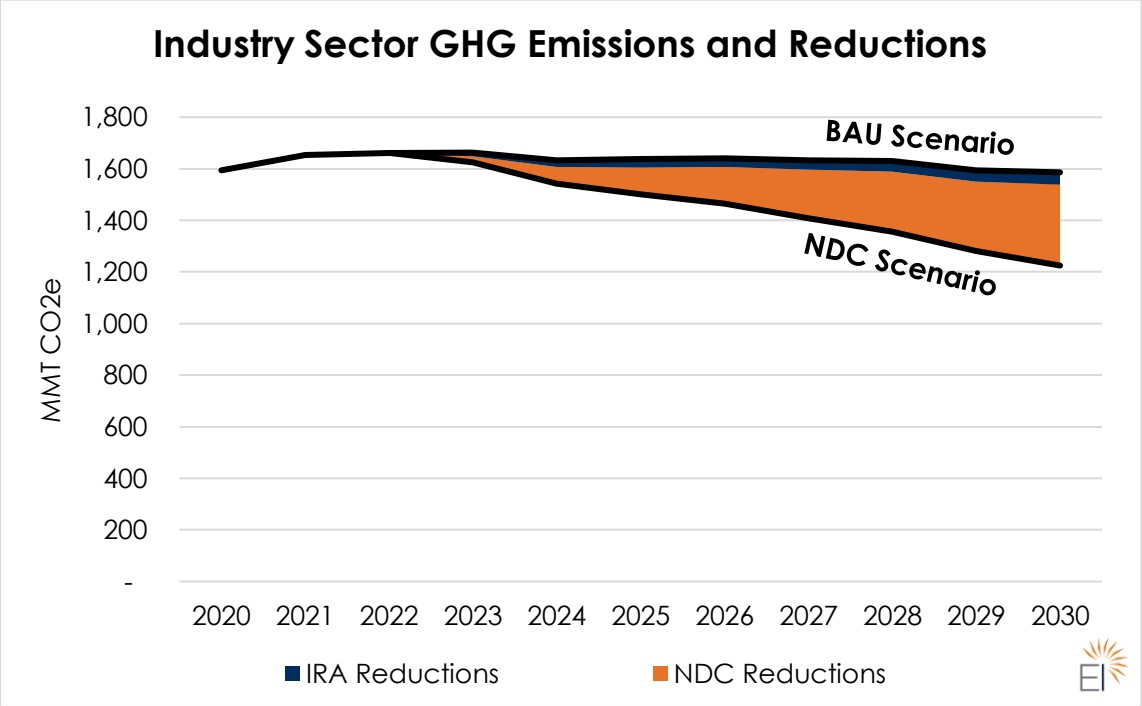

Figure 9: Reductions in industry sector emissions in the IRA and NDC scenarios relative to BAU

TRANSPORTATION

Transportation emissions make up 29 percent of total U.S. GHG emissions or around 1,540 MMT CO_2e. Of this total, roughly 85 to 90 percent is from on-road sources, such as cars, trucks, and buses. In addition to creating GHG emissions, on-road transportation causes harmful air pollution that adversely impacts public health, especially in frontline communities that experience undue pollution burdens.

To achieve net-zero emissions by 2050, all new passenger vehicles and medium- and heavy-duty vehicles must be zero-emissions vehicles (and powered by carbon-free electricity if they are electrified or zero carbon hydrogen if using fuel cells) no later than 2035 and 2045, respectively. This will require concerted efforts to build on and leverage existing policies, as well as state policy leadership, smart utility planning and regulation, and support for private sector investments in vehicles, infrastructure, and the domestic supply chain. By 2030, states should be on a clear trajectory to achieving these sales shares.

While some reduction in non-road emissions will be required by 2050, the technology options are at a much earlier stage of development, so efforts to reduce emissions by 2030 should prioritize on-road emissions. Complementary mobility policies encouraging biking, walking, and alternative transit are important for many reasons, including equity and local air quality, but are not top policies for reaching the NDC because of their comparatively smaller emissions reduction potential and poor success rate to date.

IRA Policies Targeting Transportation Emissions

The IRA includes several policy provisions aimed at encouraging the adoption of zero-emission vehicles (ZEVs), namely BEVs, plug-in hybrid vehicles (PHEVs) and hydrogen fuel cell vehicles (FCEVs), while also encouraging the build-out of a robust charging network and a competitive auto industry.

The IRA modifies and extends the 30D Personal Tax Credits for Clean Passenger Vehicles, a $7,500 tax credit for individuals and households that purchase a qualifying passenger BEV, PHEV, or FCEV. Starting in 2023, it also lifts the 200,000-vehicle-per-manufacturer cap starting, which several EV manufacturers had reached when the IRA was enacted. The details of these changes are explained in previous Energy Innovation® IRA modeling.[18]

The IRA includes a new 45W Commercial EV Tax Credit for commercial vehicles. The incentive amount is the lesser of 30 percent of a vehicle's costs, the incremental cost between a qualifying vehicle and its standard alternative, or $7,500 for smaller vehicles weighing less than 14,000 pounds and $40,000 for vehicles weighing more than 14,000 pounds. With more than 8 million commercial vehicles and trucks in the U.S. today,[19] this incentive will help tip the scale for medium- and heavy-duty EV fleets.

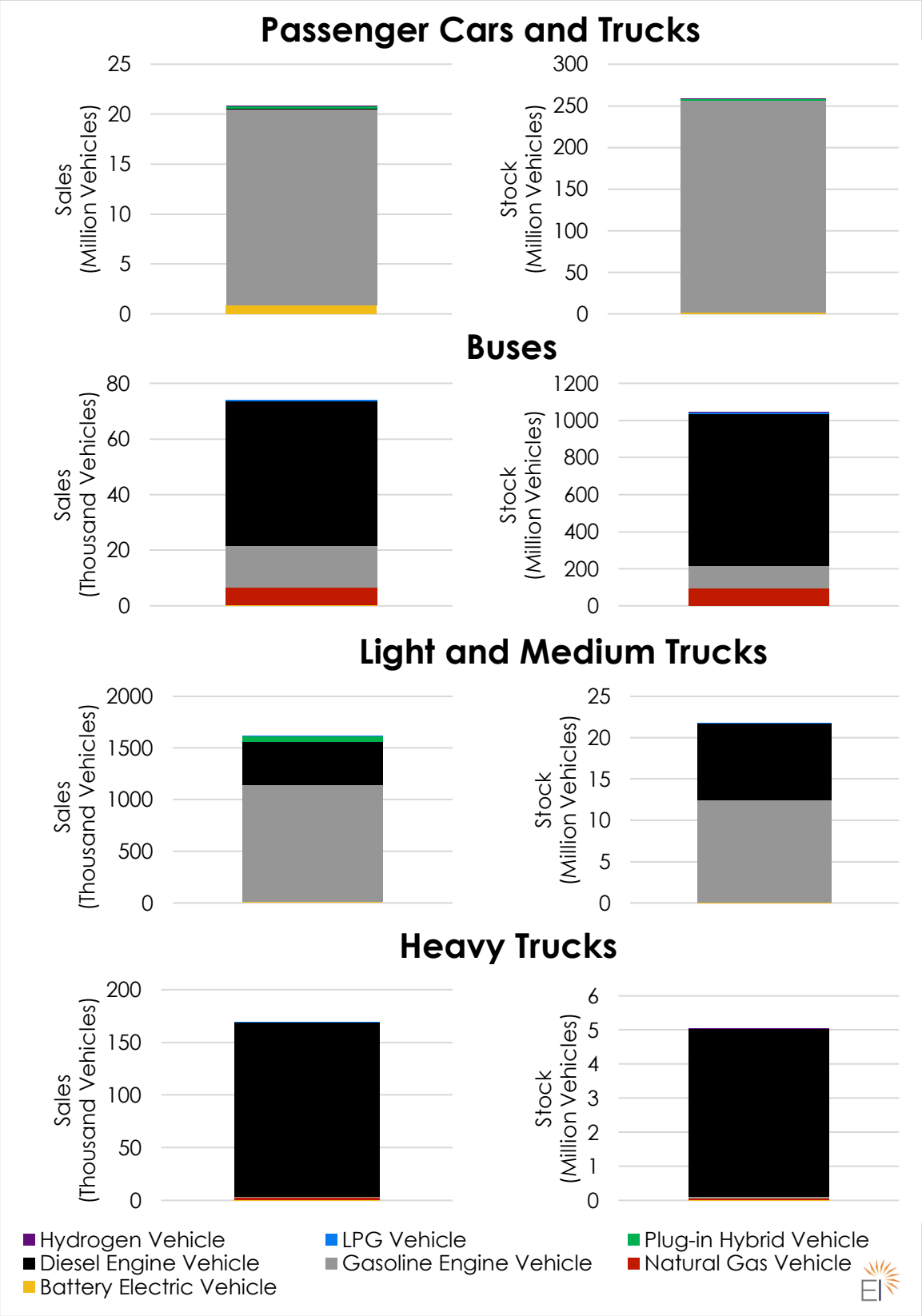

Figure 10: 2021 Sales and stock of on-road vehicles by vehicle and engine type

The IRA also includes transportation infrastructure incentives. It extends the Section 30C Alternative Fuel Refueling Infrastructure tax credit for private investments in qualified clean vehicle infrastructure for 10 years, offering an individual credit of 30 percent of installed costs, up to $1,000 per charger, provided the infrastructure is installed in a qualified census tract.[v] A commercial tax credit of 30 percent, up to $100,000 per charger (raised from the pre-IRA $30,000-per-location cap), will support private investments in a more robust national EV charging infrastructure network, and new eligibility requirements will help target EV charging access in underserved communities.

Finally, the IRA includes several incentives to help the domestic EV auto industry meet new requirements for critical minerals, batteries, and manufacturing. The Advanced Manufacturing Production Tax Credit (45X) creates an output-based tax credit for several technologies, including solar, wind energy, and batteries, as well as critical mineral production. This tax credit will help overcome cost barriers to doing business in the U.S. and encourage onshoring of new EV and battery manufacturing facilities, as well as new critical mineral facilities.

Considerable uncertainty remains over how effective IRA incentives will be for transitioning passenger vehicle stock, given the restrictive design of the incentives. Earlier Energy Innovation® modeling found the IRA could increase plug-in vehicle (BEV + PHEV) sales 1 to 10 percent in 2030. Altogether, IRA transportation sector provisions could reduce emissions between 14 and 28 MMT CO_2e in 2030. Both the sales shares and the emissions reductions are significantly less than what is required to meet the U.S. NDC and put the U.S. on the path to net-zero emissions in 2050.

Additional Policies to Reach the 2030 NDC Target

The IRA's transportation electrification incentives can jumpstart transportation decarbonization but are insufficient to cut the sector's GHG emissions at the pace needed to achieve the U.S. NDC. Mitigating the transportation sector's impact on the climate and public health will require additional policy and regulatory action in the next decade. Several high-impact policies that complement IRA provisions can help the U.S. achieve its NDC targets.

Stronger Federal and State Tailpipe and Fuel Economy Standards

Adopting more stringent tailpipe and fuel economy standards for all vehicle classes will increase the ZEV sales share while reducing emissions from newly sold internal combustion engine vehicles. The Clean Air Act directs EPA to set tailpipe emissions standards for GHGs reflecting "the greatest

[v] As defined in the IRA, where the poverty rate is at least 20 percent, in a non-metropolitan area where median family income is ≤ 80 percent of the statewide median family income, or in a metropolitan area where median family income is ≤ 80 percent of the statewide median family income or metropolitan area median family income.

degree of emission reduction achievable through the application of technology . . . available for the model year to which such standards apply, giving appropriate consideration to cost, energy, and safety factors associated with the application of such technology."[20]

In addition, the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) establishes vehicle fuel economy standards (known as Corporate Average Fuel Economy, or CAFÉ, standards), which set minimum limits on the fuel efficiency of newly sold vehicles.[vi,21] The standards set by EPA and NHTSA apply to all *new* vehicle model years covered by the rules, and they are intentionally harmonized such that meeting a fuel economy standard (miles per gallon) also complies with a GHG standard (grams of CO_2 per mile).

EPA and NHTSA should coordinate to identify the fastest and most cost-effective pathway to achieve 100 percent sales of zero-emission passenger vehicles by 2035 and 100 percent ZEV sales for all other on-road vehicles (including light-, medium-, and heavy-duty trucks and buses) by 2045. This regulatory approach would set a uniform standard across all vehicle classes and provide market "guardrails," allowing competition within those guardrails, which favors least cost-solutions."[22]

As tailpipe CAFE standards tighten, automakers will be pushed to sell an increasing share of compliant ZEVs. This will in turn compel automakers to make major sustained investments in mass production of ZEVs across all models and vehicle classes.

More stringent performance-based standards reduce vehicle costs by capturing economies of scale, accelerating the pace of innovation, and getting more EVs on the road. As costs decline, a more diverse set of drivers in more geographies will be able to access EVs. Performance standards also provide auto manufacturers and their supply chains with a fair planning and a clear rationale for near-term investment.

In addition to strong federal regulations, states should leverage their authority under Clean Air Act Section 177 to adopt more stringent standards for in-state sales that result in 100 percent ZEVs for passenger vehicle sales by 2035 and by 2045 for medium- and heavy-duty truck sales.

State leadership, combined with strong federal standards and incentives, will pave the way for widespread market transformation in the coming decade. In addition to strong standards, state adoption of complementary incentives for vehicles and infrastructure will cut emissions faster than IRA incentives alone.

The NDC Scenario assumes that a combination of federal and state tailpipe and sales standards result in a passenger car and truck ZEV sales share of 62 percent in 2030, on the way to 100 percent

[vi] NHTSA establishes fuel economy standards through authorities provided under the Energy Policy and Conservation Act of 1975, as amended by the Energy Independence and Security Act of 2007, while the EPA establishes CO2 emissions standards under the Clean Air Act, as amended.

by 2035. Commercial trucks reach sales shares in line with the Advanced Clean Trucks rules adopted by multiple states, reaching 33 percent light and medium commercial ZEV sales and 30 percent heavy commercial ZEV truck sales in 2030, respectively.

Charging Infrastructure Investment

Federal agencies, states, and local governments will need to fully leverage financial resources to expand the national EV charging network, including $7.5 billion designated for the charging network in the IIJA, and the low-cost loans and loan guarantees available through DOE's Loan Program Office.

Commercial EVs and fleets will also get a boost from the new IRA incentives, which will expand the still-nascent medium- and heavy-duty EV market. Robust commercial tax credits for EV charging infrastructure (now up to $100,000 per charger) will spur more private investment in DC fast charging to serve commercial vehicles and fleets. Policymakers and state transportation authorities can increase incentive uptake by coordinating outreach to fleet operators, truck drivers, gas station owners, and businesses to make them aware of the commercial EV and charging tax credit, while also inviting their input on local strategies.

States should adopt additional incentives and financing programs for commercial EVs and fast charging that leverage IRA tax credits and further reduce the higher up-front costs of medium- and heavy-duty vehicles (especially for small business owners). Utility regulators should direct their utilities to investigate managed charging and smart EV charging rates that support commercial EV charging in alignment with grid reliability and affordability objectives. State and local governments that own and operate large fleets should lead by example by setting EV purchase requirements and expanding their own charging infrastructure.

States should adopt additional incentives and financing programs for commercial EVs and fast charging that leverage IRA tax credits and further reduce higher up-front costs of medium- and heavy-duty vehicles (especially for small business owners). Electric utilities and regulators should incorporate aggressive forecasts for EVs and charging into ongoing grid planning proceedings, and future investments should support the build-out of adequate transmission and distribution infrastructure and generation capacity to reliably meet electricity demand from these vehicles.

Our modeling represents the lower density of EV chargers relative to gasoline pumps as an increase in the perceived purchase price for EVs, which lowers their uptake. The NDC Scenario doesn't explicitly model additional charger deployment beyond the IRA, but this deployment is necessary to ensure sufficient charging access as the sales share of ZEVs increases.

New Standards on EV Supply Chains

As automakers and supply-chain providers work to meet new requirements for critical minerals and battery components in the IRA, policymakers at all levels of government should minimize any adverse impacts of manufacturing, mining, and processing facilities. New projects will undoubtedly pose conflicts relating to land use, environmental justice, and air quality—all of which must be proactively addressed. Irresponsible mining and manufacturing practices of the past should not be the presumed template for new projects.

Policymakers should proactively include representatives from impacted communities and environmental organizations in the permitting, zoning, and development processes, both to avoid negative impacts and to identify ways to amplify local benefits and expedite remediation. All stakeholders should ensure that this industrial revolution is grounded in principles of environmental justice, equity, and environmental conservation. These pieces are not modeled in the EPS, but they are important policy considerations.

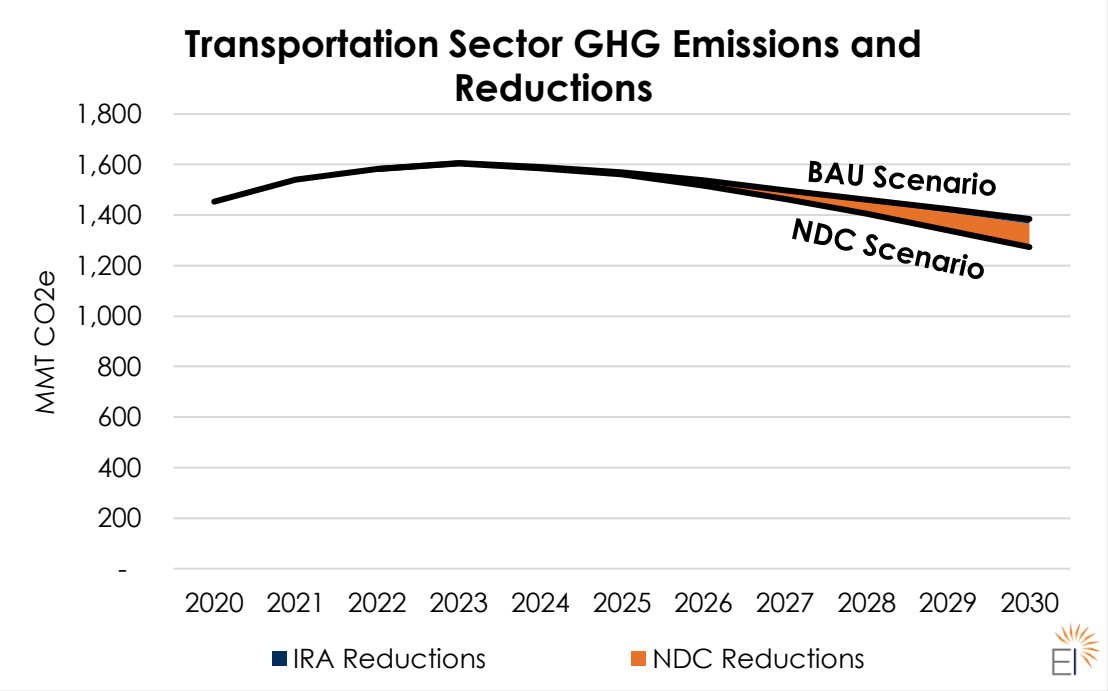

Figure 11: Reductions in transportation sector emissions in the IRA and NDC scenarios relative to BAU

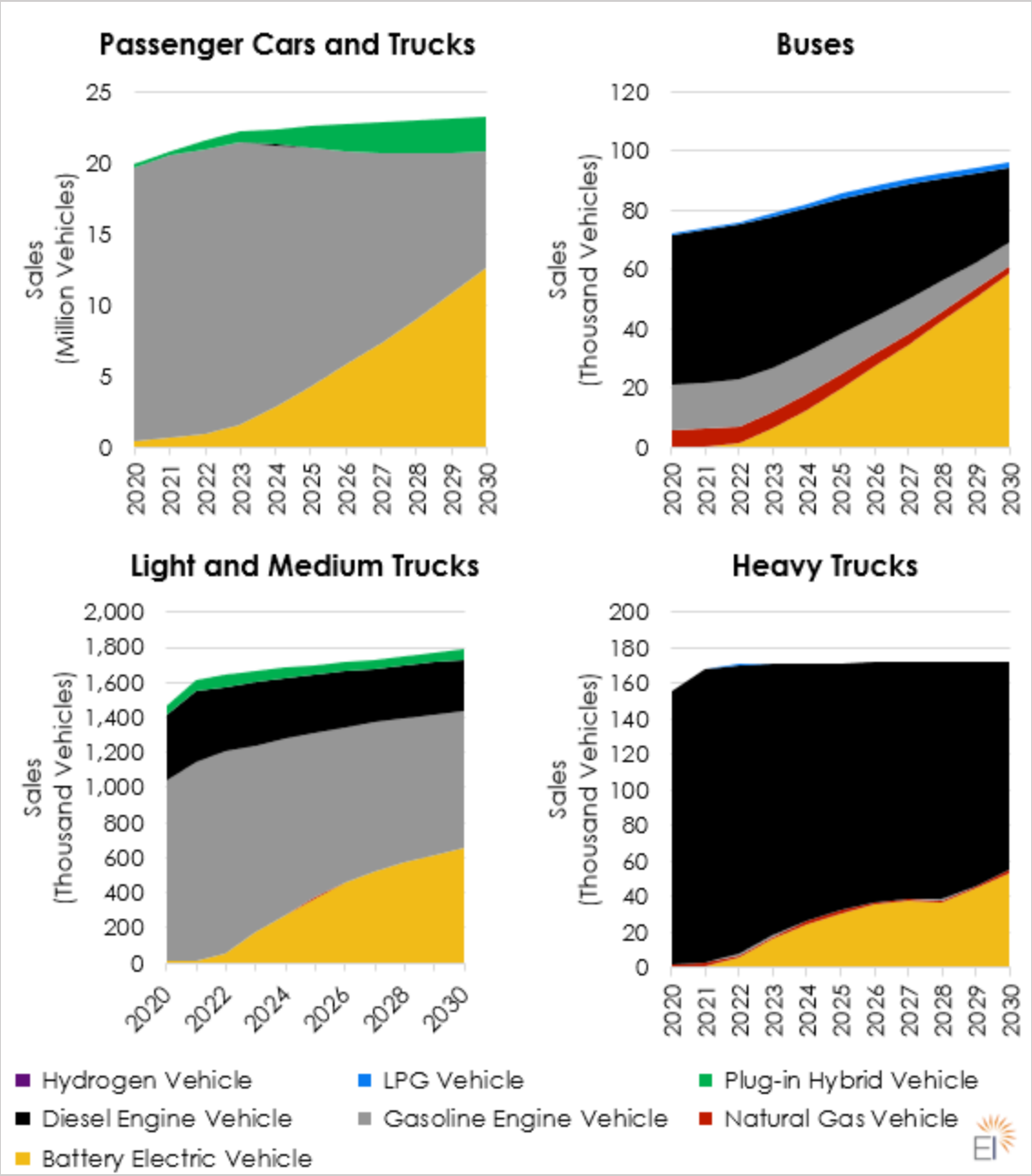

Figure 12: Vehicle sales in the NDC Scenario by vehicle and engine type

BUILDINGS

Homes and buildings account for 10 percent of U.S. GHG emissions, about 560 MMT CO_2e looking at only direct (i.e., onsite) emissions, and burning fossil fuels for space and water heating generates harmful indoor and outdoor air pollutants linked to higher rates of asthma and other negative health impacts. As a significant source of electricity demand, the building sector has large indirect emissions (i.e., emissions to produce electricity used in buildings), amounting to nearly 1,100 MMT CO_2e. Mitigating building sector pollution requires policies targeting the existing building stock (including existing appliances and equipment), as well as new construction, appliances, and equipment.

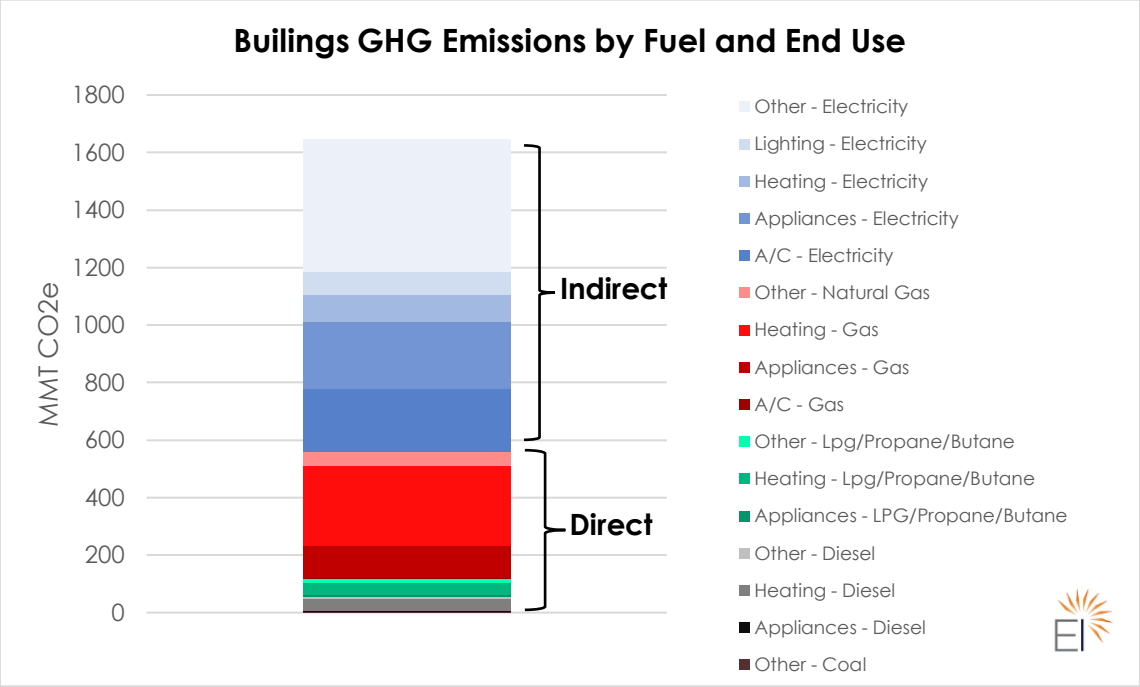

Figure 13: 2021 Building sector direct and indirect GHG emissions by end use and fuel

Policies must be multifaceted to address the unique challenges inherent to different building types; varied ownership and financing scenarios; and the individual realities of occupants, owners, and contractors. Building retrofits and equipment replacement also require upfront capital or financing, which may not be readily accessible to all building owners or occupants. Older buildings may also need other upgrades like updated electrical wiring, insulation, or remediation of safety issues, which can add expenses and time to a project.

The IRA includes a combination of incentives and funding to support an array of building technologies, building types, and income levels. According to earlier Energy Innovation® modeling,

IRA building sector provisions could reduce annual building sector emissions by 5 to 6 percent in 2030 or 32 to 33 MMT CO_2e.[vii,23] These emissions reductions are considerably smaller relative to other sectors due to slow building and appliance stock turnover and incentives amounts and available funding.

Widespread building decarbonization for climate emissions reductions between now and 2050 will require more concerted federal, state, and local action. To achieve the 2030 and 2050 NDC targets, newly sold building equipment must be fully electric by 2035 at the latest. By 2030, sales shares need to be on a trajectory aligned this requirement.

IRA Policies Targeting Building Emissions

The IRA includes tax credits and funding directed toward improving building insulation, equipment efficiency, and electrification of equipment. The key provisions from the IRA are discussed below.

Residential buildings provisions in the IRA provide rebates (such as the HOMES program); tax credits (such as the 25C Energy Efficient Home Improvement Credit); and developer/builder tax credits for individuals, households (including low- and moderate-income households), and multifamily housing owners and occupants to make home efficiency upgrades and replace fossil-fueled appliances with all-electric appliances. Commercial building incentives, such as the 179D Energy Efficient Commercial Buildings Tax Deduction, can encourage energy-saving building construction and appliance installation.

The IRA also includes funding to help states improve building codes' stringency and uptake. In particular, the Assistance for Latest and Zero Building Energy Code Adoption fund provides $1 billion for states (and local governments) to adopt and implement high-efficiency and zero-emissions energy building codes.

In addition to the directed incentives and tax credits outlined above, the IRA includes $27 billion for a federal green bank and pass-through funds for state green banks to mobilize financing and leverage private capital for clean energy and climate projects that reduce GHG emissions. Of these funds, $7 billion will support deployment of zero-emission technologies including distributed renewable energy in low-income and disadvantaged communities, and $20 billion will provide financial and technical assistance for clean energy projects to eligible entities.[24]

While the IRA can jump-start building decarbonization, much more is needed to accelerate electrification and put the building sector on track to meet the 2030 and 2050 U.S. NDC targets.

[vii] We modeled a Low, Moderate, and High scenario compared to Business-As-Usual (BAU). The scenarios reflect different assumptions regarding market uptake and successful implementation of the new policies.

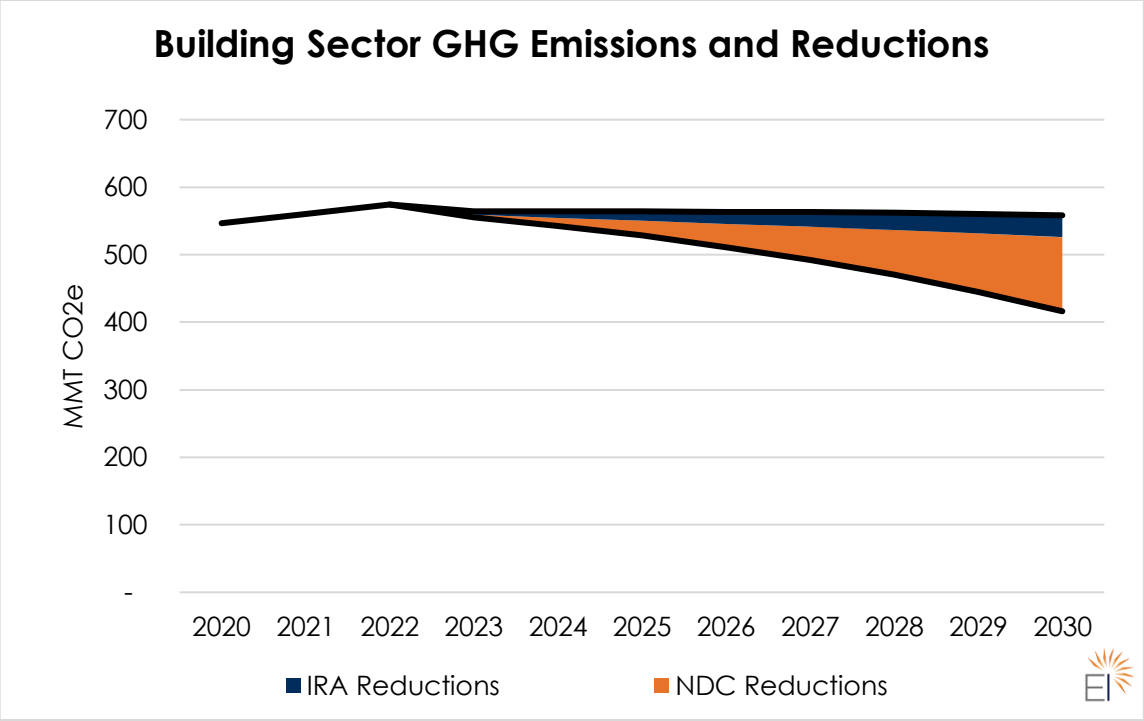

Figure 14: Reductions in Building Sector Emissions in IRA and NDC Scenarios Relative to BAU

Additional Policies to Reach the 2030 NDC Target

The IRA's historic investments will make some progress toward reducing building sector emissions, while also helping more households and businesses save money through increased energy efficiency, building electrification, and deployment of distributed renewable energy and storage. In particular, the IRA's dedicated incentives for low- and moderate-income households and underserved communities will direct the benefits of building decarbonization and weatherization to those with higher energy burdens and inadequate building stock.

Nonetheless, swift implementation and additional policy action at the local, state, and federal levels are needed to scale emissions reductions in line with the NDC. The following actions can help close the gap between the IRA emissions reductions and the 2030 NDC.

New and Stronger Federal and State Appliance Standards

Through a combination of stronger efficiency standards and increased regulation of pollution from appliances, the U.S. should aim to have 100 percent of newly sold building appliances and equipment be all-electric by 2035. Updated appliance standards and regulations that favor all-electric, highly efficient equipment can help reduce the building sector's GHG emissions at the pace

needed to achieve the NDC. Such standards could also alleviate the adverse public health impacts of indoor fossil fuel combustion. Federal agencies should act quickly to mitigate the pollution impacts of fossil-fueled appliances and adopt more rigorous appliance standards.

DOE has overseen appliance energy efficiency standards for decades, but pollution emissions from appliances are not regulated. DOE is also charged with reviewing and updating standards to keep pace with technological change.[25] EPA, which sets U.S. air pollution standards, has the authority to implement regulations to limit harmful emissions from appliances, such as nitrogen oxides, that impact indoor and outdoor air quality.[26] However, adopting new appliance emissions standards is unprecedented and will require a dedicated rulemaking.

The ENERGY STAR label, overseen by EPA and DOE, is another avenue to transition the appliance market towards more energy-efficient, all-electric alternatives. As a trusted government-backed symbol for energy efficiency, the ENERGY STAR label designates products that reduce GHG emissions and other pollutants, making it easy for consumers to choose energy-efficient products that offer energy bill savings.[27] In 2021, EPA suspended the ENERGY STAR Most Efficient for 2022 recognition of certain products that use gas (namely, furnaces, dryers, and boilers) to "help achieve President Biden's 2050 net-zero economy goal, to protect consumer health."[28] As EPA continues updating its baseline ENERGY STAR recognition criteria for all products, it should aim to adopt standards aligning with building sector net-zero emissions reductions goals through efficient, all-electric appliances.

State legislatures should also pass laws requiring certain equipment and appliances sold in the state meet specified energy efficiency or all-electric standards.[29] By setting appliance efficiency standards, states can help consumers and businesses save money while reducing GHG emissions and other pollutants. For example, Washington's new law (HB 1619) sets efficiency standards for six common household appliances, starting in January 2024, and is expected to save consumers and businesses $30 million annually on utility bills beginning in 2025 while reducing CO_2 between 2024 and 2040.[30] States should aim for standards that make all-electric efficient appliances the preferred compliance route over their fossil fuel counterparts.

State, local, and utility incentives for high-efficiency, electric products that complement IRA incentives can further reduce upfront costs and help more U.S. households and businesses electrify their buildings, especially as standards ramp up. Rebates or incentives should be offered at the point of sale, with streamlined approaches to verify eligibility based on income.

New and Stronger State and Local Building Code Adoption and Enforcement

State and local adoption and enforcement of building decarbonization codes, including ordinances requiring all-electric buildings and appliances, can reduce building sector emissions, while improving air quality and building resilience.

State and local governments should take full advantage of IRA building code funding to adopt best-in-class building decarbonization codes for all new residential, multifamily, and commercial buildings (and for major retrofits). The New Buildings Institute's model building decarbonization code provides a template.[31] Building codes or ordinances that require all-electric or electric-ready construction, in combination with energy efficiency, weatherization, and decarbonization measures, are the fastest way to ensure the future building stock is geared toward climate stability.

Many cities have adopted stretch codes and all-electric codes that align new construction with decarbonization and public health goals. States are also leading the way, including Washington, which recently adopted heat pump requirements for residential and commercial new builds, and Illinois, which set a stretch code to accelerate building electrification.[32]

The NDC Scenario assumes federal and state appliance standards, along with state and local building code adoption and enforcement, cause at least 62 percent of newly sold building equipment that would otherwise be fossil fuel powered to be electrified by 2030. It also assumes these policies improve new equipment efficiency ranging from 3 to 11 percent by 2030, depending on end use, and retrofit an additional 4.2 percent of the building stock by 2030.

LAND USE, LAND-USE CHANGE, AND FORESTRY (LULUCF) AND AGRICULTURE

The U.S. has a significant annual land use sink of 760 MMT CO_2e, which helps offset a large portion of the country's GHG emissions.[33] At the same time, the U.S. also has substantial agricultural emissions of around 600 MMT CO_2e, predominantly methane emissions from livestock.[34]

IRA Policies Targeting Land and Agriculture Emissions

The IRA includes many funding programs intended to reduce land and agricultural emissions. These programs primarily provide incentives for farmers to undertake practices that sequester and reduce CO_2 through agriculture conservation investments, conservation technical assistance, funding for forest restoration and fuels reduction, and forest conservation programs. These programs are designed to improve forest management practices, encourage forest restoration and afforestation, and encourage certain farming practices, such as advanced tillage practices. Based on earlier Energy Innovation® modeling, land and agriculture incentives in the IRA could reduce annual GHG emissions by 150 MMT CO_2e per year by 2030.

Given the magnitude of IRA-driven land and agricultural emissions reductions, it is unlikely the U.S. will be able to make further reductions by 2030. We do not model additional agriculture-related emissions reductions in the NDC scenario.

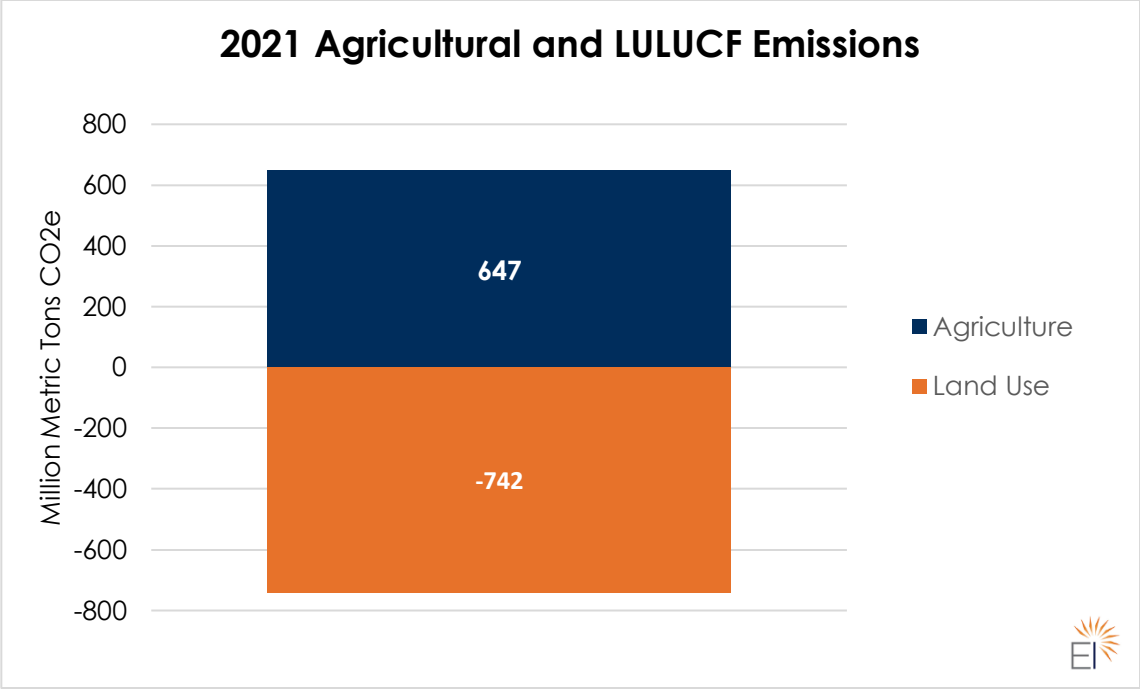

Figure 15: 2021 Agricultural and LULUCF GHG emissions

HEALTH AND ECONOMIC BENEFITS OF ACHIEVING THE 2030 U.S. NDC

The energy and emissions savings and technology investment that result from achieving the 2030 NDC yield considerable health and economic benefits for the public.

Health Benefits

The NDC Scenario expands the health benefits from the IRA Scenario, resulting in an additional 3,900 avoided premature deaths in 2030. These avoided deaths are concentrated in communities of color because polluting infrastructure is often sited in these communities. The NDC Scenario also provides significant morbidity benefits, such as reduced hospital admissions and nonfatal heart attacks. The impact of the NDC Scenario is outlined in Table 2 and Table 3 below.

Scenario	Avoided Premature Mortalities in Year 2030	Percent Change in Deaths by Race - White	Percent Change in Deaths by Race - Black	Percent Change in Deaths by Race - Asian	Percent Change in Deaths by Race – Other Race or Multiple Races
IRA	2,900	-0.09%	-0.11%	-0.12%	-0.17%
NDC	6,800	-0.20%	-0.25%	-0.31%	-0.42%

Table 2: Avoided premature deaths in the IRA and NDC scenarios

Scenario	Avoided Asthma Attacks in Year 2030	Avoided Lost Workdays in Year 2030	Avoided Premature Mortalities in Year 2030	Avoided Respiratory Symptoms and Bronchitis in Year 2030	Avoided Nonfatal Heart Attacks in Year 2030	Avoided Hospital Admissions in Year 2030	Avoided Respiratory ER Visits in Year 2030	Avoided Minor Restricted Activity Days in Year 2030
IRA	77,400	316,200	2,900	116,600	3,300	1,500	1,400	1,844,400
NDC	185,600	760,200	6,800	279,700	7,800	3,600	3,500	4,451,600

Table 3: Avoided morbidity impacts in the IRA and NDC scenarios

Economic Benefits

Achieving the NDC generates enormous near-term economic benefits, including millions of new jobs (on top of the IRA), GDP growth, and household energy savings.

The NDC Scenario yields net job increases in 2030 of nearly 4 million jobs per year relative to BAU and 2.7 million per year relative to the IRA Scenario. Net job gains are concentrated in the construction, manufacturing, services, and wholesale and retail trade sectors.

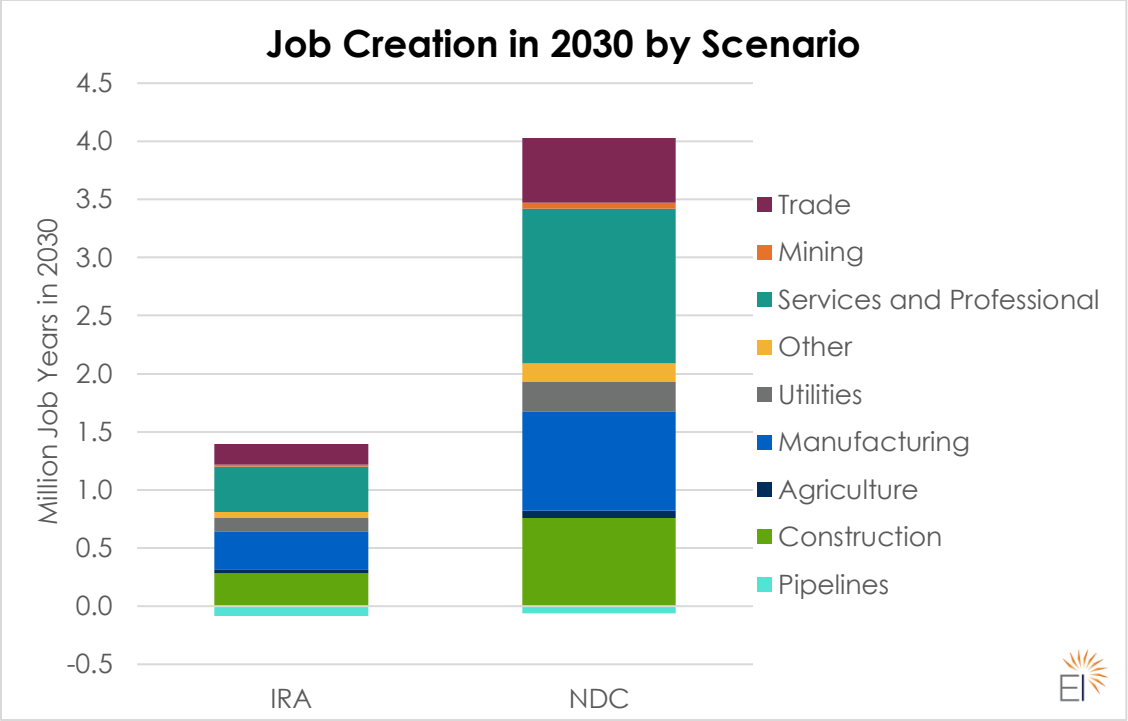

Figure 16: Change in Jobs in 2030 by Industry in IRA and NDC Scenarios

NDC policies also generate significant economic growth. By 2030, GDP increases by 1.7 percent per year relative to the IRA Scenario, or an additional $450 billion per year. Together, the IRA and NDC policies are expected to grow GDP by 2.6 percent per year relative to the BAU Scenario by 2030, or an additional $690 billion per year.

Because the NDC policies shift away from fuel-intensive technologies to capital-intensive technologies, they significantly reduce energy expenditures by 2030. The NDC Scenario would result in estimated household energy savings of $110 per household per year by 2030 based on lower electricity bills and lower spending on gasoline and diesel for transportation, which is $80 per year more in savings than the IRA Scenario.

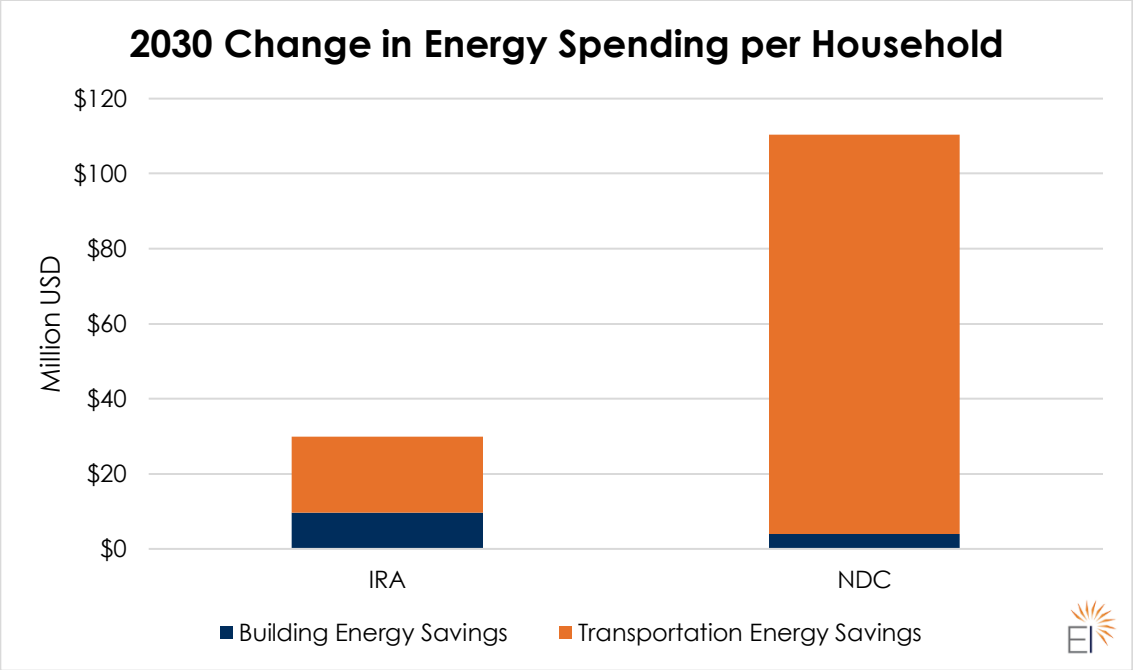

Figure 17: Household energy savings in 2030 by type of saving

Monetized Avoided Damages

By avoiding GHG emissions as well as health damaging pollution, the NDC Scenario would yield significant social benefits. Using the draft updated social cost of carbon released by EPA in November 2022,[35] avoided climate damages from the IRA and NDC scenarios together reach $383 billion per year in 2030, and a cumulative total of $1.7 trillion between 2023 and 2030. And using EPA's value of a statistical life, monetized avoided premature mortality from the IRA and NDC scenarios together reaches $65 billion per year in 2030.

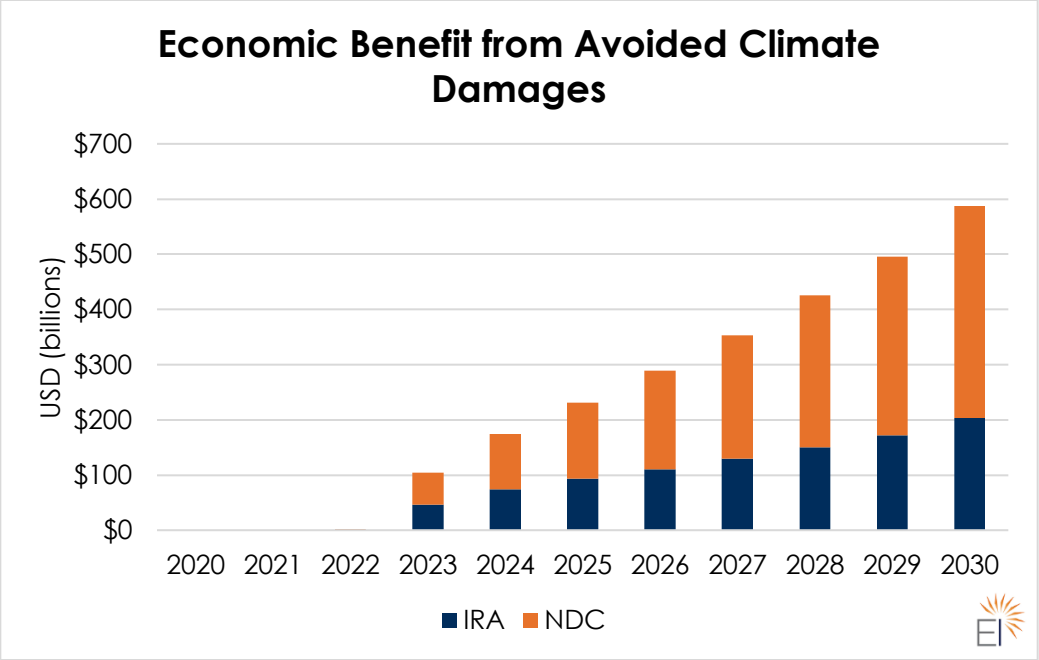

Figure 18: Avoided Climate Damages Using EPA Social Cost of Carbon from November 2022

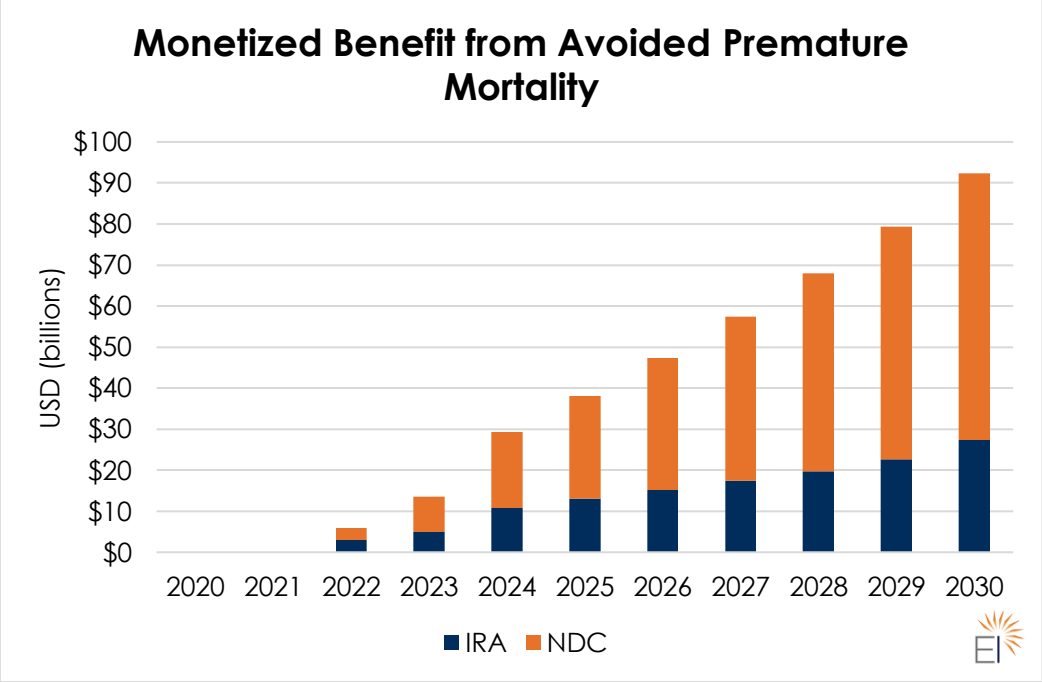

Figure 19: Monetized Avoided Health Damages using EPA's value of a statistical Life

CONCLUSION

The U.S. committed to reducing its GHG emissions to 50 to 52 percent below 2005 levels in 2030. Prior to IRA passage in 2022, the U.S. was on track to reduce emissions to about 25 percent below 2005 levels. With the IRA, emissions are expected to fall to 37 to 43 percent below 2005 levels. This marks significant progress but still leaves the U.S. short of its required 2030 reductions.

While there is more than one policy pathway to close the gap by 2030, the stock turnover characteristics of the major demand sectors and electricity sector's composition suggest the latter must drive the largest reductions in 2030. At the same time, policies to reduce emissions across all sectors of the economy are needed to achieve the NDC, given its stringency.

This report outlines a policy pathway to achieve the NDC, based on our considerations of policy options and feasibility. Where legislation or a regulatory pathway exists, we focus on these approaches to reducing emissions. However, additional federal, state, and local policy will also be required.

In the power sector, policymakers must focus on increasing the share of clean electricity generation to reach 80 percent by 2030. Remaining fossil fuel fleet emissions must be significantly reduced, such as through retiring or retrofitting existing coal plants. At the same time, significant reform is needed to address transmission and interconnection bottlenecks.

The industrial sector must begin to electrify, starting with low-temperature processes where industrial heat pumps already provide a cost-effective and highly efficient low-carbon technology option. Additional regulations are needed to control process emissions, such as F-gases and N_2O. EPA's proposed methane regulations are a good start, but based on the agency's own assessment, still leave significant emissions on the table in 2030.

In transportation, standards that increase the sales share of on-road ZEVs are required, such as the Advanced Clean Cars II and Advanced Clean Trucks rules adopted in California. EPA is actively evaluating the next round of standards for cars and trucks, and the updated rules must align with California rules if the U.S. is to meet both its 2030 NDC and its 2050 target of net-zero emissions.

The vast majority of building sector emissions come from burning natural gas in furnaces, water heaters, and for cooking. To decarbonize buildings, federal incentives and standards as well as state and local standards will need to increase the electrified share of building equipment.

Land and agriculture are important sources of emissions reductions in 2030. However, given the level of expected reductions resulting from the IRA, it is unlikely these sectors can deliver significant additional reductions by 2030. Instead, policymakers should focus on ensuring the IRA successfully delivers emissions reductions in these sectors.

The policies discussed throughout this report not only allow the U.S. to achieve its NDC, but also deliver enormous economic and health benefits in addition to those from the IRA, creating an

additional 2.7 million jobs in 2030, growing GDP by an additional 1.7 percent in 2030, and avoiding an additional 3,900 premature deaths in 2030.

The U.S. has an opportunity to build on the considerable progress made in 2021 and 2022 and close the gap to the 2030 NDC. But it will require additional federal, state, and local policies. This report serves as a roadmap for which policies and standards to prioritize and realizing the enormous benefits that await.

APPENDIX A: GLOBAL TECHNOLOGY COST REDUCTIONS FROM THE IRA

The IRA will yield significant increases in clean energy deployment through its incentives and funding mechanisms. According to earlier research by Energy Innovation®, IRA provisions could increase the 2030 share of clean electricity from 49 percent (pre-IRA) to 72 to 85 percent and add hundreds of GW of solar PV and wind to the U.S. electrical grid.

Clean energy technology costs have historically followed Wright's law, where every doubling of cumulative installed capacity results in a similar percentage decrease in capital costs, typically called a learning rate. Learning rates for clean energy technologies have typically been in the 20 to 30 percent range, meaning each doubling of technology deployment leads to a 20 to 30 percent decrease in per-unit capital costs (e.g., dollar per kilowatt).[36]

Because the IRA is expected to dramatically increase clean electricity deployment, it will likely induce additional learning that lowers domestic and international clean energy capital costs. Using learning rate data from BloombergNEF,[37] projected pre-IRA solar deployment from the International Energy Agency (IEA),[38] and projected pre-IRA onshore and offshore wind deployment from the International Renewable Energy Agency,[39] we estimate the IRA could create global cost declines of 3.8 percent for solar PV, and 2.6 percent for wind technologies by 2030.

While these percentages may seem small, they are significant when applied across the total projected installed capacity of clean electricity technologies. Based on historical spend on solar and projected deployment from the Stated Energy Policy Scenarios of IEA's World Energy Outlook modeling, these cost reductions could yield at least $11 billion per year in savings by 2030, and likely a greater amount, given anticipated growth in clean electricity deployment, amounting to hundreds of billions over the next several decades.

[1] Megan Mahajan et al., "Updated Inflation Reduction Act Modeling Using the Energy Policy Simulator" (Energy Innovation Policy and Technology LLC®, August 2022), https://energyinnovation.org/wp-content/uploads/2022/08/Updated-Inflation-Reduction-Act-Modeling-Using-the-Energy-Policy-Simulator.pdf.
[2] Mahajan et al., "Updated Inflation Reduction Act Modeling Using the Energy Policy Simulator."
[3] U.S. Energy Information Administration, "Monthly Energy Review," tbl. 11.6, accessed December 2, 2022, https://www.eia.gov/totalenergy/data/browser/index.php?tbl=T11.06#/?f=A.
[4] U.S. Energy Information Administration, tbl. 11.6.
[5] See, e.g., https://www.nytimes.com/2022/08/16/opinion/climate-inflation-reduction-act.html. See also https://ieefa.org/resources/carbon-capture-remains-risky-investment-achieving-decarbonisation.
[6] For a list of potential actions the Environmental Protection Agency can take on coal pollution, see: https://www.evergreenaction.com/blog/how-the-epa-can-and-must-reduce-pollution-from-the-power-sector.
[7] Lisa Friedman, "Democrats Designed the Climate Law to Be a Game Changer. Here's How.," *The New York Times*, August 22, 2022, sec. Climate, https://www.nytimes.com/2022/08/22/climate/epa-supreme-court-pollution.html.
[8] https://www.epa.gov/stationary-sources-air-pollution/white-paper-available-and-emerging-technologies-reducing
[9] See generally, comments of NET Power, General Electric, and Southern Company https://www.regulations.gov/docket/EPA-HQ-OAR-2022-0289.
[10] Kathryne Cleary, Karen Palmer, and Kevin Rennert, "Clean Energy Standards" (Resources for the Future, January 2019), https://media.rff.org/documents/CleanEnergy-Issue20Brief_2.pdf.
[11] Dan Esposito and Kimani Jeffrey, "How States and Utilities Can Capitalize on the Biggest Clean Energy Legislation in US History," *Utility Dive*, August 31, 2022, https://www.utilitydive.com/news/states-utilities-inflation-reduction-iraenergy-innovation/630874/.
[12] Walter Musial, Paul Spitsen, Patrick Duffy, and Melina Marquis, et. al. U.S. Department of Energy, "Offshore Wind Market Report: 2022 Edition," https://www.energy.gov/sites/default/files/2022-09/offshore-wind-market-report-2022-v2.pdf.
[13] "Explainer on the Interconnection Notice of Proposed Rulemaking" Federal Energy Regulatory Commission, September 22, 2022, https://www.ferc.gov/explainer-interconnection-notice-proposed-rulemaking.
[14] Joseph Rand et al., "Characteristics of Power Plants Seeking Transmission Interconnection as of the End of 2021" (Lawrence Berkeley National Laboratory, April 2022), https://emp.lbl.gov/sites/default/files/queued_up_2021_04-13-2022.pdf.
[15] Mike O'Boyle, Dan Esposito, and Michelle Solomon. "Implementing the Inflation Reduction Act: A Roadmap for State Electricity Policy," (Energy Innovation Policy and Technology LLC®, October 2022), https://energyinnovation.org/wp-content/uploads/2022/10/Implementing-the-Inflation-Reduction-Act-A-Roadmap-For-State-Policy-1.pdf.
[16] Unlocking the Queue with Grid-Enhancing Technologies. https://watt-transmission.org/wp-content/uploads/2021/02/Brattle__Unlocking-the-Queue-with-Grid-Enhancing-Technologies__Final-Report_Public-Version.pdf90.pdf.
[17] Smartgrid.gov. Recovery Act: Smart Grid Investment Grant Program https://www.smartgrid.gov/recovery_act/overview/smart_grid_investment_grant_program.html.
[18] Sara Baldwin and Robbie Orvis, "Implementing the Inflation Reduction Act: A Roadmap for Federal and State Transportation Policy" (Energy Innovation Policy and Technology LLC®, October 2022), https://energyinnovation.org/wp-content/uploads/2022/11/Implementing-the-Inflation-Reduction-Act-A-Roadmap-For-Federal-And-State-Transportation-Policy.pdf.
[19] "U.S. Automobile and Truck Fleets by Use (Table 1-14)," United States Department of Transportation Bureau of Transportation Statistics, accessed October 12, 2022, https://www.bts.gov/content/us-automobile-and-truck-fleets-use-thousands.
[20] "United States Code Title 30," 1231 Abandoned Mine Reclamation Fund § (n.d.).

[21] OAR US EPA, "Regulations for Greenhouse Gas Emissions from Passenger Cars and Trucks," Other Policies and Guidance, September 9, 2016, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-passenger-cars-and; "Corporate Average Fuel Economy | NHTSA," Text, accessed November 15, 2022, https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.
[22] Hal Harvey, Robbie Orvis, and Jeffrey Rissman, *Designing Climate Solutions: A Policy Guide for Low-Carbon Energy* (Island Press, 2018).
[23] Sara Baldwin and Hadley Tallackson, "Implementing the Inflation Reduction Act: A Roadmap for Federal and State Buildings Policy" (Energy Innovation Policy & Technology LLC®, November 2022), https://energyinnovation.org/publication/implementing-the-inflation-reduction-act-a-roadmap-for-federal-and-state-buildings-policy/.
[24] https://www.epa.gov/inflation-reduction-act/greenhouse-gas-reduction-fund
[25] "National Standards," Appliance Standards Awareness Project, accessed November 29, 2022, https://appliance-standards.org/national.
[26] "Factsheet: Why EPA Must Address Appliance Pollution" (RMI and Sierra Club, June 4, 2021), https://rmi.org/wp-content/uploads/2021/04/rmi_factsheet_appliance_pollution.pdf.
[27] "How a Product Earns the ENERGY STAR Label," ENERGY STAR, accessed November 29, 2022, https://www.energystar.gov/products/how-product-earns-energy-star-label.
[28] "Recognition Criteria for ENERGY STAR Most Efficient 2022" (United States Environmental Protection Agency, Office of Air and Radiation, September 28, 2021), https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Most%20Efficient%202022%20Final%20Criteria%20Memo_0.pdf.
[29] "State Standards," Appliance Standards Awareness Project, accessed November 29, 2022, https://appliance-standards.org/states.
[30] "Washington Adopts New Energy Efficiency Standards; Consumers to Save Millions," Appliance Standards Awareness Project, March 16, 2022, https://appliance-standards.org/document/washington-adopts-new-energy-efficiency-standards-consumers-save-millions.
[31] "Building Decarbonization Code, Version 1.2" (New Buildings Institute, August 2021), https://newbuildings.org/resource/building-decarbonization-code/.
[32] "Cities & States Moving to All-Electric Buildings," Climate Nexus, accessed November 29, 2022, https://gas.climatenexus.org/gas-free-buildings.
[33] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020" (United States Environmental Protection Agency, April 2022), https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf.
[34] "Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2020."
[35] U.S. Environmental Proection Agency, "Supplementary Material for the Regulatory Impact Analysis for the Supplemental Proposed Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," September 2022, https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf.
[36] Rupert Way et al., "Empirically Grounded Technology Forecasts and the Energy Transition," *Joule* 6, no. 9 (September 21, 2022): 2057–82, https://doi.org/10.1016/j.joule.2022.08.009.
[37] Michael Liebreich, "London Summit 2017: Breaking Clean," https://data.bloomberglp.com/professional/sites/24/2017/09/BNEF-Summit-London-2017-Michael-Liebreich-State-of-the-Industry.pdf.
[38] International Energy Agency, "World Energy Outlook 2022," 2022, https://www.oecd-ilibrary.org/content/publication/3a469970-en.
[39] "Global Renewables Outlook: Energy Transformation 2050 (Edition: 2020)" (Abu Dhabi: International Renewable Energy Agency, 2020), https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020.