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A 1.5°C NDC FOR CLIMATE LEADERSHIP BY THE UNITED STATES

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INTRODUCTION

According to the Intergovernmental Panel on Climate Change (IPCC), we must limit warming to no more than 1.5 degrees Celsius by 2100 to avoid catastrophic climate change impacts.[1] This requires deep greenhouse gas (GHG) emissions reductions, dropping to net zero by or before 2050 and at least a 50 percent reduction in GHG emissions in 2030 relative to 2005 levels—a climate goal the forthcoming U.S. Nationally Determined Contribution (NDC) under the Paris Climate Agreement is likely to target. Achieving such reductions requires immediate changes in how we power our economy and necessitates a transition from fossil fuel-based technologies to low- or zero-carbon technologies across the electricity, transportation, buildings and industrial sectors.

The costs of many zero-carbon technologies, including highly-efficient electric appliances and equipment, have fallen dramatically in the last ten years—making this transition possible and affordable. Since 2009, solar photovoltaic panel costs have dropped 90 percent,[2] wind turbine costs 71 percent,[3] and LED light bulbs 80 percent.[4] Meanwhile, batteries—which are now powering our vehicles and will increasingly support greater renewables integration—have fallen 80 percent in cost since 2013.[5] Because these declines will continue, today's technology and anticipated improvements mean the United States has the tools necessary to deeply decarbonize our economy while spurring massive job creation to deploy new clean energy resources.

But this transition will not happen on its own, and certainly not on the timeline outlined by the IPCC, without additional policy. Only well-designed policies can drive this technological transformation at the required pace. The good news is that decades of experience in climate and energy policy have established a deep understanding of which policies can deliver emissions reductions and show us the path forward.

New research using the U.S. Energy Policy Simulator, an open-source and non-partisan computer model developed by Energy Innovation, models a policy scenario for the United States that would accomplish a 50 percent reduction in 2030 GHGs relative to 2005.[i] This state-of-the-art modeling tool shows that a comparatively small group of policies can drive the U.S. economy toward net-zero emissions by 2050 and achieve the emissions reductions in 2030 required for a 1.5°C trajectory. Transforming the built economy also generates huge benefits. The modeling shows it could increase U.S. gross domestic product by $570 billion per year in 2030 and $920 billion in 2050 (a 2.4 percent annual GDP expansion), create more than 3.2 million new job-years by 2030 and nearly 5 million new job-years by 2050,[ii] avoid more than 45,000 premature deaths and 1.3 million asthma attacks annually by 2050, and would build an economy powered primarily by renewable energy that is insulated from fossil fuel-price volatility.

But we have no time to waste. Immediate action is required to achieve interim requirements and ensure sufficient time to replace existing fossil fuel-based equipment with zero-carbon alternatives. This paper outlines a path forward.

STEEP, IMMEDIATE REDUCTIONS REQUIRED TO LIMIT WARMING TO 1.5°C

Achieving the IPCC targets for 1.5 degrees requires cutting global carbon dioxide (CO_2) emissions roughly in half by 2030 and approaching zero by 2050. Non-CO_2 GHGs must follow a similar trajectory, with some additional time to reach net zero. While the exact percentage of emissions reductions is undefined, the IPCC has suggested that without heavy reliance on CO_2 removal technology—which does not yet exist at scale—a global decrease in GHG emissions of 34-47 percent in 2030 and 79-92 percent in 2050 relative to 2005 levels is required, with developed nations at the upper end of those ranges or even beyond them.[6,7]

Cutting emissions in line with these goals requires replacing most fossil fuel consumption with clean alternatives. By 2050, nearly all energy demand must be met with zero-carbon fuels, particularly in the buildings, electricity, industry, and on-road transportation sectors. Agricultural emissions, which account for about 10 percent of net GHG emissions, must be cut as well. CO_2 uptake from land use, land-use change, and forestry practices (LULUCF) can offset some remaining agricultural, fossil fuel, and industrial process emissions, but LULUCF mitigation potential in the United States appears modest based on existing analysis.

Interim goals, like a 2030 NDC of a 50 percent reduction in emissions, are necessary to a 1.5°C pathway because they will determine cumulative GHG emissions between now and 2050, which is ultimately what matters for climate stability. Immediate cuts are required to hit 2030 targets roughly consistent with halving emissions in the next ten years. The U.S. has already made enormous progress in the electricity sector and multiple studies indicate it can cut emissions at least 80% by 2030 by phasing out the remaining coal and cutting gas use in half. For the transportation and building sector the opportunities focus on phasing out the sale of fossil-fuel

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i This research note updated a version release in February 2021 to incorporate newer data and assumptions using EPS version 3.2.0. The Feb. note can be found here: https://energyinnovation.org/wp-content/uploads/2021/02/A-1.5-C-Pathway-to-Climate-Leadership-for-The-United-States.pdf

ii A job year defined as one year of work for one person, for instance a new construction job that lasts five years is equal to five job-years. This is a more accurate measure than "job" because one job may last for five months or five years.

fueled boilers and engines and requiring 100% clean vehicles and clean appliances between 2030 and 2035. For the industrial sector there are immediate opportunities to cut the use of fossil fuels through efficiency upgrades and electrification of low- and medium-heat processes.

Major emitting regions and businesses have already committed to steep emissions cuts with interim targets, and the United States should follow suit. In December 2020 the European Union committed to cut emissions 55 percent by 2030 relative to 1990 levels, in line with the reductions needed for a 1.5°C pathway.[8] There are large public and private utilities in the US that have committed to cut their emissions at least 80 percent by 2030 from 2005 levels, including Tri-State Coop in the Rocky Mountain West, and NIPSCO in Indiana. A major coalition of U.S. businesses recently urged the Administration to adopt at least a 50% reduction by 2030.

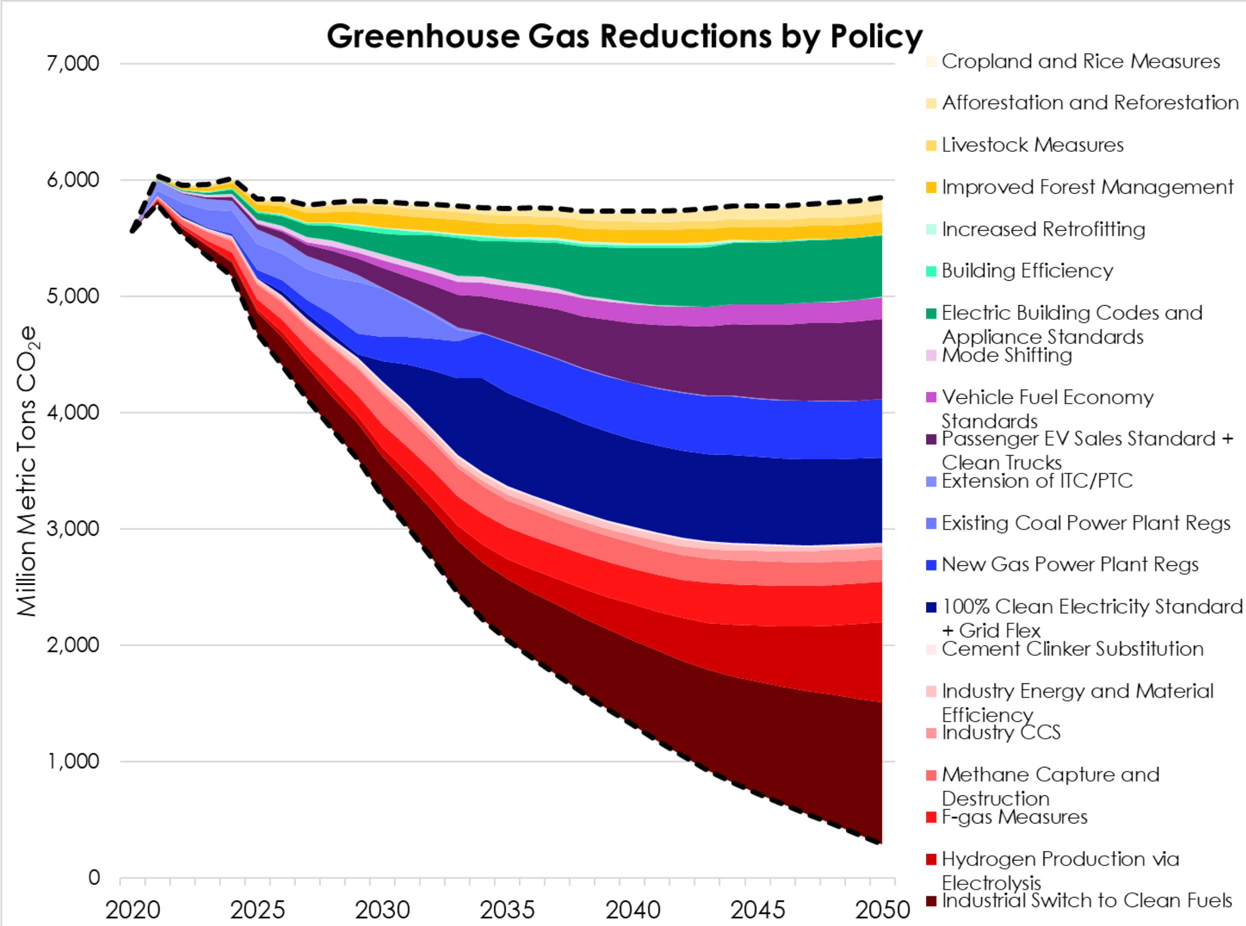
A 1.5°C POLICY PATHWAY FOR THE UNITED STATES

We used the U.S. Energy Policy Simulator to model a 1.5°C Scenario, identifying policies across all economic sectors to achieve the IPCC's recommended GHG reductions. The 1.5°C Scenario cuts CO_2 emissions 60 percent and total GHG emissions 50 percent in 2030, and 109 percent and 90 percent in 2050, relative to 2005 levels.

Year	Gases	IPCC Global Required Reductions (versus 2005)	EPS U.S. Reductions (versus 2005)
2030	CO_2	40-53%	60%
	GHG	45-46%	50%
2050	CO_2	92-94%	109%
	GHG	81-88%	90%

Table 1: Emissions Reductions in 1.5°C Scenario Relative to IPCC Required Reductions

The wedge graph below shows U.S. emissions under business-as-usual and in the 1.5°C Scenario, including how much each specific policy within the 1.5°C Scenario reduces emissions through 2050. Policies are color-coded by sector with industrial policies in red, electricity policies in blue, transportation policies in purple, building policies in green, LULUCF policies in yellow, and agricultural policies in orange. The analysis finds that while policies are needed across all sectors of the economy, a handful can achieve most required reductions.



TOP EMISSIONS REDUCTION POLICIES

Clean Electricity Standard

One of the most important immediate policies needed to reduce U.S. emissions is a strong clean electricity standard (CES), coupled with grid flexibility policies like expanded transmission and deployment of storage and demand response. A CES which requires at least 80 percent clean electricity in 2030 and 100 percent in 2035, would be a linchpin of economywide decarbonization because it unlocks massive zero-emissions opportunities in other sectors, such as electric vehicles and electric heatpumps for space and water heating. Other policy drivers to decarbonize the electricity sector include adopting regulations that require the existing coal fleet to install readily-available modern pollution controls, and requiring new gas plants install carbon capture and storage, just as required for new coal plants.

Three separate and detailed grid modeling studies released in 2020 by the University of California, Berkeley,[9] Princeton University,[10] and Vibrant Clean Energy[11] demonstrated that a deeply decarbonized grid (90 percent or more) can be both reliable and affordable. Each study found that transitioning away from coal and gas does not negatively impact cost or reliability. Coal is often the most expensive power in the market, so replacing coal plants with clean energy generates substantial cost savings. In fact, more than 90 percent of existing U.S. coal-fired power can be replaced by local wind and solar while generating customer savings.[iii] Although not all of these studies looked at decarbonizing the last 10 percent of the grid, more than a decade remains until that level of grid decarbonization is required, giving engineers and researchers ample time to develop solutions for that increment.[iv]

Industrial Switching to Zero-Carbon Fuels and Green Hydrogen

Another important policy to reduce emissions is moving away from industrial fossil fuel use toward alternatives such as clean electricity and possibly hydrogen. If hydrogen ends up providing a major share of industrial fuel use, that hydrogen must be produced from electrolysis (i.e., green hydrogen) to avoid a large emissions increase. Industrial fuel switching could be achieved through a variety of policies including air pollution or equipment standards, carbon pricing on industrial fuels, or industrial carbon caps. Any policy combination, however, must push industry toward zero-emission alternatives away from fossil fuels, then eliminate remaining emissions.

Zero-Emission Vehicle Standards

Zero-emission vehicle (ZEV) standards, which require all new sales of cars, trucks, and buses to be zero-emission no later than 2035 (cars and buses) or 2045 (trucks), are another key policy. These standards start the process of converting the bus and truck fleet to zero-carbon technologies, while allowing time for those technologies to develop.

A ZEV standard could be achieved several different ways. One option would be strengthening existing tailpipe standards to a standard of zero CO_2 grams per mile in 2035, effectively requiring all new passenger car sales to be ZEV by 2035. Another option would be separately instituting a sales standard requiring a minimum share of vehicles sold each year to be ZEVs, then steadily ramping that requirement up to 100 percent by 2035. The latter option is similar to the approach taken by California and several other states, while the former is more aligned with existing federal policy.

Electrified Building Standards

Electrifying all existing and new buildings is another top economywide decarbonization policy. Most of the U.S. building stock that will exist in 2050 is already built today, which means existing fossil fuel equipment in buildings must be replaced with electrified alternatives. This means replacing fossil fuel-powered space heating, water heating, and cooking equipment with electric alternatives such as air source heat pumps, and electric or induction cookstoves. Considering appliances can last up to 20 years, all new equipment must be electric by 2030 to ensure an all-electric building stock by 2050.

[iii] As-yet unpublished Energy Innovation analysis—can be made available on request.

[iv] Previous Energy Innovation analysis explains five possible technological pathways for cost-effectively meeting 100 percent clean electricity by 2035. See: Phadke, A., Aggarwal, S., O'Boyle, M., Gimon, E., Abhyankar, N. 2020, "Illustrative Pathways To 100 Percent Zero Carbon Power By 2035. *Energy Innovation*. https://energyinnovation.org/wp-content/uploads/2020/09/Pathways-to-100-Zero-Carbon-Power-by-2035-Without-Increasing-Customer-Costs.pdf

Various policy mechanisms can achieve this sales standard, such as using existing regulatory authority to limit pollutant emissions from new equipment and setting efficiency standards that drive new equipment sales. Upgraded building codes could require new buildings to be electric, and over forty U.S. cities have already phased out the use of gas appliance in new buildings.[v]

Eliminating Coal Emissions

Eliminating coal power plant emissions is a critical component in achieving the 2030 emissions reduction target. Our analysis finds that without eliminating coal emissions by 2030, achieving U.S. emissions reductions in line with a 50 percent reduction is impossible. Studies range in estimates of how much coal retirement is expected without additional policy, with some modeling finding low gas and renewables prices driving faster retirements, while other models factor in current utility practices of running uneconomic coal and forestalling retirement. In either case, policy will be needed to ensure coal plants are no longer emitting in 2030.

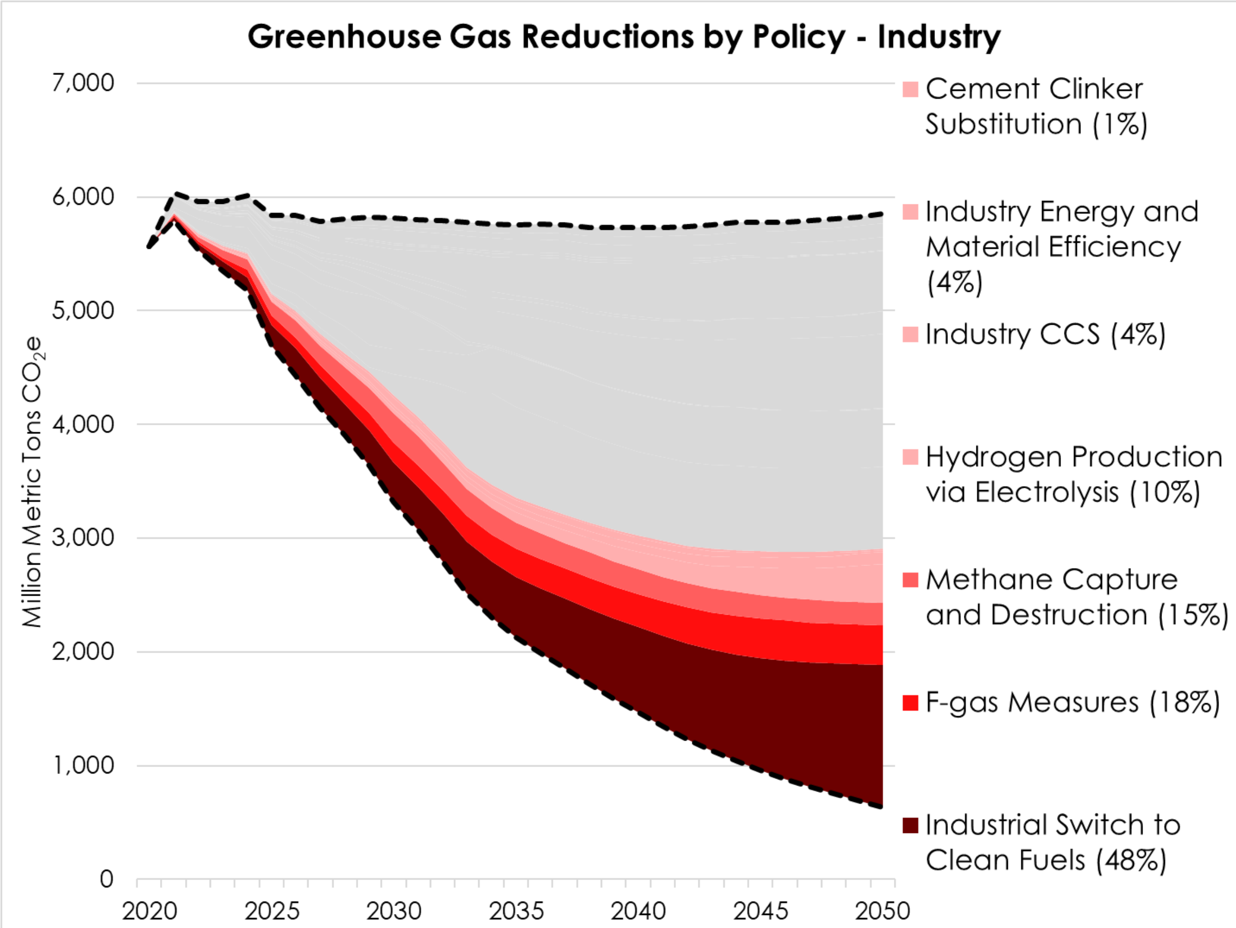
Policy could take a variety of forms, including federal regulations on coal plant emissions (both GHG and conventional pollutants), a sufficient power sector carbon price, and a robust state utility resource planning process. Our modeling assumes a combination of these policies will retire the coal fleet by 2030. Another pathway would be retrofitting existing coal plants with carbon capture, but this is prohibitively expensive at both current and future projected costs.

INDUSTRY SECTOR POLICIES

In the industry sector, which encompasses manufacturing and energy production except for electricity, standards can drive substitution of all fossil fuels with a mix of zero-carbon fuels including electricity and hydrogen. Similarly, we modeled standards ensuring all new hydrogen is produced via electrolysis by 2050. Today, nearly 95 percent of hydrogen is produced via carbon-intensive methane reforming. New and strengthened leakage regulations can significantly reduce methane emissions, with full implementation of these policies achieved by 2030. We also modeled new standards to cut emissions of fluorinated gases (F-gases), which are used primarily as refrigerants in cooling systems, and which have high global warming potential, in line with the Kigali Amendment to the Montreal Protocol.[vi] We also modeled additional reductions through measures like F-gas recovery, reclamation, and recycling.

[v] Some examples include California, Cambridge, MA, Scotland, U.K., and the European Union.

[vi] Congress authorized these reductions in the December 2020 spending bill, strengthening EPA's authority to achieve these reductions. In the past, the EPA has set limits on F-gas consumption and emissions through the Significant New Alternatives Policy (SNAP) program. Bill Pascrell, "Further Consolidated Appropriations Act, 2020," Pub. L. No. 116–94 (2020), https://www.congress.gov/bill/116th-congress/house-bill/1865/text.

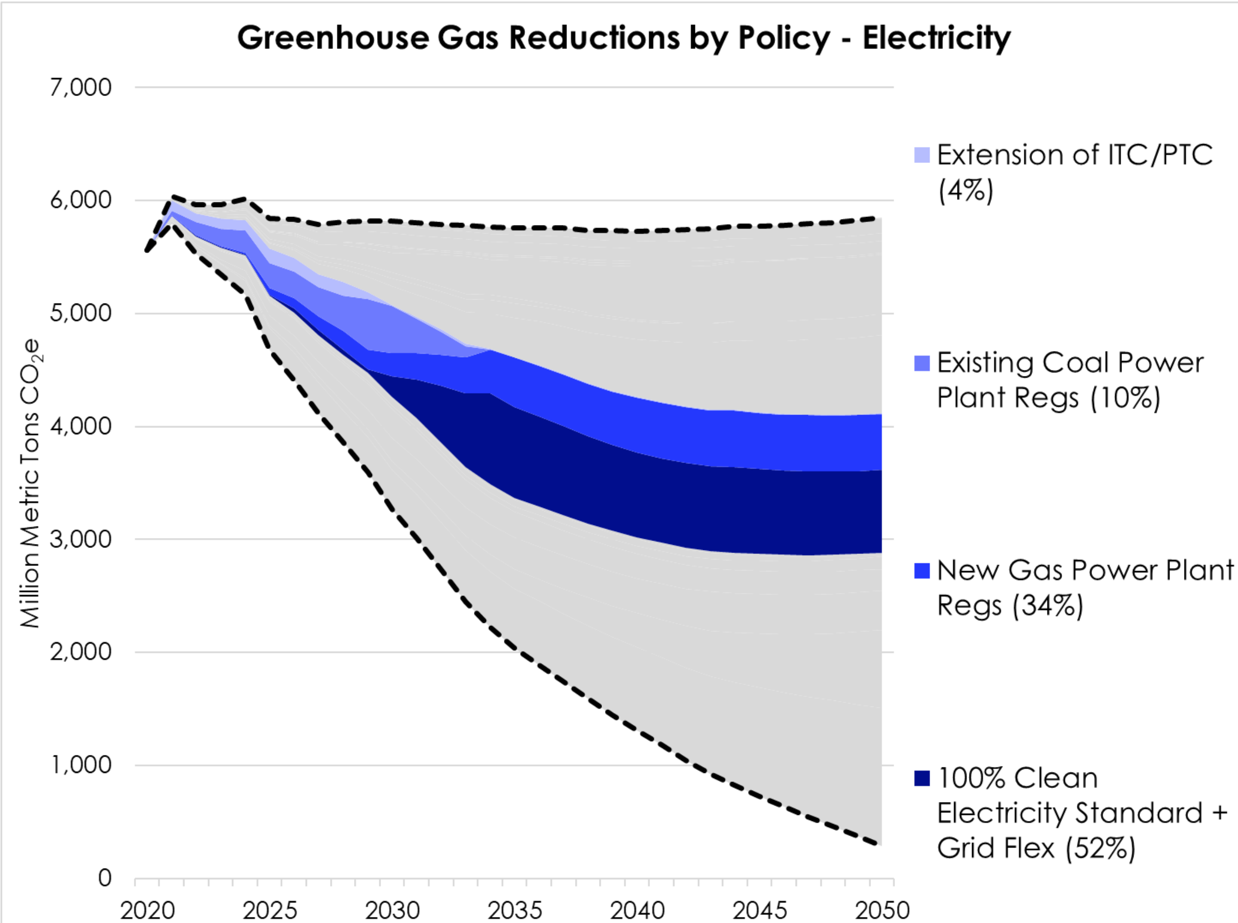


For remaining industrial process CO_2 emissions in the chemicals, cement, and iron and steel industries in 2050 (emissions not from energy combustion), we assume half of these emissions are captured and sequestered using carbon capture, utilization, and sequestration technology. We also include industrial energy efficiency policies that cut energy demand 14 percent by 2050, roughly doubling the projected business-as-usual rate of efficiency improvement. While these measures have little CO_2 impact when implemented alongside a switch to zero-carbon fuels, they are key to lowering industry-sector transition costs because they avoid the need to build additional electricity and hydrogen infrastructure. Finally, we included policies requiring an increase in the use of clinker substitutes in the cement sector and improved material efficiency, which reduce the need for new industrial commodities such as cement, iron, and steel. Like energy efficiency standards, these are key components of industry-sector decarbonization because they reduce demand for new zero-carbon infrastructure.

ELECTRICITY SECTOR POLICIES

In the electricity sector, a clean electricity standard (CES) of 80 percent by 2030 and 100 percent by 2035, coupled with policies supportive of deploying more batteries, demand response, and transmission, is the key to decarbonizing the entire economy. In the 1.5°C Scenario, most sectors rely on electrification to decarbonize, and the CES ensures this new electricity demand is met with zero-carbon electricity. However, the U.S. must eliminate coal electricity generation by

2030 to achieve the IPCC's 2030 targets. The 1.5°C Scenario assumes that a mix of standards will stop coal generation by 2030.



Cutting electricity emissions in line with a 1.5°C target also requires not building any new gas plants that lack carbon capture. The United States already has a massive oversupply of gas plants, many of which are likely to become stranded assets, and no reason exists to build more

The Role for Tax Credits

Tax credits, such as the Production Tax Credit (PTC) and Investment Tax Credit (ITC) can play an important role in increasing deployment of clean energy and lowering the costs of the transition. Tax credit extensions appear small in our modeling in part because they are working alongside other power sector policies. But on their own, tax credits would help significantly decarbonize the power sector. Our modeling suggests that a 10-year extension of existing tax credits, conversion to direct payment, and a new nuclear retention tax credit preventing additional market-based nuclear retirements would add an additional 60 GW of solar and 45 GW of wind by 2030 on top of BAU and cut power sector emissions by an additional 13 percent in 2030.

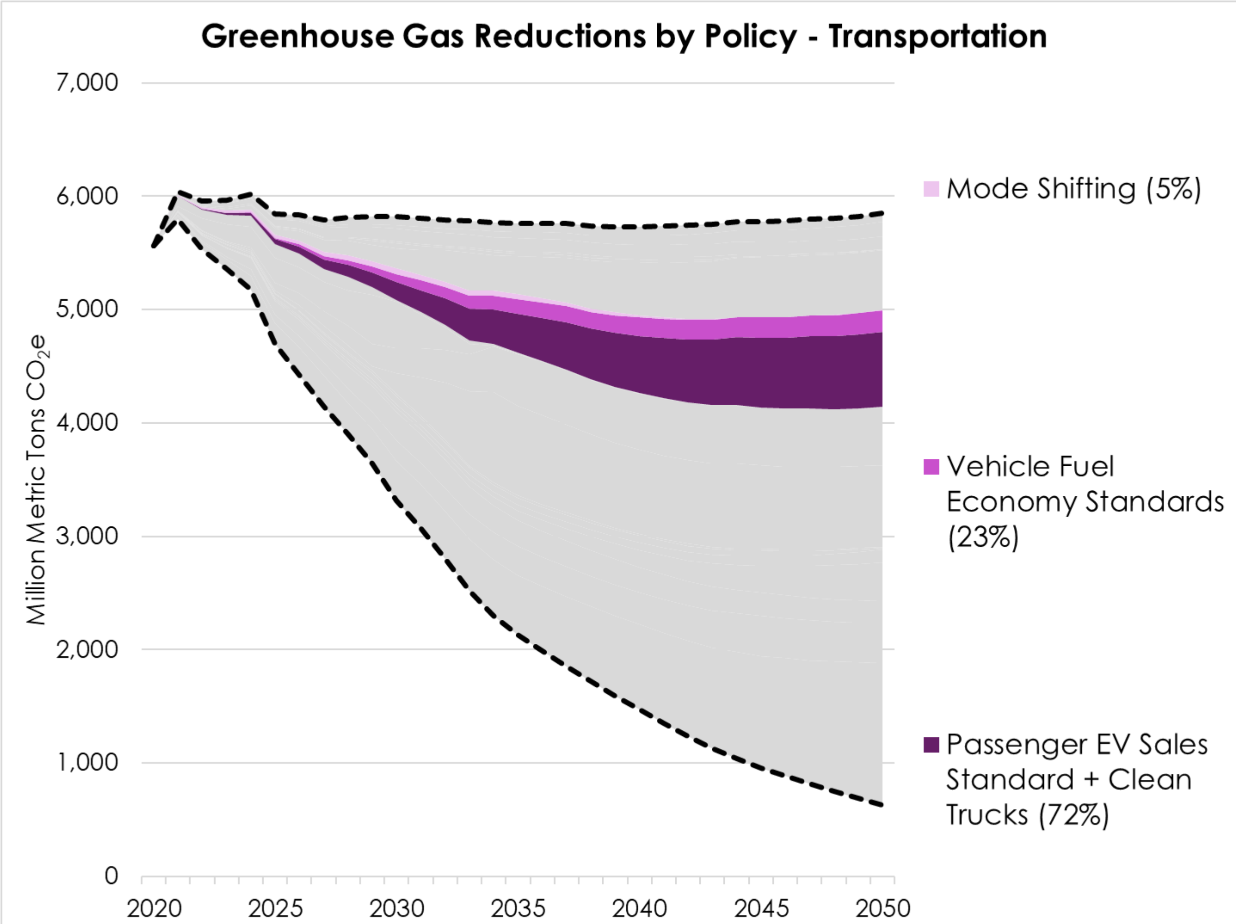
plants. Accordingly, we include policy that requires carbon capture on new gas plants, which causes no new gas plants to be built where construction hasn't already commenced. Finally, extending the Production Tax Credit and Investment Tax Credit can help ease the transition to a decarbonized grid by subsidizing part of the required new construction.

By 2030, the 1.5°C Scenario deploys 823 GW of solar and 532 GW of wind. To achieve this level of capacity deployment, the model builds an annual average of 123 GW of wind and solar between 2021 and 2030, ramping up deployment capacity through 2030. These levels of renewables deployment would put the US on par with China's 120 GW of wind and solar added in 2020.[12] By contrast the United States' annual deployment of solar and wind capacity hit new record highs in 2020 at nearly 19.2 GW[13] (this is DC, or about 15 GW AC) and 20 GW, respectively.[14] Thus achieving a 1.5°C scenario would require three to four times as much renewable capacity additions per year between now and 2030.

TRANSPORTATION SECTOR POLICIES

To decarbonize the transportation sector, newly sold vehicles—including light- and heavy-duty vehicles—must be zero-emission. We include a transition to selling 100 percent zero-emission light-duty vehicles (LDVs) and buses by 2035, and 100 percent medium- and heavy-duty trucks by 2045 in this scenario. These sales targets could be achieved through a sales standard or existing GHG tailpipe regulations. The 2035 target for light-duty vehicles and buses ensures nearly the whole stock of those vehicles is electric by 2050. For heavy-duty trucks, we allow more time for technology to develop and costs to come down.

In 2030 for the 1.5°C Scenario, there are 20 million passenger LDV sales, 65,000 bus sales, 2 million medium-duty truck sales, and 178,000 heavy-duty truck sales. Of the total sales, 13 million passenger LDVs must be zero-emission in the 1.5°C Scenario, compared with actual sales of zero-emissions passenger LDVs in 2020 which were 302,000 vehicles. For buses, 44,000 of units sold in 2030 must be zero-emission, and for medium- and heavy-duty trucks, 615,000 and 54,000 of the units sold must be zero-emission, respectively. Similar to the difference in target and actual sales of passenger LDVs, these 1.5°C Scenario sales targets for buses, medium- and heavy-duty trucks are vastly higher than current sales. Overall, total vehicle stock (including motorbikes) in the 1.5°C Scenario reaches 295 million by 2030, of which 79 million, or about 27 percent of the total stock, are zero-emission vehicles.



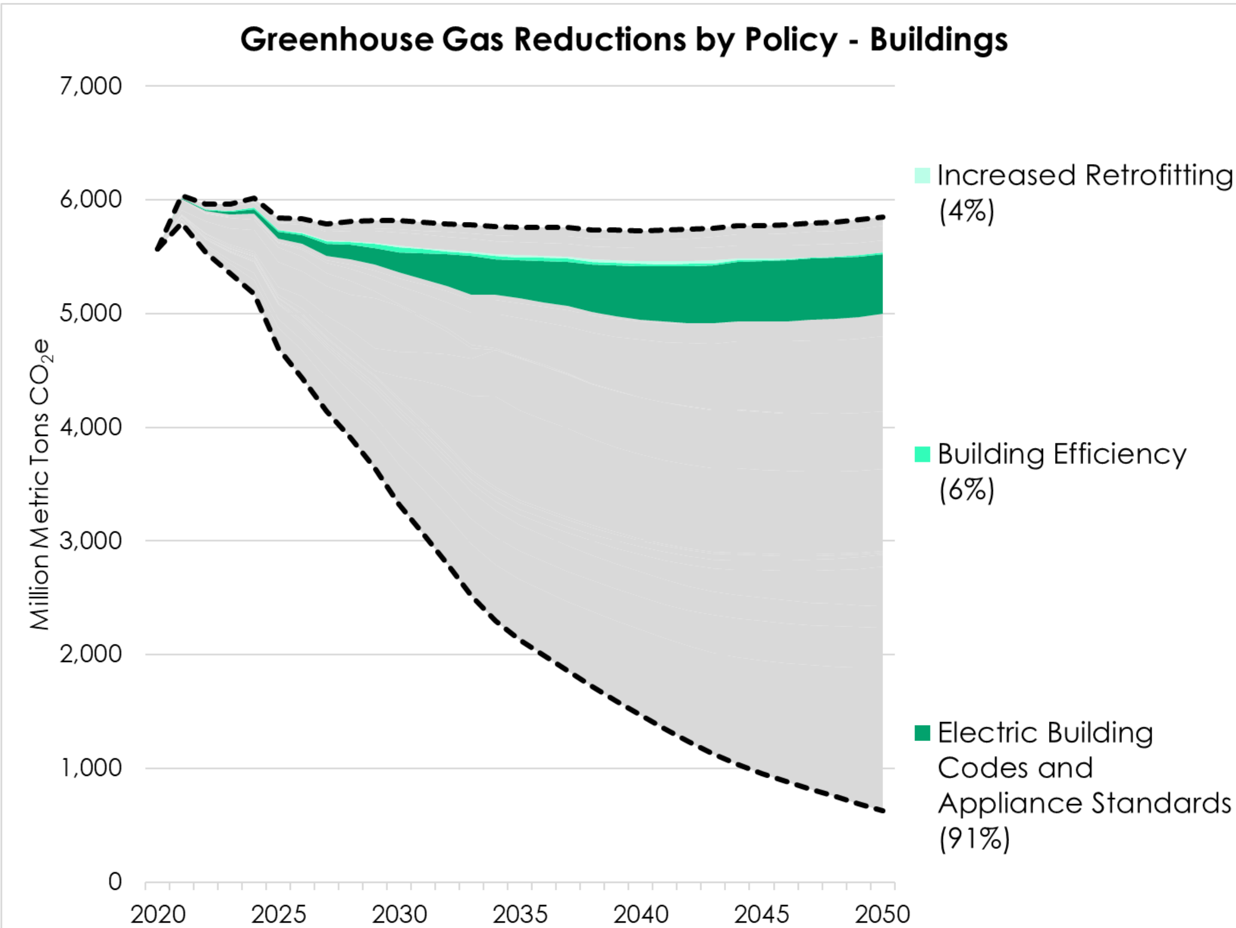
Even with these strong sales targets, a significant number of fossil fuel-powered vehicles will continue to be sold in the interim. These vehicles must be as efficient as possible to avoid locking in higher emissions. For this reason, we include a fuel efficiency standard that significantly strengthens these vehicles' efficiency before they are phased out.

We also include policies promoting better freight transport utilization and a 20 percent passenger car travel reduction, which reflects policies encouraging use of non-motorized and public transit. While these policies have smaller emissions reduction potential, they are important for public health and healthy cities—particularly in low-income neighborhoods, which have a disproportionate share of freight emissions—and they lower the cost of transitioning to a low-carbon transportation sector.

BUILDING SECTOR POLICIES

Building sector emissions primarily come from burning gas and oil in buildings, which makes transitioning to all-electric buildings the key to decarbonizing. The 1.5°C Scenario includes a sales standard requiring all newly sold building equipment to run on electricity by 2030 and all new buildings to be fully electric by 2025.

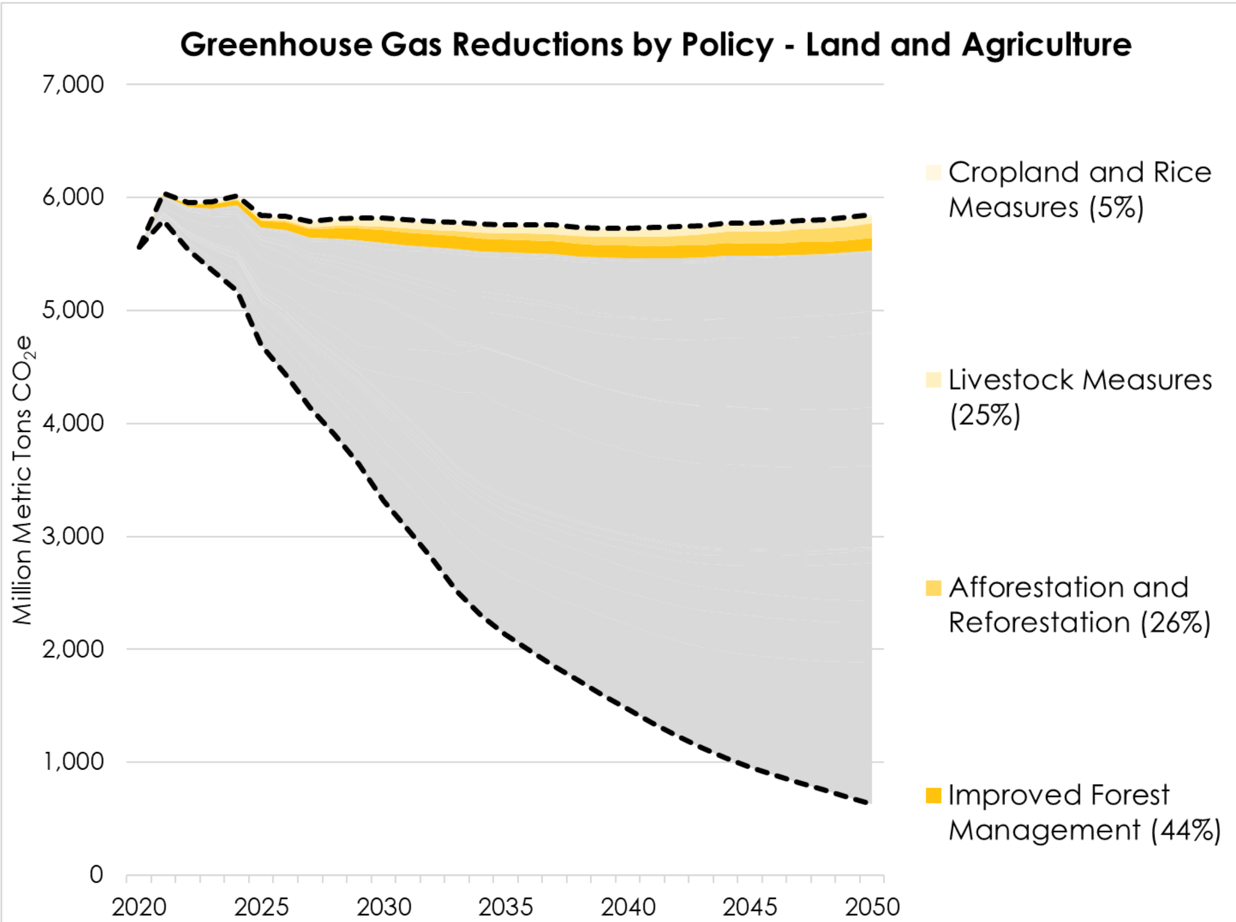
Based on projections from the National Renewable Energy Laboratory,[15] in 2030 the 1.5°C Scenario's standard would result in the sale of approximately 8.9 million residential heat pumps, 12.5 residential electric water heaters, and 7.5 million residential electric cookstoves, per year. Achieving these targets will require a multifold increase from 2021 sales, which currently stand at 2.2 million residential heat pumps, 4.2 million residential electric water heaters, and 4.4 million residential electric cookstoves, per year. This also excludes commercial buildings, which also see a significant increase in sales of electric equipment.



These policies lead to all buildings being fully electrified by 2050. We also include improved building efficiency for all equipment as well as building retrofits, so that 15 percent of the existing building stock will be retrofitted by 2050. While these policies create a smaller emissions impact in the 1.5°C Scenario because of building electrification, they lower decarbonization costs by allowing smaller equipment to be installed and by avoiding new power plant buildout. They also are massive job creators: a 2020 report by the Energy Futures Initiative estimated nearly 2.4 million Americans are employed in the energy efficiency sector.[16]

LAND AND AGRICULTURE POLICIES

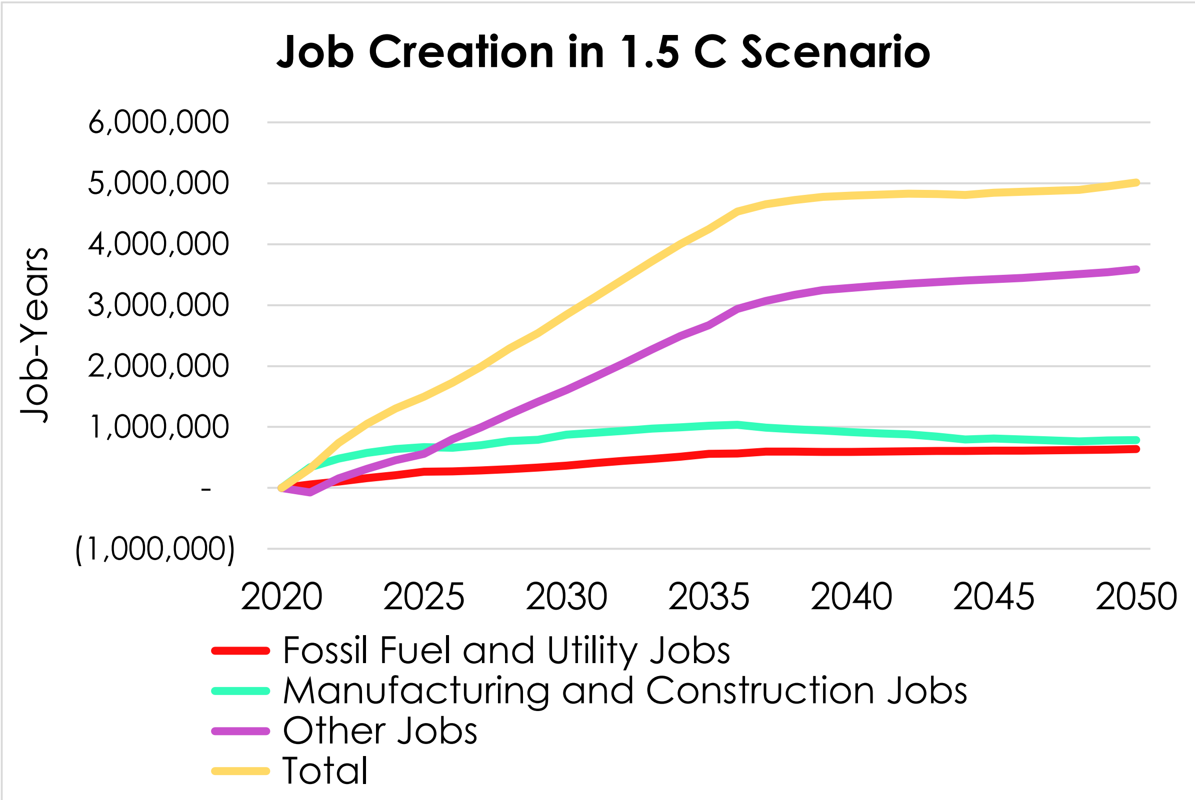
We include several land and agriculture policies in the 1.5°C Scenario, but we do not rely heavily on them due to uncertainties around abatement potential and policy implementation. This scenario includes forest management policies, improved carbon uptake, growing forested land in the U.S., and afforestation and reforestation policies.



In the agriculture sector, we include livestock and cropland measures, which primarily results in wide-scale deployment of anaerobic digesters and improved soil carbon practices, like precision and no-till agriculture.

ECONOMIC AND HEALTH

Decarbonizing our economy can create millions of new jobs and grow the economy. The 1.5°C Scenario generates more than 3.2 million new job-years by 2030 and nearly 5 million new job-years by 2050. These jobs result from deploying new infrastructure on the path to deep decarbonization, such as constructing wind and solar power plants and developing hydrogen plants used to supply the industry sector and respending of the enormous consumer savings stemming from the switch away from fossil fuels. The modeling also shows a 1.5°C pathway could increase U.S. gross domestic product by $570 billion per year in 2030 and $920 billion in 2050 (a 2.4 percent annual GDP expansion).



Of course, additional assistance will be required to ensure that workers in transitioning industries are able to retrain and take advantage of the newly created job opportunities. This assistance can come in many forms, including tax credits and subsidies for businesses in fossil fuel-dependent communities, job training, small business loan access, and support for fossil fuel pension programs, many of which, like the Pension Benefits Corporation,[17] are running huge budget deficits.

Enormous health benefits are also associated with the transition to a zero-carbon economy. Emissions of $PM_{2.5}$, a dangerous pollutant that causes adverse health effects including premature death, from fuel combustion[vii] drop 78 percent by 2050. SO_x and NO_x emissions, which form secondary $PM_{2.5}$ and also contribute to premature death, drop by more than 42 and 50 percent, respectively. As a result, the 1.5°C Scenario avoids more than 17,000 premature deaths in 2030. By 2050, the scenario avoids more than 45,000 premature deaths, nearly 1.4 million asthma attacks, over 26,000 hospital admissions, and more than 4.5 million lost workdays.

What about Fossil Fuel Exports?

By default, the EPS assumes that fossil fuels produced in but not consumed in the US can be exported for sale elsewhere based on the historical share of supply that is exported, which is roughly 100 percent for crude oil and around 15 percent for natural gas. The implication is that policies reducing demand for crude oil have almost no impact on jobs from crude oil extraction and processing, while policies reducing demand for natural gas significantly reduce natural gas supply and jobs.

This modeling assumption has important implications for potential job losses in the oil and gas industries. For oil supply and refining, it limits job losses, while for natural gas it results in large job losses. Changes in current practice, for example the addition of more US liquified natural gas export terminals or global adoption low carbon transportation policy, could significantly affect findings for the US fossil fuel industry by changing how US production is handled. These conditions can be easily tested in the EPS.

CONCLUSION

The U.S. is off-track to a sustainable climate future, and without additional policies, GHG emissions are projected to remain more or less steady for the foreseeable future. To become an international leader and align with efforts limiting warming to 1.5°C, the U.S. must immediately begin cutting emissions economywide. This includes phasing out coal power by 2030; committing to generating electricity from clean sources in line with reducing electricity emissions 80 percent by 2030 and 100 percent by 2035; ensuring new passenger cars and buses are all electric by 2035 and trucks by 2045; phasing out sales of non-electric building equipment by 2030; and significantly cutting non-CO_2 pollutants, such as methane and refrigerant emissions, over the next decade. Pursuing these and other policies outlined in the 1.5°C Scenario can put the U.S. on a path to net-zero CO_2 before 2050 and align the country with global efforts to secure a safe climate future.

These policies, and the required deployment of new clean technology, will generate millions of new jobs and help reinvigorate the U.S. economy as we emerge from the COVID-19 pandemic. The demand for new technology will create enormous opportunities for U.S. manufacturers to

[vii] We report emissions reductions of $PM_{2.5}$ from transportation, buildings, electricity, and industrial fuel consumption here, excluding $PM_{2.5}$ emissions from water and waste.

design, build, and sell this technology at home and abroad. And these policies will cut dangerous pollution that kills tens of thousands of Americans every year and causes millions more to suffer from respiratory illnesses. The 1.5°C Scenario shows how policymakers can solve both the growing climate crisis, while also creating well-paying jobs and investing in sustainable economic growth.

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