Energy Analysis & Environmental Impacts Division
Lawrence Berkeley National Laboratory

Illustrative Strategies for the United States to Achieve 50% Emissions Reduction by 2030

Nikit Abhyankar, Priyanka Mohanty, and Amol Phadke

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Lawrence Berkeley National Laboratory
1 Cyclotron Road, MS 90R4000
Berkeley CA 94720-8136

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Executive Summary

This analysis shows one possible pathway to reduce economy wide emissions in the US by 50%. Other pathways and strategies could be feasible and need to be explored further.

1. The United States can employ several strategies to realize the economy-wide greenhouse gas (GHG) emissions reductions needed to achieve a 1.5°C pathway. Our illustrative assessment shows that by 2030 a few strategies can reduce emissions by 50% from 2005 levels (excluding land use and agricultural emissions), consistent with establishing a 1.5°C pathway. Most of the emission reductions (about 80%) derive from realizing 80% carbon-free electricity by 2030, retiring all coal-fired generation by 2030, and selling only electric new cars by 2030 and trucks by 2035.
2. Due to dramatic recent declines in battery prices, rapid electrification of transport will lead to significant net savings to consumers, averaging about $1000 per year per household (cumulative saving of $2.7 trillion between 2020 and 2050). Moreover, due to deep reductions in renewable energy prices, 80% clean power and retiring all coal power plants by 2030 can be achieved without increasing wholesale electricity costs compared to today. Emissions reductions from the other strategies modeled for this analysis also potentially can be achieved without a net increase in consumer costs or energy expenditures.
3. The 2030 scenario modeled in this analysis points to wide-ranging economic and social benefits, including 500,000 to 1 million new energy sector jobs in the 2020s and avoiding over 240,000 premature deaths through 2050 due to improved air quality. Further analysis is required to assess the sectoral distribution of the job gains and spatial resolution of the public health benefits.
4. Efficiency gains related to electrification have led to electric cars, trucks, and heat pumps that are 3 to 5 times more efficient than conventional products. Electrification will increase electricity demand only modestly (about 2% per year), requiring building of 100 GW of new wind and solar capacity, and 20 GW of new battery capacity every year between 2021 and 2030 in order to ensure an 80% clean grid. For comparison, in 2020 the United States and China installed 31 and 120 GW, respectively, of grid connected wind and solar capacity.
5. Electrification also has benefits for the reduction of shorter-lived pollutants like methane and f-gas that have significantly higher global warming potential than CO2.
6. A robust policy environment and rapid infrastructure investments are required to capture the benefits outlined herein.

Analytical Methods

- We draw significantly on sectoral deep dives in the 2035 Power and 2035 Transport reports
- Economy-wide assessment performed using Energy Policy Simulator (EPS)
- Power sector strategies modeled using ReEDS and operational feasibility tested using PLEXOS
- Vehicle stock turnover model to assess the fleet level impacts of vehicle sales electrification

Data

- Sectoral emissions and economic data obtained from EPS
- Hourly profiles of electricity demand from NREL's Electrification Futures Study
- Power sector costs based on NREL's Annual Technology Baseline 2019
- Transportation costs from the latest ICCT reports and BNEF data

1. Introduction

In 2015, 194 countries signed the Paris Agreement, thereby committing to limit global temperature increase to less than 2 ºC via national pledges for reducing carbon emissions. Each country pledged a Nationally Determined Contribution (NDC) aimed at limiting the global temperature increase to 1.5 ºC to avoid the catastrophic climate impacts identified by the IPCC. Acknowledging the cost-competitiveness of clean energy resources, as well as the scale and scope of potential climate action, this memo assesses potential strategies the United States can employ to reduce emissions consistent with a 1.5 ºC maximum temperature increase.

Our analysis identified seven strategies that can cost-effectively decarbonize four economic sectors: power, transportation, buildings, and industry. Implementing the seven strategies could reduce economy-wide greenhouse gas (GHG) emissions (excluding the land use and agricultural sectors), about 50% from 2005 levels by 2030, which is consistent with the long-term goal of net-zero emissions by 2050 and would lead us to a path to limit global temperature increase to 1.5 ºC (Figure 1).

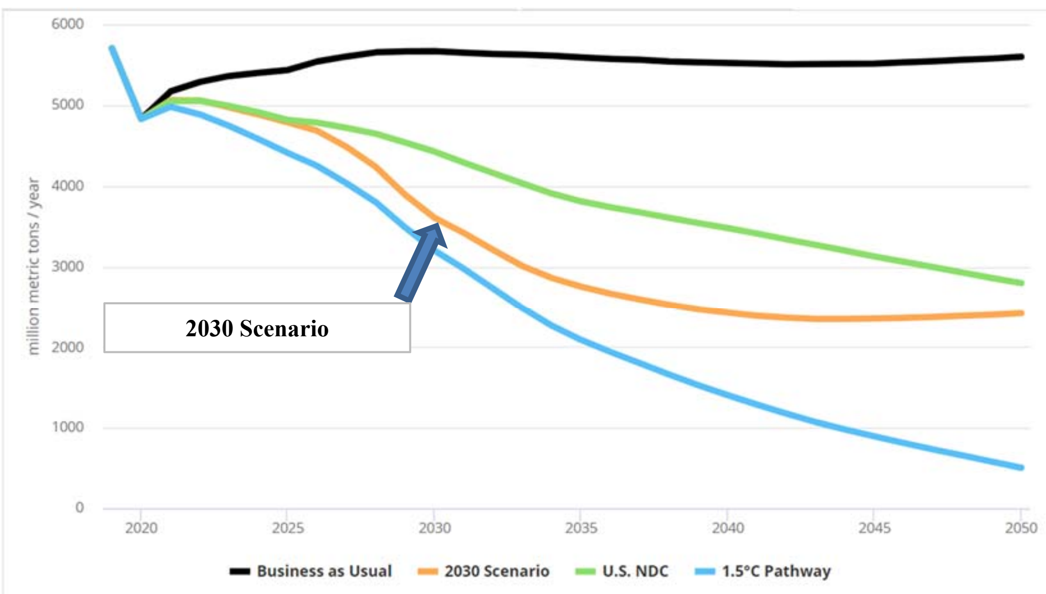

Figure 1: Economy Wide GHG Emissions in the 2030 Scenario Relative to BAU, U.S. NDC, and 1.5 ºC Goal

We estimated emissions reductions and their associated environmental and employment impacts using the Energy Policy Solutions (EPS) model, an open-source scenario-modeling tool created by Energy Innovation, while drawing extensively from the recently published 2035 Power and

2035 Transport reports by the University of California Berkeley for sectoral deep dives. The model incorporates results of U.S. BAU, the 1.5 C pathway, and the United States NDC commitments to compare to the 2030 scenario we developed. Following is a brief summary of our analytical methods and data:

Analytical Methods

- We draw significantly on sectoral deep dives in the 2035 Power and 2035 Transport reports
- Economy-wide assessment performed using Energy Policy Simulator (EPS), coupled with the insights from the 2035 Power and Transport Reports
- Power sector strategies modeled using ReEDS and operational feasibility tested using PLEXOS
- Bottom-up vehicle stock turnover model to assess the fleet level impacts of vehicle sales electrification

Data

- Sectoral emissions and economic data obtained from EPS
- Hourly profiles of electricity demand from NREL's Electrification Futures Study
- Power sector costs based on NREL's Annual Technology Baseline 2019
- Transportation costs from the International Council on Clean Transportation and Bloomberg New Energy Finance

This analysis by no means presents a comprehensive list of the potential actions that could be taken to achieve widespread decarbonization. The strategies modeled in our 50% scenario for achieving 50% of U.S. NDCs by 2030 (Table 1) were chosen based on the magnitude of their effects as well as their economic and technological feasibility. Our strategies focus primarily on electrification mainly because of the unanticipated and deep reduction in the renewable energy and battery technology costs (Figure 2). Also, findings in the 2035 Power and 2035 Transportation reports clearly show that decarbonization of the electric grid has the potential to stimulate rapid electrification of the transportation, buildings, and industrial sectors. In addition to electrification, we also modeled strategies around higher global warming potential (GWP) pollutants like methane and F-gases because they have a disproportionate impact on rising temperatures in the near term and there are low-cost established solutions for their reduction. Their reduction is also tightly linked to the electrification of power, transport and buildings. Other scenarios being developed by various other organizations model many possibilities for reducing emissions from economic sectors, including the 1.5 C scenario.

Table 1: Key emissions reduction strategies and their impacts

Sector	Strategy	Timeframe for the Emission Reduction	Emission Reduction MMT*	Contribution to the Economy Wide Emission Reduction
Economy-wide	Emissions Reductions Achieved from 2005 to 2019	2005-2019	904	13%
Power	80% carbon-free electricity generation by 2030	2019-2030	1049	15%
Power	Retirement of All Coal-Fired Power Plants by 2030 (additional to CES 80)	2019-2030	258	4%
Total Power Sector Emissions Reductions (2019-2030)			**1307**	**19%**
Transportation	Cars: 100% electrification of new sales by 2030	2019-2030	560	8%
Transportation	Trucks: 100% electrification of new sales by 2035	2019-2030	154	2%
Total Transportation Emissions Reductions from (2019-2030)			**714**	**11%**
Buildings	100% of New Building Components are Electric by 2030	2019-2030	224	3%
Industry	100% Reduction in Fluorinated gases** by 2030	2019-2030	61	1%
Industry	100% Methane Capture in Natural Gas Facilities** by 2030	2019-2030	239	4%
Total Buildings and Industry Emissions Reductions (2019-2030)			**524**	**8%**
Total Emissions Reduction		2005- 2030	**3449**	**51%**

Note: Totals may not match due to rounding.
* MMT = million metric tons of greenhouse gases
**We measure emissions reductions on a 100-year Global warming potential basis and therefore likely understates the impact short-lived climate pollutants (SLCPs) like F-gases and methane would have on temperature, particularly in the near term.

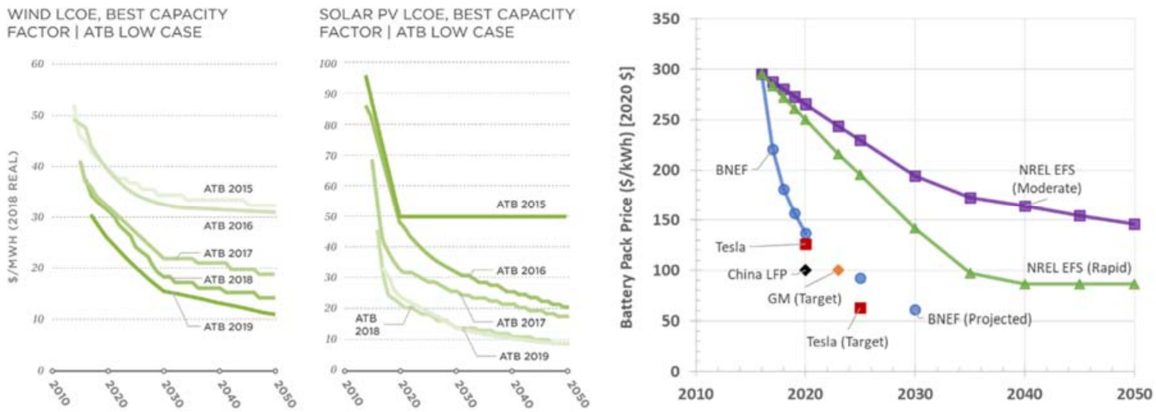

Figure 2[1]: Cost Trends for Wind, Solar, and Battery-Supplied Energy through 2050

Figures 3 and 4 break down overall emissions reductions attributable over time to the key economic sectors and strategies discussed above. Assuming BAU emissions projections for economic sectors that we did not model for in our scenario, by 2030 the United States GHG emissions are reduced ~50% from 2005 levels.

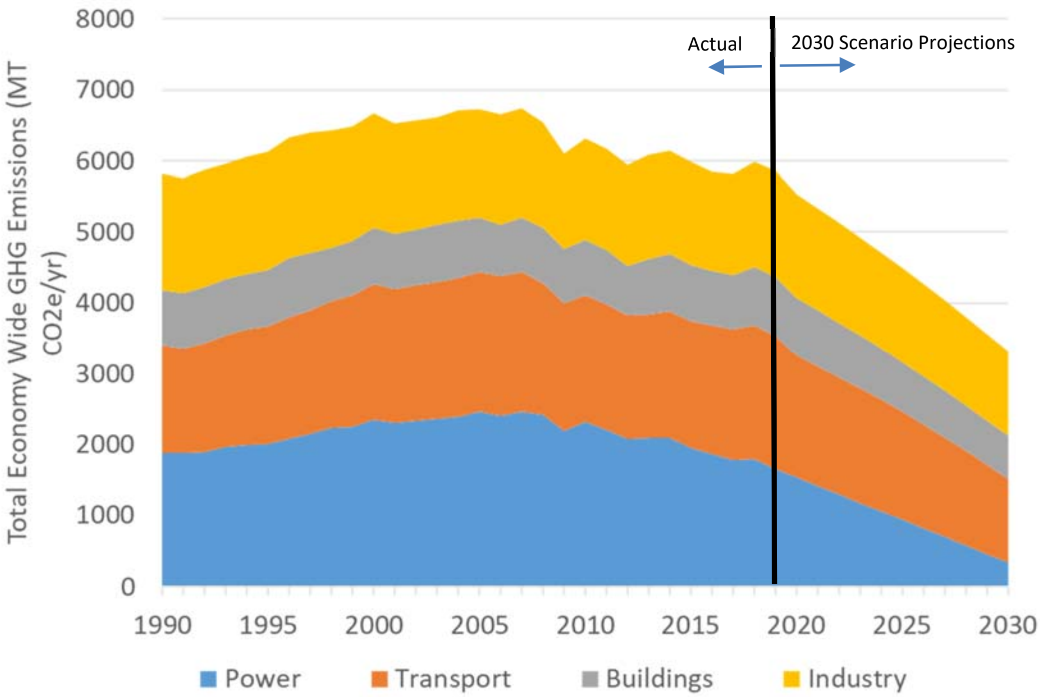

Figure 3: Economy-wide GHG Emissions (excluding land use and agricultural sectors): Historical and 2030 Scenario Projections

[1] Phadke, A. et al. "2035 Transportation Report: Data/projections from NREL, LBL, and BNEF."

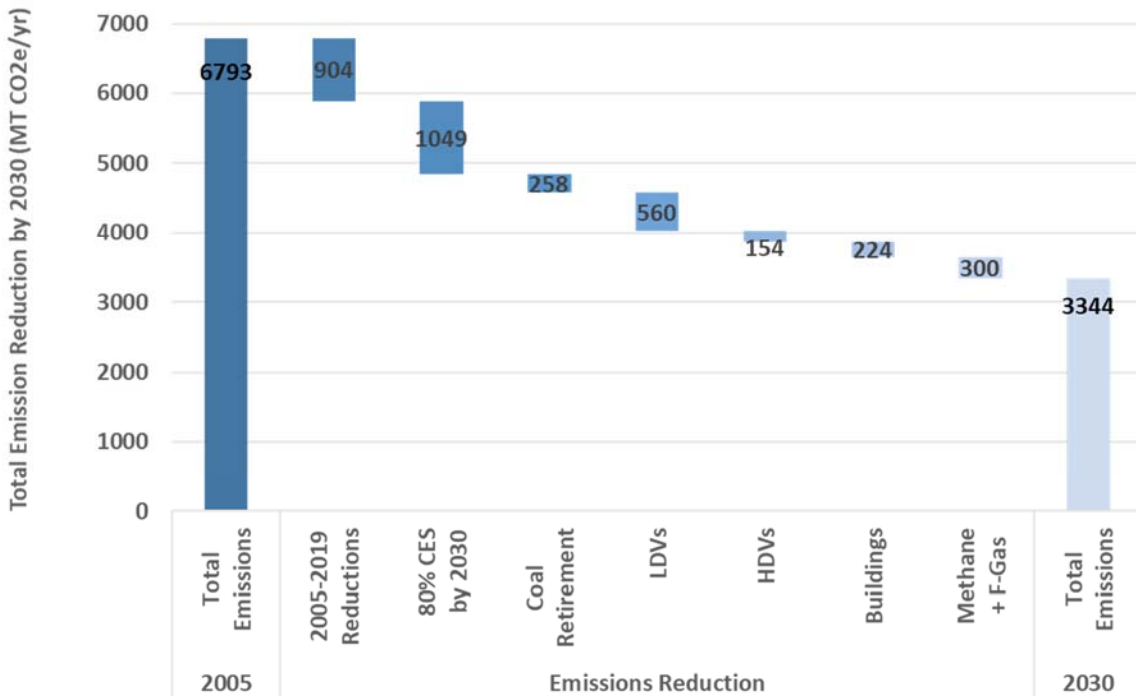

Figure 4: 2030 Scenario–GHG Emissions Reduction (in MMT) by Policy Lever

Note that Figures 3 and 4 show potential emissions reductions on a CO2-equivalent basis and therefore likely understates the disproportionate impact short-lived climate pollutants (SLCPs) like F-gases and methane would have on temperature, particularly in the near term.

The following sections briefly summarize the strategies identified for each of the four economic sectors, the techno-economic analysis of each strategy's feasibility, and the environmental and economic impacts.

2. Power

80% Carbon-Free Electricity Standard (CES) by 2030. Costs for wind, solar, and battery-supplied power continue to decline while RE sources are being incorporated increasingly into the electric grid (Figure 5). Using these renewable resources enables the grid to be decarbonized more cost-effectively than was thought possible even five years ago.[2] UC Berkeley's 2035 Power Report used advanced grid modeling to explore a path to 90% zero-carbon electricity by 2035. The authors found that by 2035 the United States could dependably meet nationwide electricity demand every hour and halt pollution from the electricity sector. Those goals can be accomplished while lowering

[2] Phadke, A. et al. (2020). Available at: https://energyinnovation.org/wp-content/uploads/2020/09/Pathways-to-100-Zero-Carbon-Power-by-2035-Without-Increasing-Customer-Costs.pdf

customer costs by approximately 10% compared to today's costs, owing primarily to lower costs for renewable energy resources and batteries.[3]

Based on such new research and data, and indications that the Biden administration supports 100% grid decarbonization by 2035,[4] we believe that an intermediate 80% target to be feasible by 2030.

According to the 2035 Report, the additional electricity demand due to transport, buildings and industrial electrification would be significant. Over the next 30 years, the electricity demand may increase at an average growth rate of about 2%. By 2030, the additional electricity demand (beyond 2019 levels) would be 22%, which would increase to about 75% by 2050. However, as shown in Figure 5, this increase in demand parallels the demand growth that the US grid has already witnessed between 1975 and 2005.

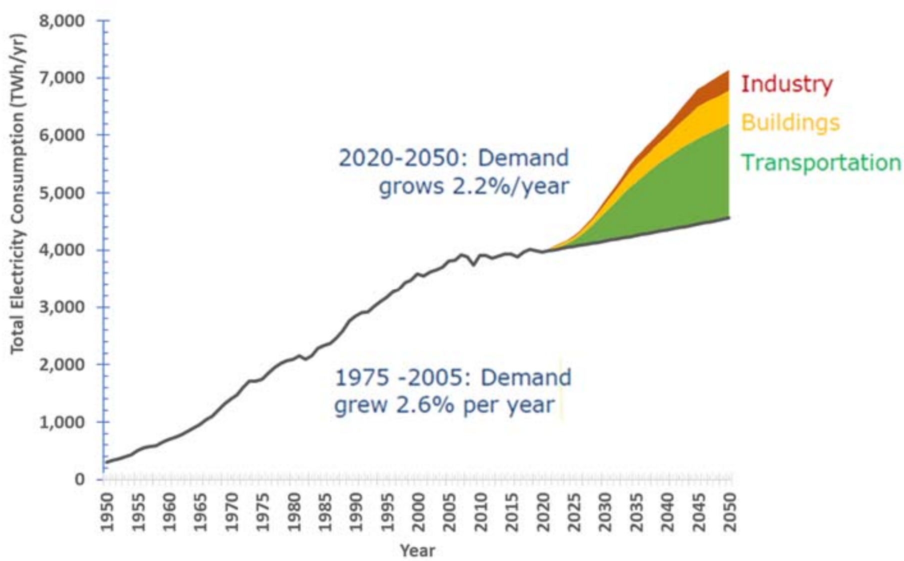

Figure 5[5]: Projected Electricity Demand and Historical Trends

Abhyankar et al (forthcoming)[6] and Phadke et al (2020)[7] show that in order to meet this load and still deliver 80% clean grid by 2030, the U.S. would need to add 60 GW of new renewable energy capacity (mainly wind and solar) every year until 2025 and 120 GW every year between 2026 and 2030 (Figure 6). This goal is eminently reachable, however, given, for example, China's

[3] Phadke et al (2020). "The 2035 Report.". University of California, Berkeley.
[4] Stokes et al (2020). "A Roadmap to 100% Clean Electricity by 2035." University of California, Santa Barbara.
[5] Ibid.
[6] Abhyankar, N, et al (2021) "Assessing the Technical and Economic Feasibility of a 80% Clean Electricity Grid by 2030 in the United States", Lawrence Berkeley National Laboratory (forthcoming).
[7] Phadke et al (2020). "The 2035 Report.". University of California, Berkeley.

installing as much as 120 GW of renewable capacity in just one year.[8] In addition, 80% clean grid would also need building over 20GW of new battery capacity every year between 2021 and 2030.

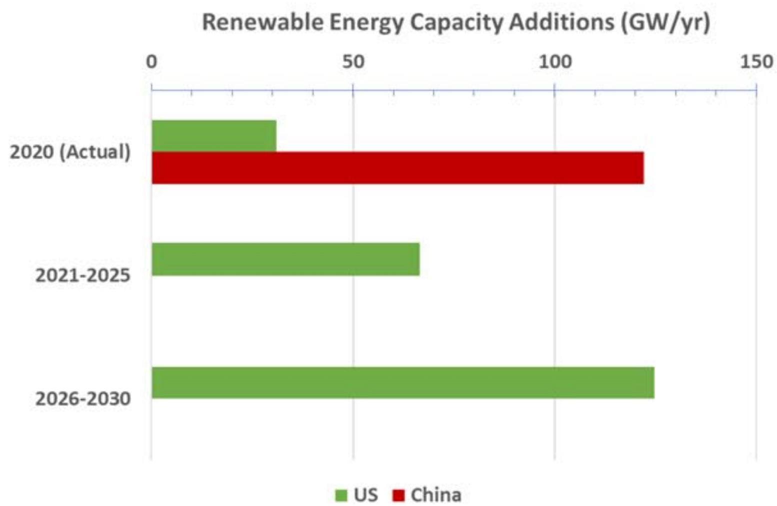

Figure 6[9]: Projected Additions to Renewable Energy Capacity to Meet 80% CES by 2030

Several policy options are available to enable 80% of power to be free of carbon pollution by 2030. Our illustrative assessment indicates that extending the current clean energy tax credits until 2030 and making them refundable, when combined with continued decreases in RE and storage costs, could make the cost of producing more than 70% clean electricity by 2030 the most cost-effective option for utilities.[10] A target federal clean electricity standard of 80% combined with retirement of coal plants by 2030 will reduce emissions significantly while not increasing wholesale electricity costs above today's costs.

Retirement of all U.S. Coal-Fired Power Plants by 2030. Much of the U.S. power sector emissions come from coal-fired electric generation. Burning coal produces about twice as much CO_2 than does burning natural gas (excluding leaks) for every unit of energy output. Burning coal also is responsible for 30% of global energy-related CO_2 emissions.[11] In 2008, 45% of U.S. electricity was coal generated, a figure that has declined to 24% and is still dropping in 2020.[12] Since 2016, 39,000 MW of coal capacity has been retired and no new coal plants have been

[8] Bloomberg Green. 2021. "China Blows Past Clean Energy Record With Wind Capacity Jump".
[9] Ibid.
[10] Abhyankar, Nikit, Umed Paliwal, Michael O'Boyle, Ric O'Connell, Amol Phadke et al (2021) "Assessing the Technical and Economic Feasibility of a 80% Clean Electricity Grid by 2030 in the United States", Lawrence Berkeley National Laboratory (forthcoming).
[11] Pearce, F. YaleEnvironment360. March 2020. Available at: https://e360.yale.edu/features/as-investors-and-insurers-back-away-the-economics-of-coal-turn-toxic.
[12] Ibid.

commissioned, while coal mining companies increasingly file for bankruptcy.[13] Despite the clear market trends, many utilities continue to operate old, uneconomical coal plants. New analysis finds that just three years from now, such plants will cost customers an additional $3.5 billion to keep open.[14]

Our analysis finds that the early retirement of coal-fired generation plants could account for close to 4% of emissions reduced from 2005 levels. Note that his number may appear small because they are additional emission reductions after the 80% CES by 2030 is implemented. Retiring coal-fired plants while providing pathways to new employment for displaced workers is a prerequisite for reducing emissions and achieving long-term economic savings. Any of the many well-designed local, state, and international environmental justice packages for workers of retiring coal plants can be used as a blueprint for national efforts to help fossil fuel communities diversify their economies.[15] Retiring coal power plants also generates enormous local air quality benefits as outlined subsequently.

3. Transport

100% Electrification of New Sales of Light-Duty Vehicles by 2030, and Medium-and Heavy Duty Vehicles by 2035. Transportation, currently the largest source of U.S. greenhouse gas emissions, accounts for approximately one-third of total national GHG emissions. More than 80% of transportation emissions come from cars and trucks. The U.S. transportation sector, however, is poised for revitalization and decarbonization in the coming decade based on a transforming market and expanding policy goals. Rapid price declines for electric vehicles (EVs) and clean electricity are creating optimal conditions for electrifying transportation nationwide. At a sub-national level, recent California and Massachusetts commitments to zero-emission vehicle sales by 2035 would represent the electrification of 6% of current national vehicle stock. Recent ZEV sales commitments from auto manufacturers like General Motors, Volkswagen, BMW, and Audi also signal private sector shifts towards electric vehicles.

2035 Transportation Report shows that 100% of all new LDVs sold by 2030 and all new MDVs and HDVs sold by 2035 were electric, consumers, the economy, the environment, and public health would all receive a net benefit. The transition to all-electric vehicles could unlock $2.7 trillion in consumer savings, a 96% reduction in pollution-related premature deaths, and near elimination of GHG emissions from cars and trucks by 2050.[16] The economic savings derive from the lower total cost of electric vehicles, which are significantly cheaper to own and operate over

[13] Ibid.
[14] Ibid.
[15] Examples include the New Mexico Energy Transition Act, British Columbia Jobs Plan, Puget-Sound Utility/Coalstrip, and Montana Partnership.
[16] Phadke et al (2021). "The 2035 Transportation Report."University of California Berkeley.

the lifetime of the vehicle. As the country transitions to increasing penetrations of clean electricity generation, declining electricity rates also keep EV charging costs low.

Cost trends for the infrastructure needed to support electrification of the transportation sector are promising. Using electricity for charging vehicles offers significant load-shifting and demand-response benefit, making it even cheaper to meet the additional demand using renewable energy by offsetting some of the energy storage requirement. Moreover, additional electrification load improves the load factor of the electricity demand and thus results in more economic generation and transmission asset utilization (Figure 7).

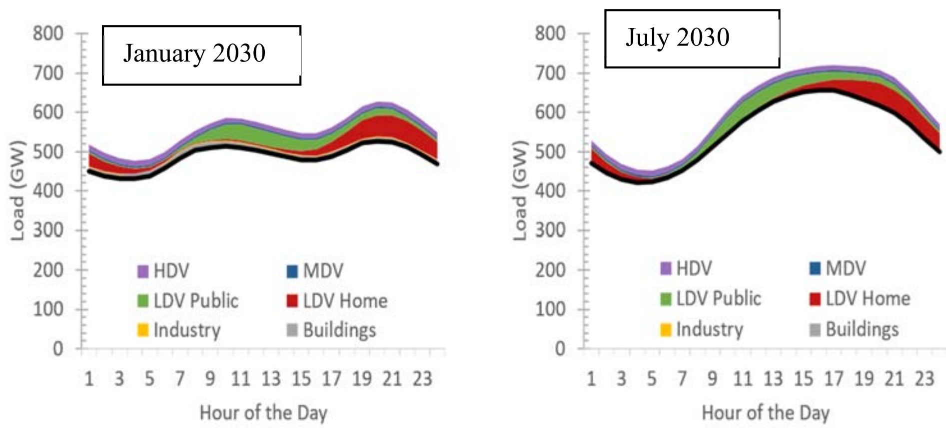

Figure 7: Average Hourly Additional Load in 2030 due to Aggressive Electrification

Our model confirms that setting new sales targets of 100% for electric LDVs by 2030 and MDVs/ HDVs by 2035 would reduce emissions from 2005 levels by about 11% by 2030.

According to the 2035 Transportation report, to enable such massive transition towards electric vehicles, the right policy framework and infrastructure scale –up would be required. For example, building 270,000 new public chargepoints for LDVs and 35,000 new chargepoints for MDVs/HDTs every year (equivalent to about $6.5 billion of new investment per year). Such scale up is challenging but not internationally unprecedented. Also, the cumulative investment in public charging infrastructure makes up a small portion of EV Total Cost of Ownership on a per mile basis. Moreover, The 2035 report also finds that in the next 2 years, the number of EV models available to consumers is expected to triple to well over 200, as growing number of electric vehicles already offer longer ranges and fast charging capabilities.[17]

[17] Ibid.

4. Buildings

Sale of 100% Electric Building Components. In 2018, direct electricity and fuel emissions from residential and commercial buildings constituted 12% of total U.S. GHG emissions.[18] Our scenario assumes that all new heating units, appliances, and other equipment should be electric by 2030. Doing so could cut emissions by 3% from 2005 levels. Market projections substantiate this recommendation. Many factors are predicted to improve the cost-effectiveness of electricity compared to natural gas. The price of heat pumps is expected to decline as the market grows and manufacturers achieve economies of scale. The National Renewable Energy Laboratory's (NREL's) Electrification Futures Study predicts cost decreases of 20% to 38% for air-source heat pumps and 42% to 48% for heat-pump water heaters by 2050.[19] Currently, more than 12 million U.S. households use electric heat pumps, which are increasingly able to operate efficiently in cold weather, as their primary source of heat.[20]Electrification will also have implications for potential methane emission reductions along the natural gas supply chain, which include building heating and cooling. Recent estimates suggest ~2.3% of natural gas from the US oil and natural gas supply chain leaks to the atmosphere, without including leaks from local distribution and end-use.[21] Methane warms the planet 80 times as much as CO2 over the first 20 years after it is released, thus leaks of this magnitude produce radiative forcing comparable to the CO2 from natural gas combustion over this 20 year horizon, effectively doubling the climate benefit of switching away from natural gas to electricity based end uses.

Electrification of the buildings sector also have social and economic benefits. The buildings sector generates numerous energy-related jobs, particularly in retrofitting buildings. Energy-efficiency work showed the highest overall employment growth in 2019 and was projected to increase another 3% in 2020.[22] During the COVID-19 pandemic, approximately 360,000 energy-efficiency workers lost their jobs.[23] Building electrification provides an opportunity to re-create those jobs. One estimate indicates that in California alone building electrification could provide more than 100,000 net jobs by 2045.[24] Other benefits of building component electrification include

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[18] U.S. EPA."Sources of Greenhouse Gas Emissions." 2021. Available at: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

[19] Jadun, P. et al. "Electrification Futures Study: End-Use Electric Technology Cost and Performance Projections through 2050." 2017. National Renewable Energy Laboratory. NREL/TP-6A20-70485. https://www.nrel.gov/docs/fy18osti/70485.pdf.

[20] lbid.

[21] Alvarez, R. *et al. Science, 2020.* http://dx.doi.org/10.1126/science.aar7204

[22] Environmental and Energy Study Institute. 2019. https://www.eesi.org/papers/view/fact-sheet-jobs-in-renewable-energy-energy-efficiency-and-resilience-2019

[23] BW Research Partnership, prepared for E2. "Clean Energy Unemployment Claims in COVID-19 Aftermath." June 2020. https://e2.org/reports/clean-jobs-covid-economic-crisis-august-2020/.

[24] Jones, B. et al. "California Building Decarbonization: Workforce Needs and Recommendations." November 2019. UCLA Luskin Center for Innovation. uploads/2019/11/California_Building_Decarbonization.pdf.

greater flexibility for managing loads, opportunities for customers to provide services that support grid operations, reduced air pollution, improved quality of some energy services in buildings, and better product quality in some industrial processes.[25]

5. Industry

Methane Capture from Natural Gas/Petroleum. Today 10% of U.S. GHG emissions are attributable to methane. As mentioned in the previous section, the global warming potential of methane making their radiative forcing potential comparable to the radiative forcing potential of CO2. The methane that escapes during the drilling, fracking, and processing of oil and gas is exceedingly difficult to quantify, but estimates range from 1.5% to 3% of total U.S. methane emissions.[26] The industry's venting[27] jumped by about 66% in 2018, not including unintended leaks.[28] Corroborating studies have found that methane leaks from drilling sites are 50% higher than previously estimated, but that the leaks are not widespread. Rather, leaks can be attributed to a small group of "super-leaker" facilities.[29] The Obama administration promulgated methane regulations for new facilities, but the Trump administration rolled back many of the rules. Meanwhile, equipment for capturing methane has become increasingly cost-effective. Many studies have noted that when producers use practices such as green completions to capture or control emissions, leakage-related methane emissions are reduced dramatically.[30]

Methane capture is eminently feasible given the combination of regulations and new technology in detection and emission-control engineering.[31] When our scenario combines the 100% methane capture assumed by 2030 with reductions in fluorinated GHG (F-gases), overall emissions can be reduced by about 5% from 2005 levels.

F-Gas Reduction. Fluorinated gases, which are among the most potent greenhouse gases, are produced primarily by manufacturing industrial appliances. As of 2009, F-gases accounted for 3%

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[25] Deason, Jeff, Wei, Max, Leventis, Greg, Smith, Sarah, and Schwartz, Lisa C. Electrification of buildings and industry in the United States: Drivers, barriers, prospects, and policy approaches. United States: N. p., 2018. Web. https://www.osti.gov/biblio/1430688 doi:10.2172/1430688.

[26] Drouin, R. April 2014. YaleEnvironment360. https://e360.yale.edu/features/on_fracking_front_a_push_to_reduce_leaks_of_methane

[27] Venting is the intentional release of methane to the atmosphere, while flaring involves a controlled burn of methane, which releases carbon dioxide.

[28] The Rhodium Group. "Preliminary US Emissions Estimates for 2019." 2019. Available at: https://rhg.com/research/preliminary-us-emissions-2019/

[29] Brandt, A.R. et. al. "Methane Leaks from North American Natural Gas Systems." 2014. Science Magazine. Available at: https://science.sciencemag.org/content/343/6172/733

[30] Allen, D.T. et al. "Measurements of methane emissions at natural gas production sites in the United States." 2013. PNAS. Page 3 of: https://www.pnas.org/content/pnas/early/2013/09/10/1304880110.full.pdf.

[31] Ibid.

of U.S. emissions.[32] Although F-gases do not represent a large percentage of GHG emissions, they are up to 4,000 times more potent at trapping heat than is CO_2 with one of the highest GWPs and are the fastest growing GHGs.[33] Due to their short lifetime in the atmosphere, reducing F-gases can have major implications for overall temperature reductions. Setting efficiency standards and minimum performance standards for industrial appliances, replacing hydrofluorocarbons with low-global warming potential alternatives, providing efficiency labeling, and investing in energy-efficient appliances are all proven methods for reducing F-gas emissions.

International examples show that reducing F-gases can be relatively cost-effective. When the European Union passed legislation to control F-gas emissions, their public announcement noted that there are climate-friendly alternatives to many of the products and equipment that use F-gas. F-gases can be reduced significantly at relatively low cost and can drive innovation in the refrigeration and air conditioning industries.[34]

6. Jobs and Public Health Benefits

The 2030 scenario points to wide-ranging economic and social benefits. According to the 2035 Power and Transportation reports, the strategies recommended for the energy sector could create 500,000 to 1 million new U.S. jobs in the 2020s. Additional analysis would be needed to break down the sectoral distribution of this job growth. Moreover, 80% clean power grid by 2030 would avoid over 90,000 premature deaths by 2050 mainly because of the reduced SOx emissions from coal power plants. Additionally, 100% vehicle sales electrification by 2035 would avoid 150,000 premature deaths by 2050 because of the reduced vehicular air pollution primarily from the heavy duty trucks. In total, our 2030 scenario presented here can avoid 240,000 premature deaths through 2050, which also presents strong case for environmental justice since several studies have shown that the impacts of local air pollution are disproportionately faced by the frontline communities, low-income communities, and communities of color.

7. Conclusion

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[32] U.S. Energy Information Administration. "Emissions of Greenhouse Gases in the U.S." 2021. Available at: https://www.eia.gov/environment/emissions/ghg_report/ghg_gwp.php

[33] Greenhouse Gas Protocol. "Global Warming Potential Values." 2016. Available at: https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-PotentialValues%20%28Feb%2016%202016%29_1.pdf

[34] European Commission Climate Action. "EU legislation to control F-gases." 2020. Available at: https://ec.europa.eu/clima/policies/f-gas/legislation_en

Instituting the strategies outlined in this paper can reduce the US economy wide GHG emissions by 50% from 2005 levels by 2030. This 2030 scenario is consistent with limiting global temperature increases to 1.5 ºC, produces significant consumer savings, spurs job growth, and unlocks substantial health benefits. Both a robust policy framework and rapid investment in the necessary infrastructure are required to capture these economic, environmental, and public health gains. It is important to understand that several pathways exist to reach the 50% emission reduction goal by 2030. We have only present one illustrative pathway. Significant additional work is needed to assess the optimal pathway and key issues in rapidly decarbonizing each economic sector discussed in this note.