IER INSTITUTE FOR ENERGY RESEARCH®

THE CHALLENGES AND COSTS OF NET-ZERO AND THE FUTURE OF ENERGY

THE CHALLENGES AND COSTS OF NET-ZERO AND THE FUTURE OF ENERGY

Published by
The Institute for Energy Research

August 2023

EXECUTIVE SUMMARY

Around the world, governments, activists, and researchers have begun to converge on the idea that reaching "net-zero" carbon dioxide (CO_2) emissions is a minimum requirement of adequate action on climate change. The targets for achieving net-zero are set several decades into the future with much fanfare, but the actual steps required to reach such targets, and the impacts of those steps, are rarely discussed. This paper seeks to fill that information gap with what net-zero really means for the United States and its energy future.

In the U.S., discussions from advocates for action on climate change usually begin with the premise that the U.S. is "behind" or "not taking action" to reduce CO_2 emissions. The reality is that such concerns about the U.S. are misplaced – and were misplaced long before the passage of the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA) – recent legislation touted as historic action on climate. The U.S. was already a climate leader long before the IIJA and the IRA became law.

- From 2000 to 2021, CO_2 emissions in the European Union (EU) fell by 22 percent. In the U.S., they fell by 17 percent. However, the population of the U.S. grew by 18 percent, while the population of the EU only grew by only 4 percent. As a result, per capita CO_2 emissions fell over 30 percent in the U.S. versus only 25 percent in Europe.

- Arguably the most important metric is the absolute change in carbon emissions. From 2000 to 2021, the U.S. reduced more carbon emissions than Europe: a 275 million metric ton reduction of carbon for the U.S. compared to a 221 million metric ton reduction of carbon for the EU.[1]

But even as the U.S. has substantially reduced CO_2 emissions, it is still a long way from reaching net-zero by any definition. This indicates that reaching net-zero, or anything close to it, will be a massive undertaking. Absent unforeseeable technological breakthroughs, likely nothing short of a massive reordering of how society uses energy will be required.

1 Global Carbon Project, 2021 National Emissions v1.0, Territorial Emissions, https://data.icos-cp.eu/licence_accept?ids=%5B%22Ayyw1HeihXdTUoO000dGcxrP%22%5D

- A widely stated study on achieving net-zero CO_2 emission reductions is titled "Net-Zero America: Potential Pathways, Infrastructure, and Impacts" (Net-Zero America) from the Andlinger Center for Energy and the Environment at Princeton University.[2] In all of the study's net-zero pathways, fossil fuel use declines in the U.S. energy mix by at least 62 percent in the next 30 years.

- However, from 1990 to 2021, fossil fuel use only fell by 7.1 percent, from producing 85.6 percent of total primary energy consumed in the U.S. to 78.7 percent of total energy consumed.

- Achieving any of the net-zero pathways in Net-Zero America requires heroic assumptions about land use, coal use, sales of electric vehicles (EVs), and construction of new generation and infrastructure. Achieving any one of these assumed target values would require massive, unprecedented, and rapid change. Hitting net-zero would require all these unprecedented targets to be achieved.

Another recent study on net-zero was conducted by the Energy Policy Research Center (EPRINC), which examines the impacts of net-zero on oil and gas investment and is a useful compliment to this paper for those seeking another element of this issue.

To reach a net-zero goal, a massive buildout in renewables generation, new conventional generation, infrastructure, and EVs would be required. This, in turn, would require significantly more mineral and material resources than the current conventional energy and vehicle technologies that we rely on today. This switch from an energy system dominated by hydrocarbons to one that relies primarily on minerals and processed materials would have far-reaching implications.

- The International Energy Agency's (IEA) "sustainable development scenario" results in a 42-fold increase in lithium demand, a 25-fold increase in graphite demand, a 21-fold increase in cobalt demand, a 19-fold increase in nickel demand, and a 7-fold increase in rare earth demand by 2040.[3]

2 https://netzeroamerica.princeton.edu/the-report

3 International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

- There are simply not enough minerals in the pipeline to meet this kind of demand. One example of this is shown by research done by EV expert Steve LeVine. Using major metals production forecasts, LeVine found that by 2030, there will only be enough metals for 15.6 million EVs, while automakers claim they want to produce over 40 million.[4]

- While there are massive minerals and material needs from net-zero technologies, the Biden administration has not expedited any mines and has slow-walked or been hostile to new mining projects such as Resolution in Arizona, Twin Metals in Minnesota, and Ambler Mining District in Alaska.

Even if the materials challenges can be met, attempting to achieve net-zero will result in massive damage to the American economy.

- According to the Heritage Foundation's clone of the National Energy Modeling System (NEMS), the impacts of net-zero would be so severe that the Department of Energy's (DOE) own model is unable to estimate the impacts – the model crashes before it gets there.

- At just the halfway point on the way to net-zero, aggregate GDP drops $7.7 trillion, employment shortfall averages 1.2 million jobs, average annual household electric bill increases $840 (in 2017 dollars), and gasoline prices rise 236 percent.

Attempting to achieve net-zero will require wrenching change. The already substantial, world-leading CO_2 emissions reductions made by the U.S. are only a fraction of what would be required. Rapid and unprecedented reordering of American energy production and use would have to happen along with huge increases in mineral production. The economy would be severely damaged. And even with all that, achieving net-zero still requires dubious assumptions and projections about future technology and behavior that likely make net-zero an impossible near-term target. Understanding these challenges and costs at the outset must inform policymakers before they pursue any version of a net-zero target.

4 Steve LeVine, Twitter, Apr. 24, 2022, https://twitter.com/stevelevine/status/1518378692254310401. *See also* Steve LeVine, Just How Many EVs Can Be Made? Far Fewer Than Expected, *The Electric from The Information*, Apr. 24, 2022, https://subscriptions.theinformation.com/newsletters/the-electric/archive/just-how-many-evs-can-be-made-far-fewer-than-expected

INTRODUCTION

President
Joe Biden

Photo Courtesy: Gage Skidmore

Concerns about climate change are central to the Biden administration's policies. Within the first week of taking office, President Biden signed two executive orders focused on climate change.[5] These executive orders directed federal agencies to focus on climate concerns, revoked the cross-border permit for the Keystone XL pipeline, halted oil and gas leasing on federal lands, and stated that climate considerations shall be an essential element of U.S. foreign policy.

Months later, the administration set a goal for the U.S. to achieve a "50-52 percent reduction in greenhouse gas (GHG) emissions by 2030 and reach net-zero GHG emissions by 2050."[6] A major portion of President Biden's legislative agenda has focused on climate-related measures in an attempt to meet this goal.

In November 2021, the president signed the IIJA. The White House touted passage of this legislation as a "critical step towards reaching the goal of a net-zero emissions economy by 2050."[7] The $1.2 trillion dollar expenditure allocates $21.5 billion to create an Office of Clean Energy Demonstrations at DOE, $2.4 billion to advanced nuclear projects, $3.5 billion for carbon capture projects, $8 billion to develop clean hydrogen and $5 billion for transmission and reliability initiatives. It includes an additional $9 billion

5 Executive Order 13990, Protecting Public Health and the Environment and Restoring Science To Tackle the Climate Crisis and Executive Order 14008, Tackling the Climate Crisis at Home and Abroad.

6 President Biden, FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies, Apr. 22, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

7 White House, FACT SHEET: The Bipartisan Infrastructure Deal Boosts Clean Energy Jobs, Strengthens Resilience, and Advances Environmental Justice, Nov. 8, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/08/fact-sheet-the-bipartisan-infrastructure-deal-boosts-clean-energy-jobs-strengthens-resilience-and-advances-environmental-justice/

for grid-balancing technologies, and $7.5 billion for an EV charging network.[8]

President Biden then worked with Democrats in Congress to whittle down a massive budget reconciliation bill, known as Build Back Better, into the IRA, which was signed into law in August 2022. The White House claimed that this legislation would "position America to meet President Biden's climate goals of cutting climate pollution in half by 2030 and reaching net-zero emissions by no later than 2050."[9] Together, the IIJA and the IRA provide well over $1 trillion of federal climate-related funding, such as continued subsidies for the renewables industry and EV manufacturers, which are already heavily subsidized.[10]

Together, the IIJA and the IRA provide well over $1 trillion of federal climate-related funding, such as continued subsidies for the renewables industry and EV manufacturers, which are already heavily subsidized.

While these two pieces of legislation authorize billions of dollars in climate-related funding over the coming years, it is important to ask how much progress these measures will make towards the massive challenge of achieving net-zero emissions. It is also important to recognize that, well before these programs were signed into law, the U.S. already had an impressive track record of emission reductions.

Before the IIJA and the IRA were signed into law, the U.S. was already a leader in reducing CO_2 emissions. It achieved this status without major federal mandates, federal CO_2 regulations, carbon taxes, or serious economic harm – a feat that no other country concerned about climate change has managed.

Part 1 of this paper explains the U.S. track record of CO_2 emissions reductions. Part 2 examines the various pathways to achieving net-zero. Part 3 addresses the mineral and material processing challenges to a massive buildout in renewable energy, conventional energy, infrastructure, and EVs needed to achieve net-zero targets. Part 4 analyzes the results of economic modeling of attempting to achieve net-zero. It concludes with thoughts on the future of energy.

8 IER, *The Infrastructure Bill is Stuffed with Climate Change Policies*, Aug. 6 2021, https://www.instituteforenergyresearch.org/climate-change/the-infrastructure-bill-is-stuffed-with-climate-change-policies/.

9 White House, FACT SHEET: How the Inflation Reduction Act Builds a Better Future for Young Americans, Aug. 16, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/16/fact-sheet-how-the-inflation-reduction-act-builds-a-better-future-for-young-americans/

10 *See* Biden's Inflation Reduction Act Now Forecast to Cost Taxpayers Triple the Government Estimate, Institute for Energy Research, Mar. 28, 2023, https://www.instituteforenergyresearch.org/renewable/bidens-inflation-reduction-act-now-forecast-to-cost-taxpayers-triple-the-government-estimate/.

TABLE OF CONTENTS

SECTION 01 . . . . **09**
IS THE U.S. "BEHIND" OR "NOT TAKING ACTION ON CO_2 EMISSIONS?

SECTION 02 . . . . **16**
WHAT IS NEEDED FOR THE U.S. TO ACHIEVE NET-ZERO EMISSIONS?

SECTION 03 . . . . **23**
WHAT ARE THE MATERIAL AND MINERAL REQUIREMENTS FOR ACHIEVING NET-ZERO?

SECTION 04 . . . . **41**
WHAT IS THE IMPACT OF NET-ZERO ON AMERICAN JOBS?

SECTION 01

IS THE U.S. "BEHIND" OR "NOT TAKING ACTION ON CO_2 EMISSIONS?

There is a common narrative amongst proponents of government action to reduce GHGs in the atmosphere that the U.S. is "behind" or not "taking action" on climate change. For example, Energy Secretary Jennifer Granholm recently stated that "we are playing catch up with Germany," that Germany "and other EU parties have already made incredible progress" and that "[t]hese are the kind of results we need to replicate in here in the United States."[11]

Another similar example comes from President Biden, who stated, "if the Senate will not move to tackle the climate crisis and strengthen our domestic clean energy industry, I will take strong executive action to meet this moment."[12]

Here we see both the idea that the U.S. isn't doing enough to tackle climate change, and the idea that absent action by Congress, executive overreach is the solution to that problem.

The common thread of this viewpoint is that CO_2 emission reductions can only happen through mandatory government policies. For example, Rob Barnett, a Senior Analyst at Bloomberg Intelligence and former Senior Energy Economist at IHS CERA, said the following about the climate commitments of companies: "Without mandatory policies (e.g., cap and trade, carbon tax), it's hard to imagine significant GHG reductions."[13]

11 https://www.energy.gov/articles/remarks-prepared-delivery-secretary-granholm-berlin-energy-transition-dialogue

12 Statement by President Joe Biden, July 15, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/07/15/statement-by-president-joe-biden-5/#:~:text=Action%20on%20climate%20change%20and,action%20to%20meet%20this%20moment.

13 Rob Barnett, https://twitter.com/barnettenergy/status/1490701552104914945

The problem with such views is that the U.S., in many respects, has an impressive record of "taking action on climate change" and the U.S. has achieved this without mandatory policies at the federal level, such as cap and trade or a carbon tax. Since Secretary Granholm brought up the example of Germany, let's compare Germany's record and the U.S.' record.

THE U.S. VS. GERMANY: AN ILLUSTRATIVE EXAMPLE

In 2000, Germany launched a policy to reduce the CO_2 emissions from their energy supply through subsidies and preferential policies. In 2010, the German legislature passed *Energiewende* or "energy turnaround." In the German government's document at the time, they described "renewable energies as a cornerstone of future energy supply" and "energy efficiency as the key factor" in their plan "for an environmentally sound, reliable and affordable energy supply."[14]

Here's how energy scholar Vaclav Smil describes Germany's efforts:

> In 2000, Germany launched a deliberately targeted program to decarbonize its primary energy supply, a plan more ambitious than anything seen anywhere else. The policy, called the Energiewende, is rooted in Germany's naturalistic and romantic tradition, reflected in the rise of the Green Party and, more recently, in public opposition to nuclear electricity generation….
>
> The policy worked through the government subsidization of renewable electricity generated with photovoltaic cells and wind turbines and by burning fuels produced by the fermentation of crops and agricultural waste….
>
> During the past two decades, the Energiewende has been praised as an innovative miracle that will inexorably lead to a completely green Germany…

Germany has been widely praised as a leader in reducing GHG emissions, so Smil's conclusion will be surprising to many who think Germany is outperforming the U.S.

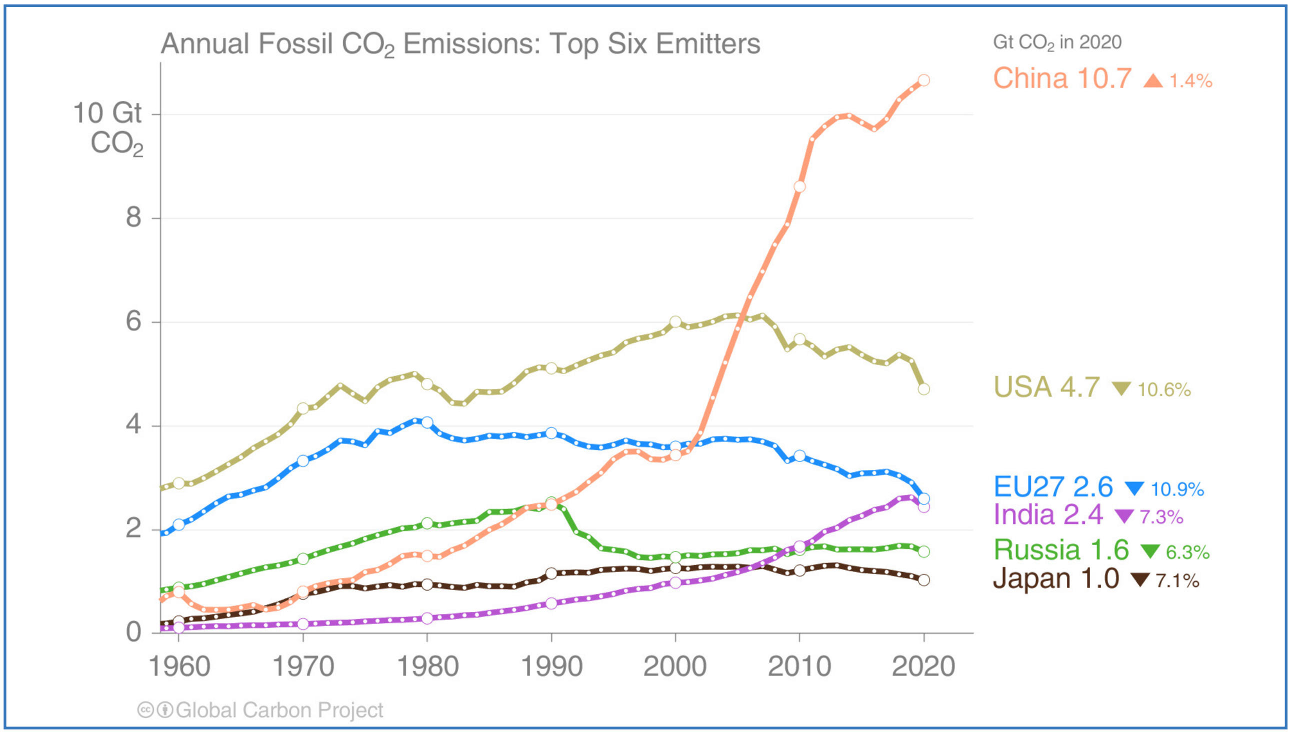
Smil writes:

> We can measure just how far the Energiewende has pushed Germany toward the ultimate goal of decarbonization. In 2000, the country derived nearly 84 percent of its total primary energy from fossil fuels; this share fell to about 78 percent in 2019. If continued, this rate of decline would leave fossil fuels still providing nearly 70 percent of the country's primary energy supply in 2050.
>
> Meanwhile, during the same 20-year period, the United States reduced the share of fossil fuels in its primary energy consumption from 85.7 percent to 80 percent, ***cutting almost exactly as much as Germany did. The conclusion is as surprising as it is indisputable. Without anything like the expensive, target-mandated Energiewende, the United States has decarbonized at least as fast as Germany, the supposed poster child of emerging greenness.*** [emphasis added][15]

14 German Federal Ministry of Economics and Technology, *Energy Concept*, 28 Sept. 2010, https://web.archive.org/web/20161006040646/http://www.germany.info/contentblob/3043402/Daten/3903429/BMUBMWi_Energy_Concept_DD.pdf

15 Vaclav Smil, Germany's Energiewende, 20 Years Later, IEEE Spectrum, 25 Nov. 2020, https://spectrum.ieee.org/germanys-energiewende-20-years-later

FIGURE 1: ANNUAL FOSSIL CO_2 EMISSIONS: TOP SIX EMITTERS



Source: Global Carbon Project, *Global Carbon Budget 2022*, https://www.globalcarbonproject.org/carbonbudget/22/presentation.htm

Energiewende has also been expensive for Germans. Smil also notes, "The average cost of electricity for German households has doubled since 2000. By 2019, households had to pay 34 American cents per kilowatt-hour, compared to 22 cents per kilowatt-hour in France and 13 cents in the U.S.."[16]

These higher energy prices in Germany have likely contributed to faster GDP growth in the U.S. compared to Germany over the past 20 years. In fact, GDP increased 10 percent faster in the U.S. than in Germany over that time period.[17]

CO_2 EMISSION REDUCTIONS IN THE U.S.

As Smil notes, in terms of decarbonization of the entire economy, the U.S. compares well to Germany. But it's also important to look at CO_2 emissions changes over time in various countries and the U.S.

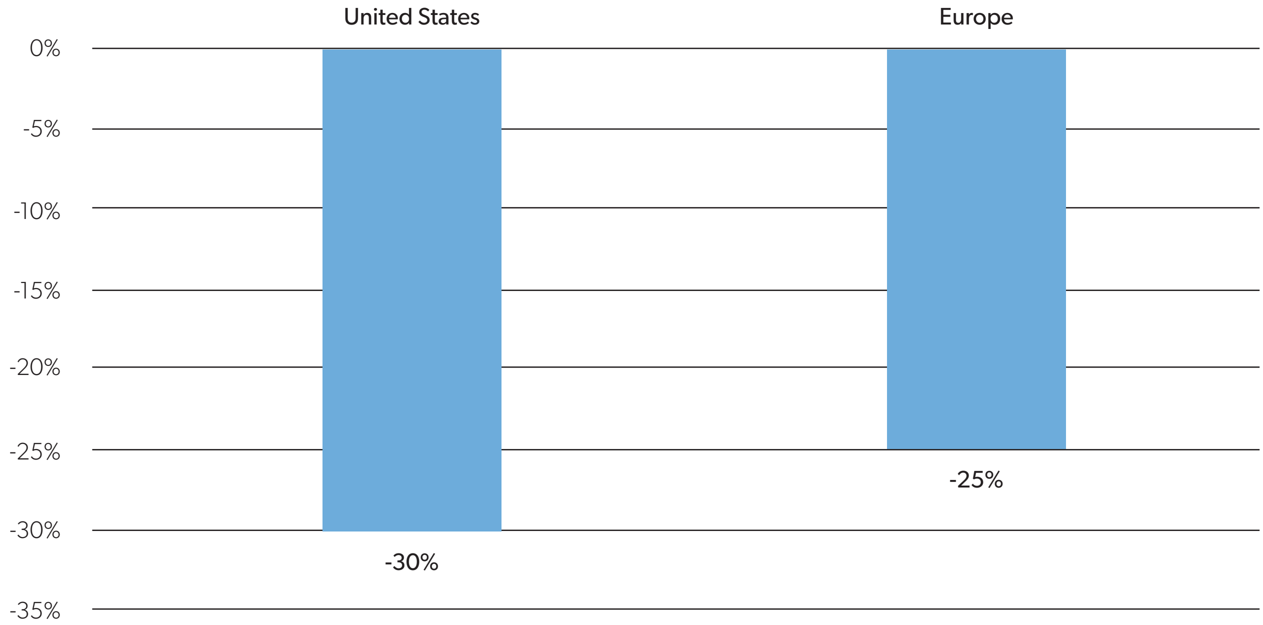
The following chart from the Global Carbon Project shows the annual CO_2 emissions from fossil fuels since 1960.[18] A few things stand out. The first is the incredible rise in CO_2 emissions in China since 2000. Second, the U.S. CO_2 emissions peaked in 2005 and have been falling ever

16 *Id.*

17 https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=DE-US

18 Global Carbon Project, *Global Carbon Budget 2022*, https://www.globalcarbonproject.org/carbonbudget/22/presentation.htm

FIGURE 2: PER CAPITA CO_2 EMISSIONS REDUCTIONS 2000-2021



Source: Calculated from data on p. 6 of Global Carbon Project power point. *See* https://www.globalcarbonproject.org/carbonbudget/22/files/GCP_CarbonBudget_2022.pptx

since. Third, CO_2 emissions from the EU peaked in about 1980 and have also been falling.

From 2000 to 2021, CO_2 emissions in the EU fell by 22 percent. In the U.S., CO_2 emissions fell by 17 percent over that same time period. From these data, it may appear that Europe is outperforming the U.S. on CO_2 emission reductions, but percentage reductions are not the whole, or arguably the most important, story.

If we compare per capita CO_2 emissions, it turns out that CO_2 emission reductions in the U.S. outpaced Europe from 2000 to 2021. In Europe, per capita CO_2 emissions fell 25 percent from 2000 to 2021, but per capita CO_2 emissions fell by over 30 percent in the U.S.[19] The reason for the difference is that the population of the U.S. grew by 18 percent over those 20 years, but the population of the EU grew by only 4 percent.[20]

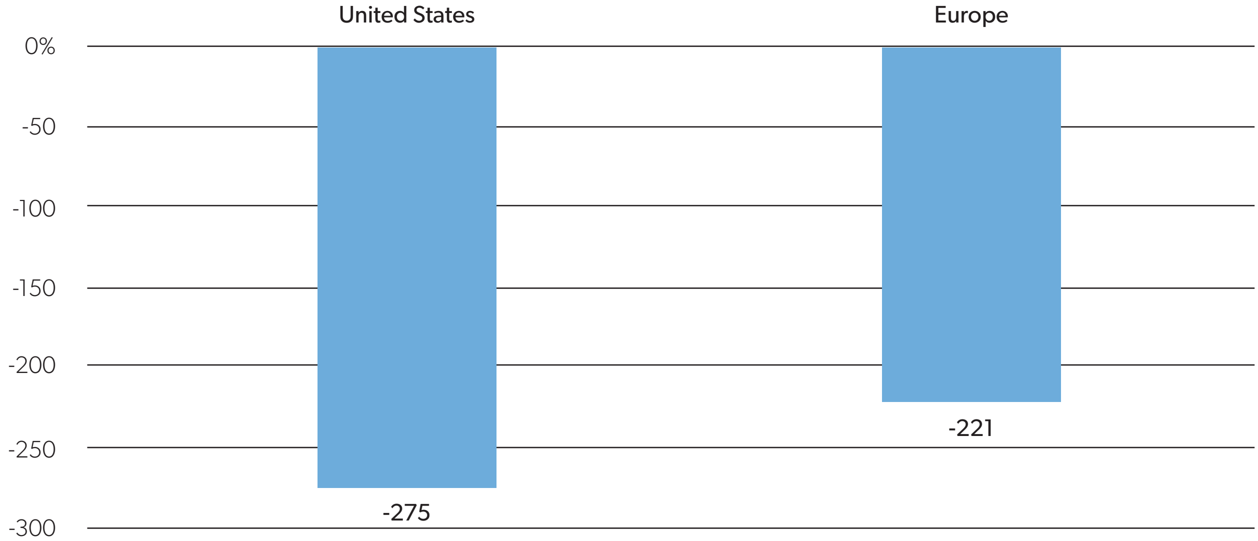
One more important metric is the absolute change in CO_2 emissions. Arguably this is a more compelling metric because the atmospheric concentration of CO_2 is more important than the percentage change from a certain country. On this metric, from 2000 through 2021, U.S. carbon emissions fell by 275 million metric tons, while EU emissions fell by 221 million metric tons.[21]

19 Calculated from data on p. 6 of Global Carbon Project power point. *See* https://www.globalcarbonproject.org/carbonbudget/22/files/GCP_CarbonBudget_2022.pptx.

20 EU Population data: *See* Eurostat Data Browser, Population change – Demographic balances and crude rates at national level, https://ec.europa.eu/eurostat/databrowser/view/DEMO_GIND__custom_5477367/default/table?lang=en: US Population Data: *See* https://web.archive.org/web/20111005052538/http://www.census.gov/prod/2001pubs/mso-01icdp.pdf and https://www.census.gov/popclock/

21 *See* Global Carbon Project, 2022 National Fossil Carbon Emissions 2022 v1.0, Territorial Emissions, https://data.icos-cp.eu/licence_accept?ids=%5B%22zL1wtJrG7Q5xdvF39YIg3IUw%22%5D

FIGURE 3: CO_2 EMISSIONS REDCUTIONS 2000-2021 IN MILLIONS TONS OF CARBON



Source: Global Carbon Project, *2022 National Fossil Carbon Emissions 2022 v1.0, Territorial Emissions*, https://data.icos-cp.eu/licence_accept?ids=%5B%22zL1wtJrG7Q5xdvF39YIg3IUw%22%5D

As these data show, the U.S. has an impressive record in terms of CO_2 emissions reductions. By many measures, the U.S. has a more impressive record than Germany or Europe, despite the narrative that Europe is far superior due to its carbon and renewable policies.

Further, the U.S. has achieved these reductions while the economy has grown faster than Germany's, and the air quality is superior to Europe's.[22] According to data from the World Health Organization, the U.S. has lower average concentrations of PM2.5 than Europe.[23]

Most climate policies are predicated on the belief that we need the heavy hand of government in the form of massive subsidies, set-asides, and mandates to achieve meaningful reductions. But that has not been the experience of the U.S.

WHAT CAN WE LEARN FROM THE U.S. REDUCTION OF CO_2 EMISSIONS?

Up until now, Europe, Germany, and the U.S. have taken very different approaches to decarbonization and attendant GHG emission reductions. While wind, solar and electric vehiclesEVs have certainly benefitted from federal and state subsidies, U.S. reductions, for the most part, have been obtained through energy innovation.[24] In fact, the vast majority of GHG emission reductions in the past have been the result of plunging prices for natural gas and, to some extent, improved wind and solar technologies.

The important lesson is that natural gas has played the

22 Jonathan Brun, Air Quality in Europe vs the United States, Nimonik, May 3, 2018, https://nimonik.com/2018/05/air-quality-in-europe-vs-the-united-states/

23 See World Health Organization, WHO Ambient Air quality database, May 15, 2023, https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database

24 The wind production tax credit and the solar investment credit having both driven more wind and solar installations than otherwise, but as noted in this section, natural gas played a bigger role than the increase in renewable generation.

central role in GHG emission reductions. According to data from the Environmental Protection Agency (EPA), 93 percent of the reduction in GHG emissions in the U.S. from 2000 to 2019 came from the electricity generation sector.[25] The majority of those emissions reductions came from the switch from coal to natural gas. In fact, in 2019, natural gas contributed 60 percent more of the reduction in emissions than non-carbon generation (mainly wind and solar).[26]

According to data from the Environmental Protection Agency (EPA), 93 percent of the reduction in GHG emissions in the U.S. from 2000 to 2019 came from the electricity generation sector. The majority of those emissions reductions came from the switch from coal to natural gas.

This boom in electricity generation from natural gas happened because natural gas production in the U.S. greatly expanded, leading to a much greater supply and significantly lower prices. This shale revolution was due to a number of factors, including better technology, reasonable regulation, political jurisdiction, and private property rights (including private ownership of the subsurface).

The shale revolution is considered to have begun in the 2000s, but that was when it culminated. It began as a series of research partnerships beginning in the 1970s between several government agencies (now largely part of DOE) and the private sector that set the stage for the boom in oil and gas production from shale formations here in the U.S.[27] DOE spent millions of dollars on various technologies that advanced the state of the art. These technological improvements included hydraulic fracturing, directional drilling, and improved subsurface imaging. But advancing the state of the art was not enough for a revolution to occur. Entrepreneurs had to take those advances in technology and further experiment by drilling wells and fracturing them to figure out how to make everything work in a cost-effective manner.

This experimentation occurred mostly on state and private land, not in large measure on federal lands. The main reason for this is the regulatory environment. State and private lands allowed for shale experimentation while still protecting the environment. For example, to get a permit to drill on federal lands in 2012, it took an average of 307 days, but only 10 days on state and private lands in North Dakota, 14 days in Ohio, and 27 days in Colorado.[28] The regulatory and permitting morass on federal lands made permitting and experimentation prohibitively expensive.

25 EPA Greenhouse Gas Inventory Data Explorer, https://cfpub.epa.gov/ghgdata/inventoryexplorer/#allsectors/allsectors/allgas/econsect/all

26 U.S. Energy Information Administration, U.S. Energy-Related Carbon Dioxide Emissions, 2019, https://www.eia.gov/environment/emissions/carbon/archive/2019/pdf/2019_co2analysis.pdf

27 Breakthrough Institute, *Where the Shale Gas Revolution Came From*, May 23, 2012, https://thebreakthrough.org/issues/energy/where-the-shale-gas-revolution-came-from

28 *See* Institute for Energy Research, *U.S. Oil Production Up, But On Whose Lands?*, Sept. 24, 2012, https://www.instituteforenergyresearch.org/fossil-fuels/gas-and-oil/u-s-oil-production-up-but-on-whose-lands-2/

In other words, the shale revolution was helped along by federal funding to advance technology, but hindered by federal regulations on federal lands.

In other words, the shale revolution was helped along by federal funding to advance technology, but hindered by federal regulations on federal lands. As a result, the U.S. saw a shale revolution gather speed almost exclusively on private and state lands in places like Pennsylvania, Texas, North Dakota, Ohio, and Colorado. And that is why the vast majority of shale production in the U.S. still occurs on state and private lands.

There are a couple of important takeaways from this history. First, the federal government indeed helped the hydraulic fracturing revolution by providing research funding to advance the technology. Second, federal regulations meant that the revolution, and subsequent CO_2 emission reductions, might not have happened if the resource was unavailable on state and private lands where entrepreneurs had access to reasonable regulatory environments.

SECTION 02

WHAT IS NEEDED FOR THE U.S. TO ACHIEVE NET-ZERO EMISSIONS?

As noted above, total CO_2 emissions from the U.S. have fallen by more than CO_2 emissions in Europe. However, there still is a long way to go to get to the Biden administration's goal of 50 percent reductions from 2005 levels by 2030 and net-zero emissions by 2050. Achieving these goals will be more than just a serious challenge. Absent a significant zero-carbon technological advancement, these goals will either be unobtainable, incredibly expensive, or simply impossible.

THE CHALLENGE OF NET-ZERO

One recent study touting pathways to get to net-zero also demonstrates how incredibly difficult achieving net-zero would be in the real world. In December 2020, after President Biden won the election, the Andlinger Center for Energy and the Environment at Princeton University released a study titled "Net-Zero America: Potential Pathways, Infrastructure, and Impacts."[29] As John Holdren, President Obama's former chief science advisor, wrote in the introduction, "This *Net-Zero America* study aims to inform and ground political, business, and societal conversations regarding what it would take for the United States to achieve an economy-wide target of net-zero emissions of greenhouse gases by 2050."[30]

To achieve net-zero, the report provides some examples of what would be required, such as:

- In all five cost-minimized energy-supply pathways, coal use is essentially eliminated by 2030.[31]

29 Eric Larson et. al., *Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final Report Summary*, Princeton University, Oct. 29, 2021, https://netzeroamerica.princeton.edu/img/Princeton%20NZA%20FINAL%20REPORT%20SUMMARY%20(29Oct2021).pdf

30 *Id.* at 5.

31 *Id.* at 10.

- Overall, fossil fuels in the primary energy mix need to decline by 62 percent to 100 percent from 2020 to 2050 across the scenarios. Oil and gas need to decline by 56 percent to 100 percent.[32]

- Renewable energy (primarily wind and solar power) supply 100 percent of primary energy in the case of high electrification and 100 percent in the renewable case by 2050 and accounts for the majority of primary energy in 2050 (60-68 percent) in the other scenarios.[33]

- Sales of light-duty EVs are between 210 million and 330 million by 2050.[34]

- 1.3 to 5.9 terawatts (TW) of solar and wind are installed, up from 0.2 TW in 2020[35]

- 2 to 5 times as much electricity transmission infrastructure is needed[36]

- In the lower renewable energy scenario, up to 250 new 1-gigawatt (GW) nuclear reactors (or 3,800 small modular reactors) are built.

- In the lower renewable energy scenario, more than 300 natural gas combined cycle plants with carbon capture and sequestration (CCS) are constructed.[37]

These changes would be massively expensive. And while there will certainly be some impressive energy technology advancements between now and 2050, it is highly unlikely that everything will line up to achieve net-zero. Here is where things stand today with respect to these challenges:

Net-Zero America Scenario Examples:

- **In all five cost-minimized energy-supply pathways, coal use is essentially eliminated by 2030.**

While there will certainly be some impressive energy technology advancements between now and 2050, it is highly unlikely that everything will line up to achieve net-zero.

For a number of years, coal use has been dramatically falling in the U.S. Electricity generation from coal peaked in 2007 and then fell by 62 percent by 2020.[38] If those trends continued, coal-fired generation could be eliminated not long after 2030.

The trends, however, did not continue. In 2021, coal use reversed course and actually increased. In fact, coal electricity generation grew by 16 percent from 2020 to 2021. One reason for this is that COVID depressed electricity demand in 2020, but it picked up in 2021.

32 *Id.*

33 *Id.*

34 *Id.* at 17

35 *Id.* The summary on page 17 says GW instead of TW, but this is obviously a typo.

36 *Id.*

37 *Id.*

38 U.S. Energy Information Administration, Monthly Energy Review March 2022, Table 7.2a, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

In 2022, coal generation resumed its decline. Coal generation fell by 8 percent from 2021, but was still up 7 percent from the lows of 2020. In 2022, coal still generated 19.5 percent of total generation, while wind and solar contributed almost 14 percent of total electricity generation. Wind and solar generation have rapidly increased. However, there are a number of factors that make it highly unlikely they will more than double over the next six years to help replace electricity generation from coal.

Net-Zero America Scenarios Continued:

- **Overall, fossil fuels in the primary energy mix decline by 62 percent to 100 percent from 2020 to 2050 across scenarios. Oil and gas decline 56 percent to 100 percent.**
- **Renewable energy (primarily wind and solar power) supply 100 percent of primary energy in the case of high electrification and 100 percent in the renewable case by 2050 and accounts for the majority of primary energy in 2050 (60-68 percent) in the other scenarios.**

To understand the challenge of a massive reduction in fossil fuel use over the next 30 years, consider the resilience of fossil fuels over the past 30 years. In 1990, coal, natural gas, and petroleum accounted for 85.6 percent of total U.S. energy consumption. In 2021, despite large increases in renewable energy production, fossil fuels still provided 78.7 percent of primary energy consumption in the U.S..[39]

In 1990, wind and solar produced 0.1 percent of the total energy consumed in the U.S. By 2022, wind and solar produced 5.7 percent of total energy consumed in the U.S. Fueled in part by subsidies and mandates along with advances in technology, energy consumed from wind and solar increased by 5.6 quadrillion BTUs between 1990 and 2022—an impressive growth.[40]

And yet, while the growth from wind and solar has been impressive, the reality is that energy consumption from fossil fuels has grown even faster. From 1990 to 2022, energy consumption from fossil fuels grew by 6.8 quadrillion BTUs.[41]

And yet, while the growth from wind and solar has been impressive, the reality is that energy consumption from fossil fuels has grown even faster. From 1990 to 2022, energy consumption from fossil fuels grew by 6.8 quadrillion BTUs.

While coal use has declined, energy consumption from natural gas has more than made up the difference. Energy consumed from natural gas increased by 13.8 quadrillion BTUs from 1990 to 2022—more than double the increase by wind and solar combined.[42]

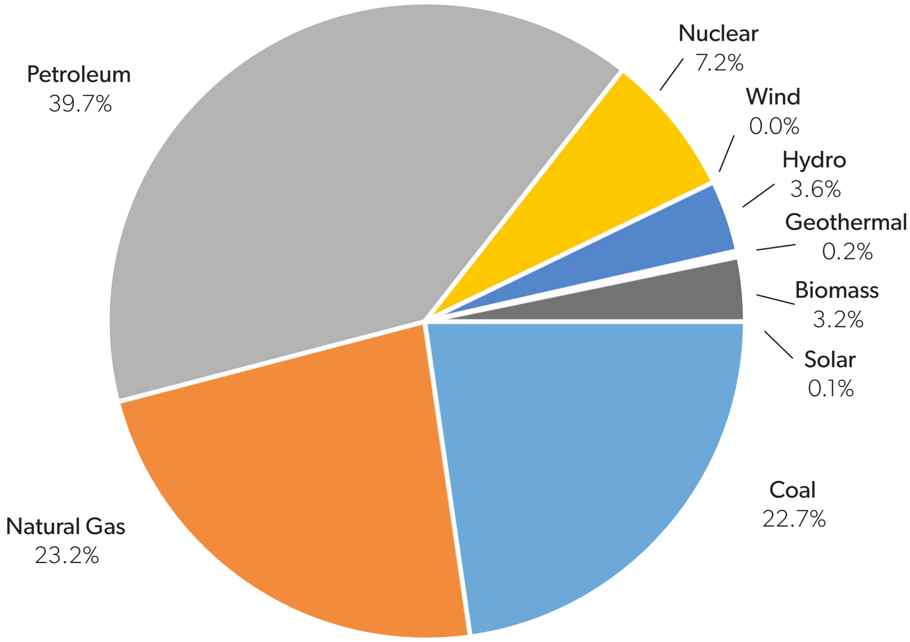
39 U. S. Energy Information Administration, Monthly Energy Review April 2023, Table 1.3, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

40 U. S. Energy Information Administration, Monthly Energy Review April 2023, Table 1.3, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

41 U. S. Energy Information Administration, Monthly Energy Review April 2023, Table 1.3, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

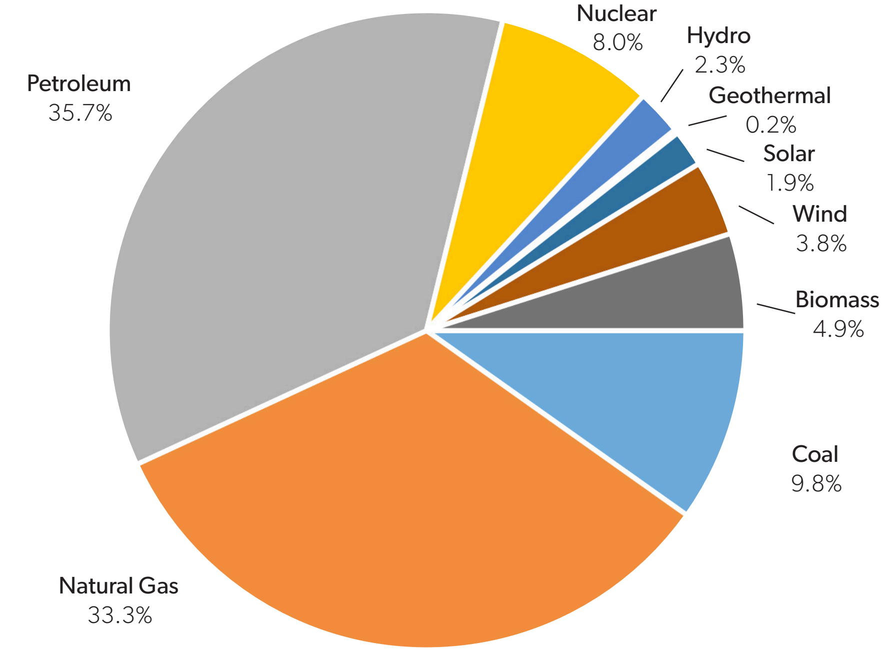
42 *Id.*

FIGURE 4: PRIMARY ENERGY CONSUMPTION BY SOURCE -- 1990



Source: Global Carbon Project, *2022 National Fossil Carbon Emissions 2022 v1.0, Territorial Emissions*, https://data.icos-cp.eu/licence_accept?ids=%5B%22zL1wtJrG7Q5xdvF39YIg3lUw%22%5D

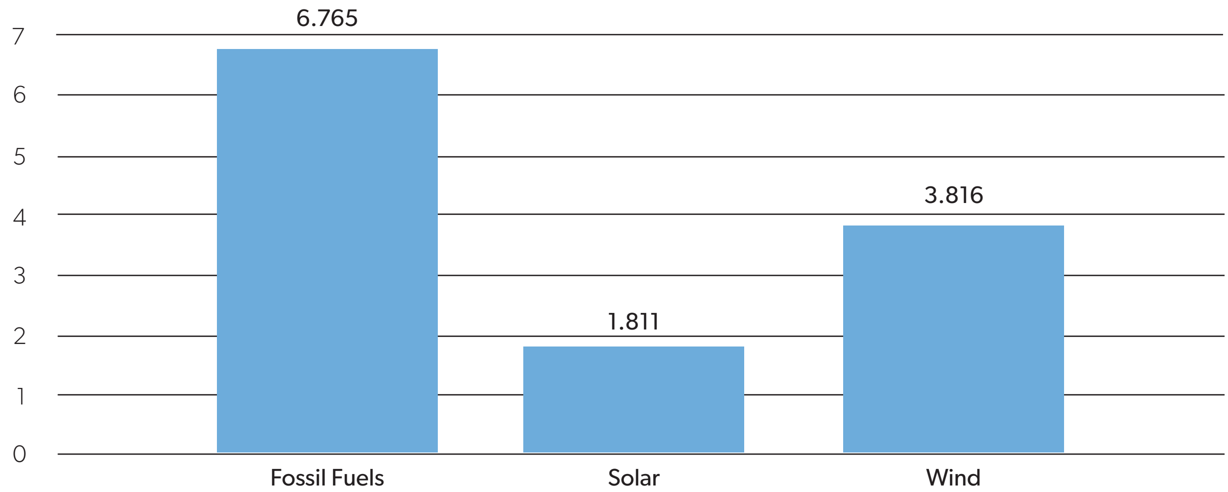
FIGURE 5: PRIMARY ENERGY CONSUMPTION BY SOURCE -- 2022



Source: Global Carbon Project, *2022 National Fossil Carbon Emissions 2022 v1.0, Territorial Emissions*, https://data.icos-cp.eu/licence_accept?ids=%5B%22zL1wtJrG7Q5xdvF39YIg3lUw%22%5D

FIGURE 6: INCREASE IN ENERGY CONSUMPTION FROM FOSSIL FUELS VERSUS SOLAR AND WIND --1990-2022

in quandrillion BTUs



Source: U. S. Energy Information Administration, Monthly Energy Review April 2023, Table 1.3, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

The net-zero scenarios model massive declines in energy from fossil fuels over the next 30 years, but over the last 30 years, energy consumption from fossil fuels has actually increased. Over the past 30 years, energy consumption from all renewables has doubled, but to replace the energy consumed from natural gas, petroleum, and coal, renewables would need to more than sextuple over the next 30 years. To replace the amount of energy currently consumed from natural gas, coal, and petroleum, with wind and solar alone would require wind and solar to increase by 14 times today's levels.[43] This will be exceedingly difficult given the growing challenges to permitting new wind and solar and the demands on land use.

Net-Zero America Scenarios Continued:

- **Between 210 million and 330 million light-duty EVs by 2050.**[44]

The last couple years have been banner years for EV sales. In 2022, a total of 807,180 EVs were sold in the U.S.—5.8 percent of all vehicles sold.[45]

Cumulatively, there have been about 3.7 million sales of plug-in EVs since 2010.[46] As of 2021, the Bureau of Transportation Statistics reports that there are 257 million light-duty vehicles in the U.S..[47] Currently, EVs account for

43 *See* U. S. Energy Information Administration, Monthly Energy Review March 2022, Table 1.3, https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

44 *Net-zero Summary* at 17.

45 William Boston, EVs made Up 10% of All New Cars Sold Last Year, Wall Street Journal, Jan. 16, 2023, https://www.wsj.com/articles/evs-made-up-10-of-all-new-cars-sold-last-year-11673818385

46 Argonne National Laboratory, *Light Duty Electric Drive Vehicles Monthly Sales Updates*, https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates.

47 Bureau of Transportation Statistics, *Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances*, Table 1-11, https://www.bts.gov/content/number-us-aircraft-vehicles-vessels-and-other-conveyances This includes light duty vehicles, long wheel base, and light duty vehicle, long wheel base.

about 1.4 percent of the stock of light duty vehicles in the U.S..

To achieve net-zero, the Princeton report projected needing between 6 and 17 percent of the vehicle stock to be EVs by 2030.[48] To get to 6 percent of the vehicle stock to be EVs by 2030, about 2.8 million EVs a year would need to be sold—3 times as many EV sales per year as the record breaking sales in 2022.[49] EV sales will certainly grow, but they are unlikely to grow enough so that 6 percent of the U.S. fleet are EVs by 2030, let alone 17 percent.

Net-Zero America Scenarios Continued:

- **1.3 to 5.9 TW of solar and wind installed, up from 0.2 TW in 2020.**
- **2 to 5 times as much electricity transmission infrastructure.[50]**

One challenge with building vast amounts of renewables is that these renewable power plants tend to take up more space per-watt than a nuclear, natural gas, or coal power plant. As Bloomberg explains, a "200-megawatt (MW) wind farm, for instance, might require spreading turbines over 13 square miles (36 square kilometers). A natural-gas power plant with that same generating capacity could fit onto a single city block."[51]

A stark example is between the land requirements of fossil fuels versus renewables today with liquid transportation fuels. Today only about 3.5 million acres of land are devoted to oil and petroleum products, while 51.5 million acres are devoted to biofuels.[52] In 2021, biofuels only made up 6 percent of domestic production, making biofuels far less land-efficient than oil production.[53]

Land use issues are also important for increased wind and solar electrification because these facilities require massive amounts of land.

The Net-Zero America report's high electrification scenario with constrained renewables results in 1.3 TW of wind and solar by 2050[54] (in that scenario, renewable buildout is constrained to 30 percent greater than the historical maximum).[55] The high electrification scenario with 100 percent renewable results in a buildout of 5.9 TW by

48 *Net-zero Final Report* at 43.

49 There are currently 253 million light duty vehicles. *See* Bureau of Transportation Statistics, *Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances*, Table 1-11, https://www.bts.gov/content/number-us-aircraft-vehicles-vessels-and-other-conveyances. From 2012 through 2021, total registered highway vehicles increased by 11 percent. If we assume the same rate of change from 2021 to 2030, then there will be about 286 light duty vehicles in 2030. *See* Bureau of Transportation Statistics, *Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances*, Table 1-11, https://www.bts.gov/content/number-us-aircraft-vehicles-vessels-and-other-conveyances. This means that by 2030, there would need to be 17.1 million EVs on the road if 6 percent of the fleet is EVs. To reach 17.1 million EVs by 2030, sales would need to total 2.4 million a year. In 2021, the US broke records with EV sales of nearly . Alex Kierstein, 2021 Sucked Generally, But Specifically Was Good for Hybrids and EVs, MotorTrend, Jan. 10, 2022, https://www.motortrend.com/news/2021-hybrid-ev-vehicle-sales-us/

50 *Id.*

51 Dave Merrill, *The U.S. Will Need a Lot of Land for a Zero-Carbon Economy*, June 3, 2021, https://www.bloomberg.com/graphics/2021-energy-land-use-economy/

52 Dave Merrill, *The U.S. Will Need a Lot of Land for a Zero-Carbon Economy*, June 3, 2021, https://www.bloomberg.com/graphics/2021-energy-land-use-economy/

53 *See* Energy Information Administration, *Monthly Energy Review May 2022*, Table 2.5 Transportation Sector Energy Consumption, https://www.eia.gov/totalenergy/data/monthly/pdf/sec2_13.pdf

54 *Net-zero Final Report* at 140.

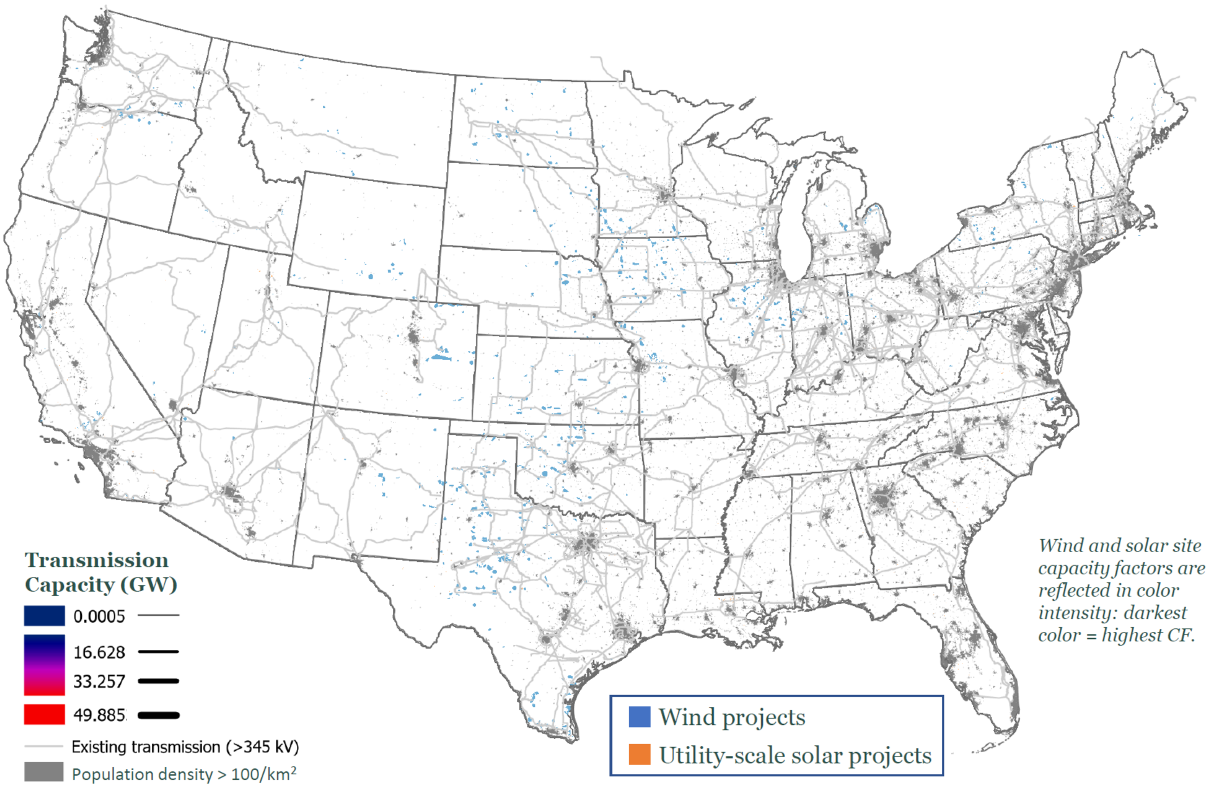
55 *Net-zero Summary Report* at 10.

2050.[56] Achieving this wind and solar buildout would require decades of record-breaking installations.

To build 1.3 TW of wind and solar by 2050 would require a cumulative capital investment of $1.4 trillion and consume a massive land area.[57] As the report explains, "by 2050, wind and solar farms span a total area of about 260,000 km^2, with wind farms accounting for 95 percent of this." To put 260,000 km2 in perspective, it is larger than the size of Oregon, Wyoming, Michigan, or New England.[58]

The maps below show the projected buildout necessary to achieve net-zero.

FIGURE 7: 2020 E + RE- BASE



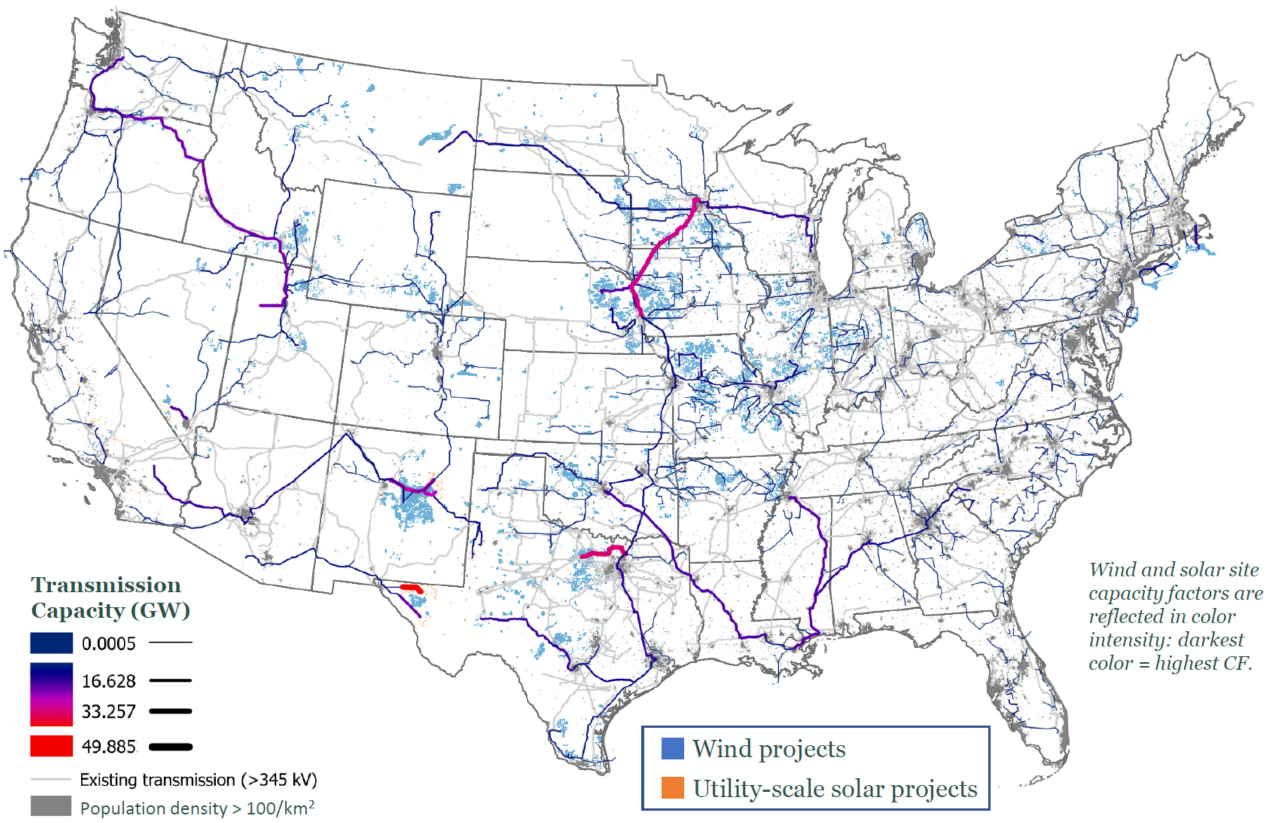
Source: *Net-zero America Final Report* at p. 137

56 *Net-zero Final Report* at 133.

57 *Net-zero Final Report* at 136.

58 *See* List of U.S. states and territories by area, Wikipedia, accessed May 27, 2022, https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_area#:~:text=Land%2C%20water%20and%20total%20area%20by%20U.S.%20state%2C,%20%203%2C535%2C948.12%20%2019%20more%20rows%20

FIGURE 8: 2050 E + RE- BASE



Source: *Net-zero America Final Report* at p. 140

The graphic shows the buildout in the high electrification, constrained renewable scenario.

This constrained renewable energy scenario results in 270 GW of solar and onshore wind installed by 2030 and 650 GW of each by 2050.59 As of the beginning of 2023, there were 142 GW of solar capacity and 146 GW of onshore wind capacity installed,60 so this scenario calls for doubling the total wind and solar capacity that has been built over the last 30 years in the next 6 years, and a 4.5 times increase over the next 30 years.

While it may be possible to increase the wind and solar capacity this quickly, the scenario calls for an unlikely 40 percent increase in transmission capacity by 2030 and a 100 percent increase in transmission capacity by 2050.[61] To comprehend how difficult that would be to achieve, it is important to understand that from the 1970s to the late 2010s, transmission grew by about 1.5 percent per year. In the last five years, that growth has been reduced to 1 percent per year.[62] At this rate 40 percent growth in 5 years and 100 percent growth in 27 years seem incredibly unlikely.

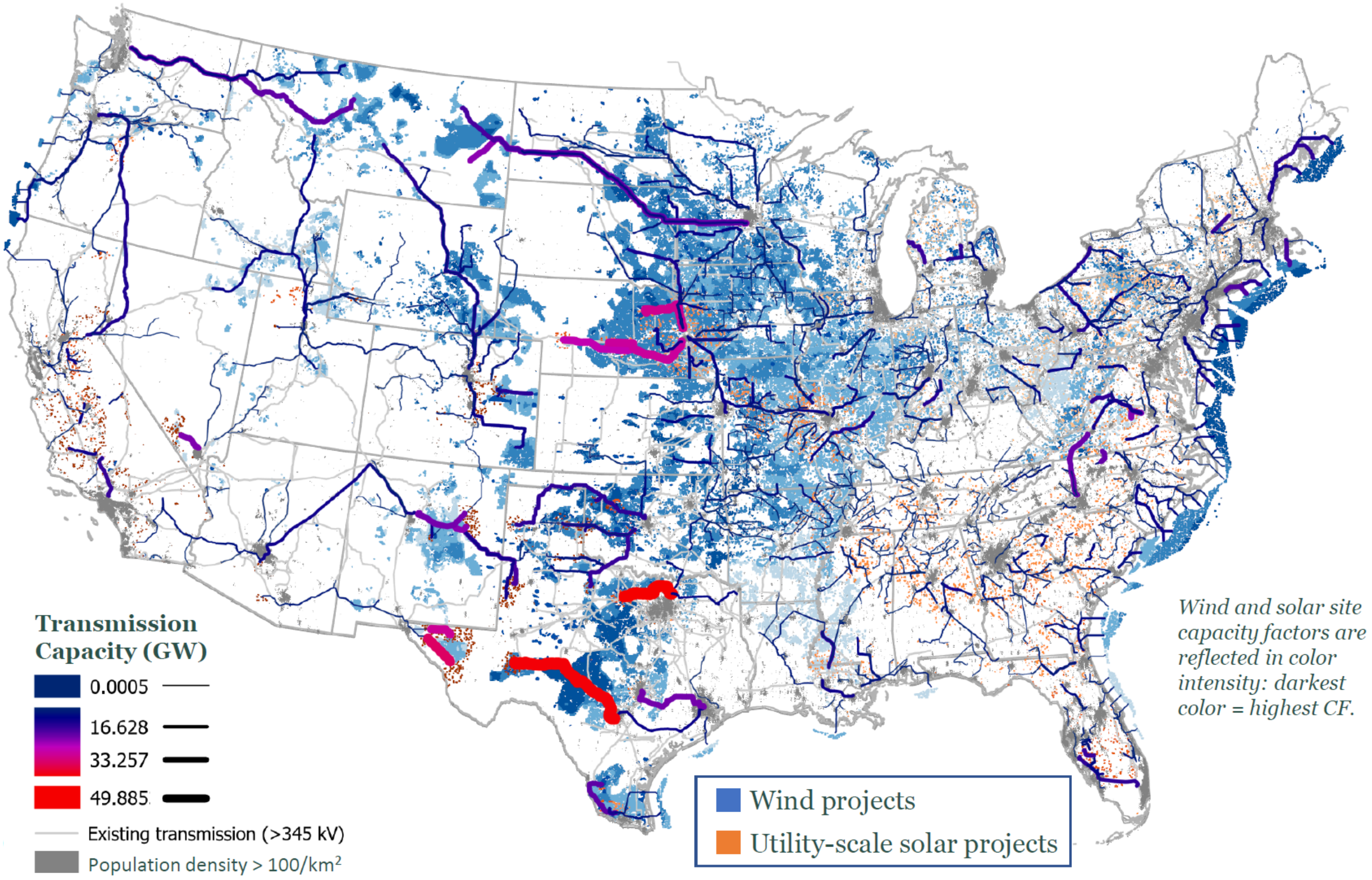
59 *Net-zero Final Report* at 136.

60 American Clean Power, Wind power facts, https://cleanpower.org/facts/wind-power/#:~:text=Today%2C%20nearly%2070%2C000%20wind%20turbines%20across%20the%20country,serve%20the%20equivalent%20of%2043%20million%20American%20homes.

61 *Net-zero Final Report* at 136.

62 Michael Cembalest, *Growing Pains: The Renewable Transition in Adolescence*, J.P. Morgan, March 28, 2023, https://assets.jpmprivatebank.com/content/dam/jpm-wm-aem/campaign/energy-paper-13/growing-pains-renewable-transition-in-adolescence.pdf

FIGURE 9: 2050 E + RE+ BASE



Source: *Net-zero America Final Report* at p. 133

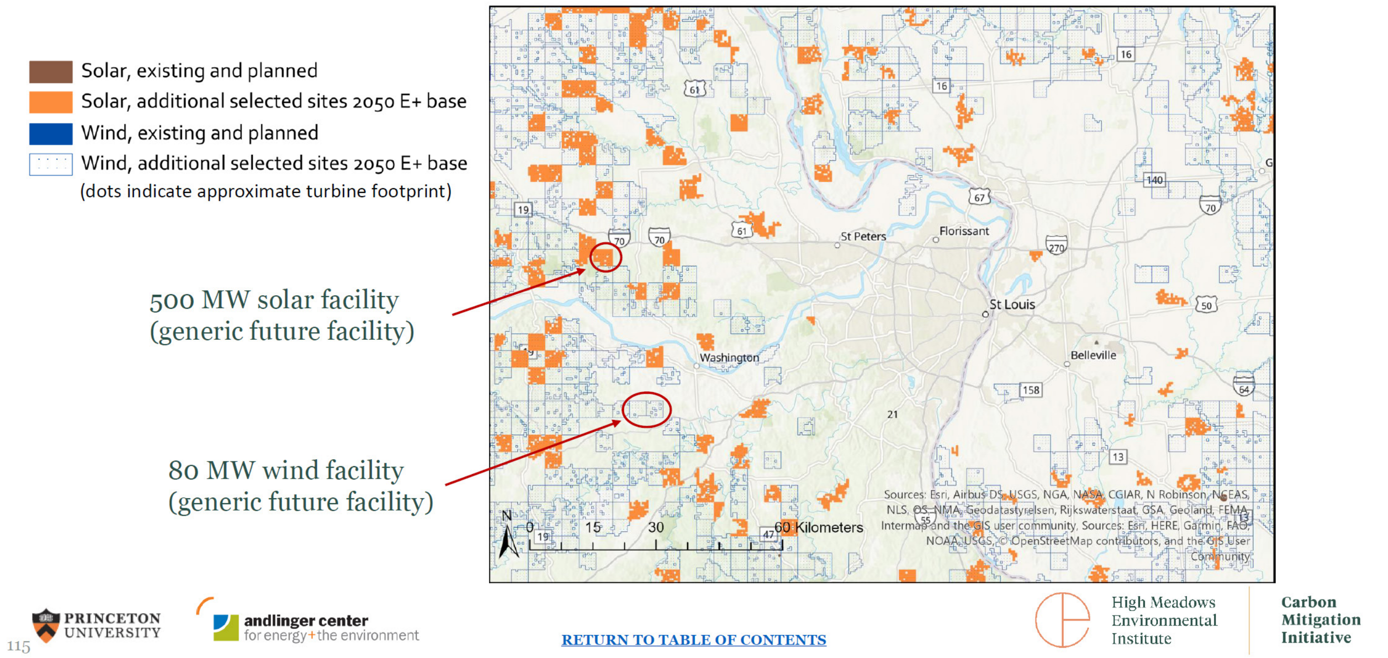
The 100 percent renewable scenario would require installing 5.8 TW of wind and solar capacity by 2050.[63] This is over 20 times as much new wind and solar in the next 30 years as has been built in the U.S. to date. Not only would it require a massive buildout of wind and solar generation, but it would also require transmission capacity to grow by 75 percent by 2030 and 400 percent by 2050.[64] The 100 percent renewable case would also use more than 1,000,000 km^2 for renewable generating facilities. That is nearly the size of all of the states that comprise the eastern seaboard from Georgia to Maine and does not include the battery storage that would be needed.

There are a number of reasons it will be challenging to build this much wind and solar. The Net-Zero America report provides excellent examples not only of the overall maps of the U.S., but some examples of what this buildout looks like over a much smaller area, such as the St. Louis region or Minneapolis region. Note that in the two examples below, there are very few existing wind and solar facilities.

63 *Net-zero Final Report* at 129.

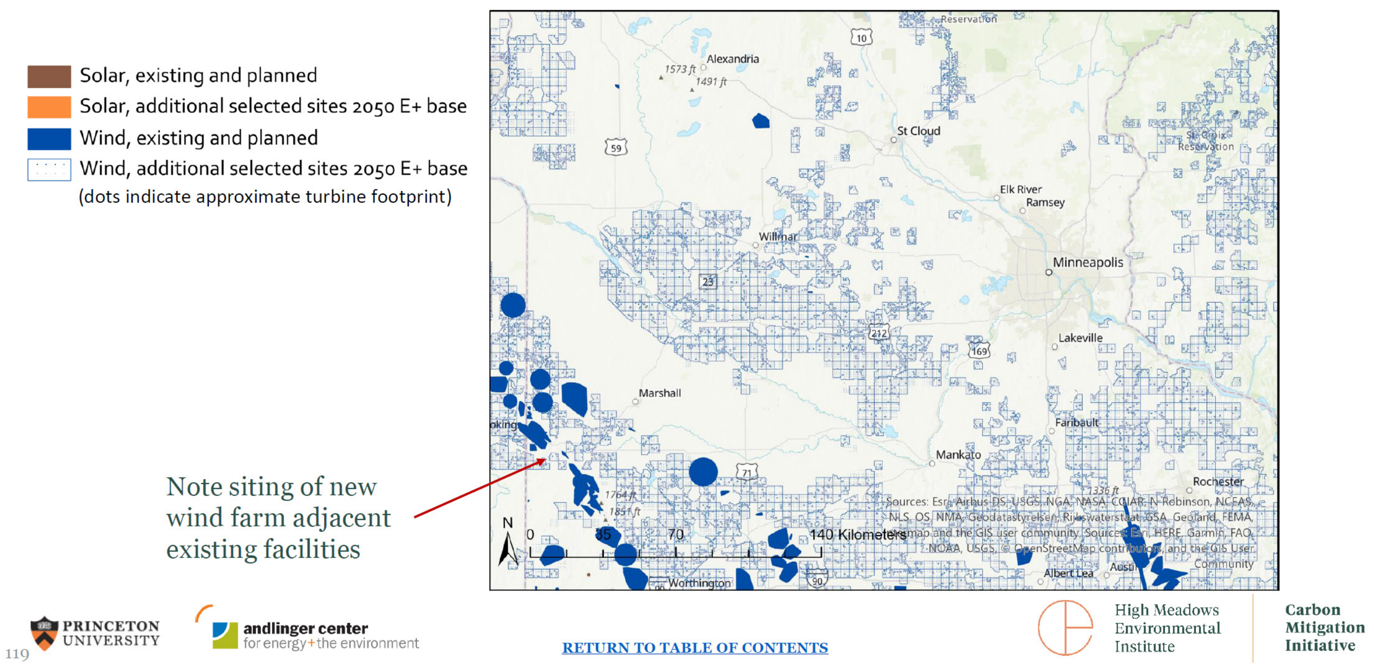
64 *Net-zero Final Report* at 129.

FIGURE 10: EXAMPLE AREA DETAIL: ST. LOUIS, MO, 2050 WIND AND SOLAR FARMS (E+ BASE SITING)



Source: *Net-zero America Final Report* at p. 115

FIGURE 11: EXAMPLE AREA DETAIL: MINNEAPOLIS, MN, 2050 WIND AND SOLAR FARMS (E+ BASE SITING)



Source: *Net-zero America Final Report* at p. 119

THE LACK OF SOCIAL ACCEPTANCE FOR BUILDING MASSIVE AMOUNTS OF RENEWABLE GENERATION

One serious challenge to building this much wind and solar is the lack of social acceptance for such a massive buildout. For example, the Sierra Club recently chronicled this with an article titled, "The NIMBY Threat to Renewable Energy."[65] As the Sierra Club explains, "in Vermont, everyone loves clean energy—when it comes from someplace else." Vermonters rejected new wind development in 2015, 2016, and again in 2020. In 2016, the town of Swanton rejected a small wind development of only seven towers by a vote of 731 to 160.[66] "Wind is a four-letter word in Vermont," one Vermonter told the Sierra Club.[67]

Here is how the Sierra Club explains the overall challenge:

> Some opposition to renewable energy projects is based on legitimate concerns about protecting natural spaces. But a good portion of the resistance is due to NIMBYism—the "not in my backyard" syndrome. Both anti-development gadflies and wealthy communities with big bankrolls have become adept at stopping needed projects. In Vermont—as elsewhere in the nation—you can't underestimate the power of people not wanting to look at something and having the means to make the problem go away.
>
> "It's people with good intentions not wanting to see change in their little piece of the world," Moore says. "We might dress it up in flannel in Vermont, but NIMBYism is NIMBYism. I think we are dangerously close to letting the perfect be the enemy of a livable planet."[68]

The challenge of building new wind and solar projects is not limited to the opposition in Vermont. Author Robert Bryce has documented 350 rejections or restrictions on wind and solar projects in the U.S. since 2015.[69] These include rejections and restrictions in California, Rhode Island, Iowa, Montana, and many other states.[70]

Bryce explains how California's net-zero goals will run up against the difficulty of building new generation. He writes:

> In March, the California Energy Commission issued a report on "how the state's electricity system can become carbon free by 2045." According to the report, achieving that goal will require adding new renewable capacity "at a record-breaking rate for the next 25 years. On average, the state may need to build up to 6 GW of new renewable and storage resources annually. By comparison over the last decade, the state has built on average 1 GW of utility solar and 300 MW of wind per year."[71]

---

65 Jim Motavalli, The NIMBY Threat to Renewable Energy, Sierra, Sept. 20, 2021, https://www.sierraclub.org/sierra/2021-4-fall/feature/nimby-threat-renewable-energy

66 Robert Bryce, *Here's The List Of 317 Wind Energy Rejections The Sierra Club Doesn't Want You To See*, Forbes, Sept. 26, 2021, https://www.forbes.com/sites/robertbryce/2021/09/26/heres-the-list-of-317-wind-energy-rejections-the-sierra-club-doesnt-want-you-to-see/?sh=7efd1c065bad

67 *Id.*

68 Jim Motavalli, The NIMBY Threat to Renewable Energy, Sierra, Sept. 20, 2021, https://www.sierraclub.org/sierra/2021-4-fall/feature/nimby-threat-renewable-energy

69 Robert Bryce, *Renewable Rejection Database*, https://robertbryce.com/renewable-rejection-database/

70 *See* id.

71 Robert Bryce, *Renewable Rejection Database*, https://robertbryce.com/renewable-rejection-database/

The challenge of building more renewable generation is not limited to the U.S. This is a global issue, especially in areas with mature renewable facilities. For example, in Germany, the buildout of wind and solar facilities has greatly slowed.

According to Deutsche Welle (DW), a state funded media outlet:

> All over Germany, only 35 new windmills with a combined output of a mere 290 MW were installed in the first half of 2019 — a decline of more than 80 percent compared with the same period [the previous] year and the lowest total in almost two decades. In 2018, Germany installed wind turbines with a total capacity of 2,800 MW. That in itself was a sharp drop from 2017 when Germany added more than 5,000 MW of wind capacity on land.
>
> "The situation in the wind power sector is a catastrophe. We are facing the slowest buildup of capacity in the past 20 years, while the government at the same time is claiming to fully support and implement the Paris climate goals," says Reiner Priggen, a former MP of the Greens and now a chief wind power lobbyist for Germany's Renewable Energies Association.[72]

In Germany, wind capacity grew by only 2.1 percent from 2019 to 2020, while wind capacity grew by 13.4 percent over the same time period in the U.S..[73] While there have been a number of rejections of renewable projects in the U.S., it could certainly get worse, as the example of Germany shows.

THE CHALLENGE OF BUILDING ELECTRICITY TRANSMISSION

The challenge of building enough to meet net-zero targets is not only limited to new wind and solar facilities but also transmission. Net-Zero America's high electrification, constrained renewable scenario requires 96 percent more transmission in 2050 than today, and the 100 percent renewable scenario requires a 409 percent increase over today's electrical transmission.[74]

The challenge of building enough to meet net-zero targets is not only limited to new wind and solar facilities but also transmission.

Building new transmission is exceedingly difficult. In November 2021, 59 percent of voters in Maine banned the construction of "high-impact" transmission lines and required a two-thirds approval from the state legislature to build similar projects.[75] This stopped the construction of the New England Clean Energy Connect powerline designed to bring hydropower from Quebec through Maine to Massachusetts. This is not the first time that New Englanders have killed renewable-friendly transmission.

72 DW, German wind energy stalls amid public resistance and regulatory hurdles, April 9, 2019, https://www.dw.com/en/german-wind-energy-stalls-amid-public-resistance-and-regulatory-hurdles/a-50280676

73 BP, Statistical *Review of World Energy 2021*, Renewable energy: Wind capacity, p. 59,

74 *Net-zero Final Report* at 133.

75 David Iaconangelo, *$1B transmission smack down may upend Northeast renewables*, Energywire, Nov. 12, 2021, https://www.eenews.net/articles/1b-transmission-smack-down-may-upend-northeast-renewables/

The Northern Pass line would have run from Canada through New Hampshire but was rejected in 2019.

New England is not the only region to reject new transmission lines. Citizens in the mid-Atlantic states killed the Potomac-Appalachian Transmission Highline, and citizens in Montana and Idaho killed the Mountain States Transmission Intertie. The 700-mile Plains and Eastern Line, also known as Clean Line, would have delivered renewable electricity from Oklahoma to Georgia, the Carolinas, and Florida. It was killed because people in Arkansas and Tennessee saw no benefits, only downsides to the transmission line for their state.[76]

New England is not the only region to reject new transmission lines. Citizens in the mid-Atlantic states killed the Potomac-Appalachian Transmission Highline, and citizens in Montana and Idaho killed the Mountain States Transmission Intertie.

Another issue with building new transmission is the time it takes for final approval. For example, the SunZia transmission project, which would traverse 520 miles from New Mexico to Arizona, has been in development since 2006 and has yet to begin construction.[77] In May 2023, the Biden administration celebrated that they approved the Record of Decision for the Environmental Impact Statement for this transmission line.[78] This is good news, but it can take years after the Record of Decision for the government to take the next step and issue a Notice to Proceed. In fact, in the case of the TransWest Express transmission line, the federal government issued four Records of Decision from December 2016 through June 2017, but the federal government didn't grant the Notice to Proceed to construction until April 2023—nearly six years after the last Record of Decision.[79]

An example of a transmission line that did get the green light to proceed is the 732-mile TransWest Expressline, which received final approval to proceed from the Bureau of Land Management in April, and will carry power from two Wyoming wind projects to California. But even this approved project is facing pushback and has been 18 years in the making.[80]

Building new electricity transmission is difficult and time-consuming. To double our current transmission infrastructure over the next 30 years, as is envisioned in one of Net-Zero America's lower-renewable scenarios, would be a massive undertaking. As with a massive buildout of new renewable generation, there does not appear to be the social license to build any substantial new transmission, let alone a doubling or a quintupling of it.

76 *See* Dave Flessner, *Environmentalists blast TVA for killing major wind project*, Chattanooga Times Free Press, Dec. 31, 2017, https://www.timesfreepress.com/news/local/story/2017/dec/31/cleline-power-plsetbackenvironmentalists-blas/460332/

77 SunZia, From Concept to Reality, https://sunzia.net/timeline/. In the case of SunZia, the NEPA process alone lasted 6 years. https://www.blm.gov/programs/planning-and-nepa/plans-in-development/new-mexico/proposed-sunzia-transmission-project

78 U.S. Department of Interior, Biden-Harris Administration Advances SunZia Southwest Transmission Project, May 18, 2023, https://www.doi.gov/pressreleases/biden-harris-administration-advances-sunzia-southwest-transmission-project.

79 TransWest Express, *Schedule and Timeline*, https://www.transwestexpress.net/about/timeline.shtml

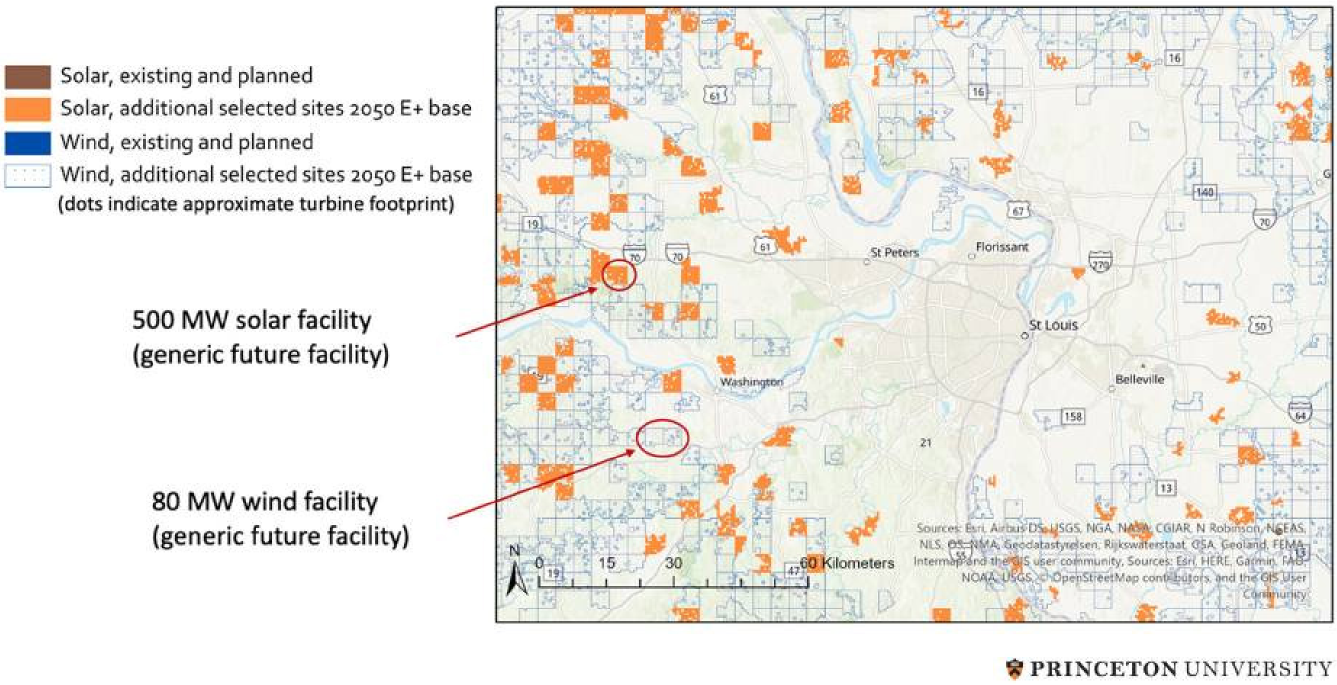
80 Gabriela Aoun Angueira, *Massive transmission line will send wind power from Wyoming to California*, Grist, April 17, 2023, https://grist.org/energy/massive-transmission-line-will-send-wind-power-from-wyoming-to-california/.

WHO IS IMPACTED BY NET-ZERO LAND USE REQUIREMENTS

Another challenge to building the renewables and transmission necessary to achieve net-zero goals is that the people most frequently impacted by the land use requirements do not share equally in the benefits. One example is this project highlighted by the map below, which shows possible wind and solar buildout around St. Louis.[81] What is striking about the map is that the buildout is primarily in rural and exurban areas and not in suburban areas around St. Louis.

This raises issues of disproportionate impact on poorer communities, the sorts of issues that the Biden administration and activists classify as "equity and social justice." If the wishes and desires of urban and suburban communities trump rural and exurban communities, which are generally poorer, a massive renewables and transmission buildout is unlikely to meet the standards for equity and social justice that the administration and many states are insisting on being factored into the regulatory decision-making processes. This will only exacerbate the permitting and approval challenges already facing transmission and renewables projects.

FIGURE 12: EXAMPLE AREA DETAIL: ST. LOUIS, MO, 2050 WIND AND SOLAR FARMS (E+ BASE SITING)



Source: *Net-zero America Final Report* at p. 123

81 *Net-Zero America, Interim Report*, p. 123, https://environmenthalfcentury.princeton.edu/sites/g/files/toruqf331/files/2020-12/Princeton_NZA_Interim_Report_15_Dec_2020_FINAL.pdf

WILL THE COST OF RENEWABLES CONTINUE TO FALL?

Another challenge to the massive buildout of renewable energy is the cost of renewables. One of the reasons wind and solar capacity has dramatically increased in the U.S. over the past 20 years is that the cost of installations has fallen dramatically. For example, solar panel costs fell by 90 percent from 2011 to 2020. But that decrease is not guaranteed to continue. Indeed, recently that trend has reversed.[82] Solar panel prices in 2021 were up by 18 percent.[83]

Price increases do not necessarily mean that wind and solar will not be installed, but rather that the rate of their installation will slow down. In 2021, installed solar increased by 23.6 GW in the U.S., a 19 percent increase over 2020.[84] But Wood Mackenzie recently decreased their near-term solar forecast by 19 percent due to supply chain, inflation, and interconnection challenges.

Commodity prices have greatly increased over the past few years, and renewable energy technologies are much more material intensive than coal, oil, and natural gas technologies. According to data from IEA, offshore wind requires 13 times as many minerals as natural gas, onshore wind requires more than 8 times as many, and solar requires nearly 6 times as many minerals.[85] It remains to be seen how higher commodity costs translate into the final price of solar, wind, and other renewable technologies or how long they will continue to climb.

Net-Zero America Scenarios Continued:

- **In the lower renewable energy scenario, up to 250 new 1-GW reactors (or 3,800 small modular reactors [SMRs]).**
- **In the lower renewable energy scenario, more than 300 natural gas combined cycle plants with CCS.[86]**

THE CHALLENGE OF NEW NUCLEAR PLANTS

Some scenarios in the Net-Zero America report reach net-zero through the use of large amounts of nuclear energy as well as fossil-fuel power plants utilizing CCS. Again, it is unclear how this could actually happen given today's regulatory and economic realities in the case of nuclear and technological and economic financial realities in the case of natural gas with CCS.

Of the 99 GW of nuclear generation capacity that existed in 2017, 95 GW came on line between 1970 and 1990.[87] Between 1996 and 2016, no new commercial nuclear reactors came on line. In 2016, Watts Bar Nuclear Generation Station entered commercial operations. Construction on Vogtle Electric Generation Plant Units 3 and 4 was started in 2013, but Unit 3 didn't reach 100 percent power until May 29, 2023, and Unit 4 is projected

82 Dan Murtaugh and Brian Eckhouse, *Solar Power's Decade of Falling Costs Is Thrown Into Reverse*, Bloomberg, May 23, 2021, https://www.bloomberg.com/news/articles/2021-05-23/solar-power-s-decade-of-falling-costs-is-thrown-into-reverse

83 *Id.*

84 Solar Energy Industry Association, *Solar Market Insight Report 2021 Year in Review*, https://www.seia.org/research-resources/solar-market-insight-report-2021-year-review

85 *See* International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

86 Solar Energy Industry Association, *Solar Market Insight Report 2021 Year in Review*, https://www.seia.org/research-resources/solar-market-insight-report-2021-year-review

87 Energy Information Administration, *Most U.S. nuclear power plants were built between 1970 and 1990*, Apr. 27, 2017, https://www.eia.gov/todayinenergy/detail.php?id=30972#tab2

to be completed in late 2023 or early 2024.[88] The cost of the two reactors is now estimated at over $30 billion, more than twice the original estimate.[89]

SMRs are also interesting. These are advanced reactor designs of less than 300 MW(e) per unit which can be used individually or used together for additional power. They have advantages over traditional reactor designs because of this modularity, ease of transportation, and passive safety features inherent to the design.[90] But, not a single unit is in commercial operation in the U.S., let alone the thousands necessary to scale up to the 3,800 SMRs envisioned to get to net-zero.

THE CHALLENGE OF CCS PLANTS

Similar issues challenge the idea that hundreds of natural gas plants will be fitted with CCS technologies and still make natural gas-powered generation economical. Like new nuclear, the only carbon capture plants that have been built have been plagued by cost overruns. A CCS plant was constructed in Kemper, Mississippi, for about $7.5 billion.[91] It was years behind schedule and billions over budget. In the end, the plant did not perform well and was mothballed.[92] Another CCS plant, Petra Nova in Texas, was more successful than Kemper in part because the CO_2 it captured was used for enhanced oil recovery. But in 2020, when oil prices plummeted, the plant was shuttered.[93]

Given the history of nuclear and CCS plants in the U.S., there is little evidence to suggest it is possible to build dozens of new plants let alone hundreds or, in the case of SMRs, thousands. Major regulatory and financial hurdles must be overcome before we begin considering building even a few dozen of these types of plants.

CONCLUSION FOR CHALLENGES OF NET-ZERO

The Net-Zero America report shows the possible pathways to get to net-zero. It also shows how incredibly difficult achieving net-zero will be given current technologies and economic conditions.

To get to net-zero, coal use would need to go away rather quickly, but even though coal generation has been falling, it still produced nearly 20 percent of electricity generation in 2022, while wind and solar combined only produced 14 percent. The Biden administration is seeking to regulate coal generation out of existence. Still, it would be incredibly difficult to replace 20 percent of total electricity generation in the U.S. in only 6 years without severe economic consequences. This is especially true because wind and solar, which currently generate only 14 percent of our electricity, is not dispatchable. Overall, in the net-zero scenarios, coal, oil, and natural gas use needs to decrease by at least 56 percent over the next 30 years, but even with the large increases in wind and solar over the past 30 years, the percentage of energy consumption from fossil fuels only fell from 85.6 percent of total energy

---

88 Southern Company, *Building carbon-free nuclear energy: Plant Vogtle Units 3 and 4*, https://www.southerncompany.com/innovation/vogtle-3-and-4.html

89 Jeff Amy, *'Outrageous' price tag: Plant Vogtle cost doubles to $28.5 billion as other owners balk*, The Augusta Chronicle, Nov. 4. 2021, https://www.augustachronicle.com/story/news/2021/11/04/georgia-power-nuclear-reactors-plant-vogtle-cost-doubles-energy-costs/6286729001/ ; Jeff Amy, "Georgia nuclear plant again delayed at cost of $200M more' Associated Press, Feb. 16th 2023, https://apnews.com/article/georgia-power-co-southern-climate-and-environment-business-3b1d6c65353c6a65b1ccfddede753ab7

90 Joanne Liou, *What are Small Modular Reactors (SMRs)?*, IAEA, Nov. 4, 2021, https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs

91 Katie Fehrenbacher, *Carbon Capture Suffers a Huge Setback as Kemper Plant Suspends Work*, Greentech Media, June 29, 2017, https://www.greentechmedia.com/articles/read/carbon-capture-suffers-a-huge-setback-as-kemper-plant-suspends-work

92 Kristi E. Swartz, *The Kemper project just collapsed. What is signifies for CCS*, Energywire, Nov. 26, 2021, https://www.eenews.net/articles/the-kemper-project-just-collapsed-what-it-signifies-for-ccs/

93 NRG, *Petra Nova status update*, Aug. 26, 2020, https://www.nrg.com/about/newsroom/2020/petra-nova-status-update.html

consumption to 78.7 percent. Also, the total use of fossil fuels grew by nearly 7 quadrillion BTUs over the same time period. In other words, over the past 30 years, our use of fossil fuels grew even as our use of wind and solar grew.

EV sales would need to rapidly increase to displace the use of gasoline and diesel-powered vehicles. From 2020 to 2021, EV sales grew by an impressive 83 percent. However, in Net-Zero America's low electrification scenario, EV sales would need to be 5 times current sales every year through 2030.

Displacing coal, natural gas, and oil consumption and replacing them with renewable energy would require over 280 millions of acres to be turned over to wind and solar alone.[94] As we have already seen, many people do not like these changes to land use, resulting in the cancelling of hundreds of renewable projects as well as many transmission projects. The massive renewable buildout also raises issues about the disproportionate impact on poorer communities. Further, an all renewable scenario would mean massive amounts of battery storage would be needed, requiring even more land areas and expense. At the moment, there simply does not appear to be the needed social license for such a massive renewable buildout.

Displacing coal, natural gas, and oil consumption and replacing them with renewable energy would require over 280 millions of acres to be turned over to wind and solar alone.

While nuclear energy and natural gas projects with CCS technology could be one path to net-zero, we need some real world examples of these projects working in a cost-effective manner. Before Vogtle, the last commercial nuclear reactor came online more than 7 years ago, two decades after the next newest unit. SMRs are very interesting and could be very valuable, but they are not yet commercially viable. The few carbon capture projects built in the U.S. have all failed.

94 Net-Zero Final Report at 129 (More than 1 million km2 for wind and solar onshore; 64,000 km2 for offshore wind; 66,000 km2 for lands directly impacted by wind and solar facilities).

SECTION 03

WHAT ARE THE MATERIAL AND MINERAL REQUIREMENTS FOR ACHIEVING NET-ZERO?

An energy economy powered by renewables and batteries would require far more materials than a hydrocarbon-based energy economy. As the World Bank has stated, "the technologies assumed to populate the clean energy shift—wind, solar, hydrogen, and electricity systems—are in fact significantly more material intensive in their composition than current traditional fossil-fuel-based energy supply systems."[95]

This reality creates several major challenges. First, the supply chains for these materials, especially materials processing, are much more concentrated than fossil fuel production, with China dominating the processing of these materials. Second, commodity prices have rapidly increased in recent years, questioning whether we will continue to see massive cost decreases that have enabled the impressive expansion of wind, solar, and batteries. Third, the increase in costs highlights the fact that the supply chains and capacity for the volume of materials needed for net-zero do not currently exist and it will likely take decades to grow them.[96]

THE CONCENTRATION OF NET-ZERO SUPPLY CHAINS

A number of international organizations, including the World Bank and IEA, have explained the reality that a net-zero economy, or a "clean energy shift," requires far more materials than an energy economy dominated by natural gas, oil, and coal.

95 World Bank Group, *The Growing Role of Minerals and Metals for a Low Carbon Future*, June 2017, https://documents1.worldbank.org/curated/en/207371500386458722/pdf/117581-WP-P159838-PUBLIC-ClimateSmartMiningJuly.pdf

96 *See* Gabrielle Coppola, *'Mr. Lithium' Warns There's Not Enough Battery Metal to Go Around*, Bloomberg, Apr. 22, 2022, https://www.bloomberg.com/news/articles/2022-04-22/mr-lithiumalr-warns-there-s-not-enough-battery-metal-to-go-around

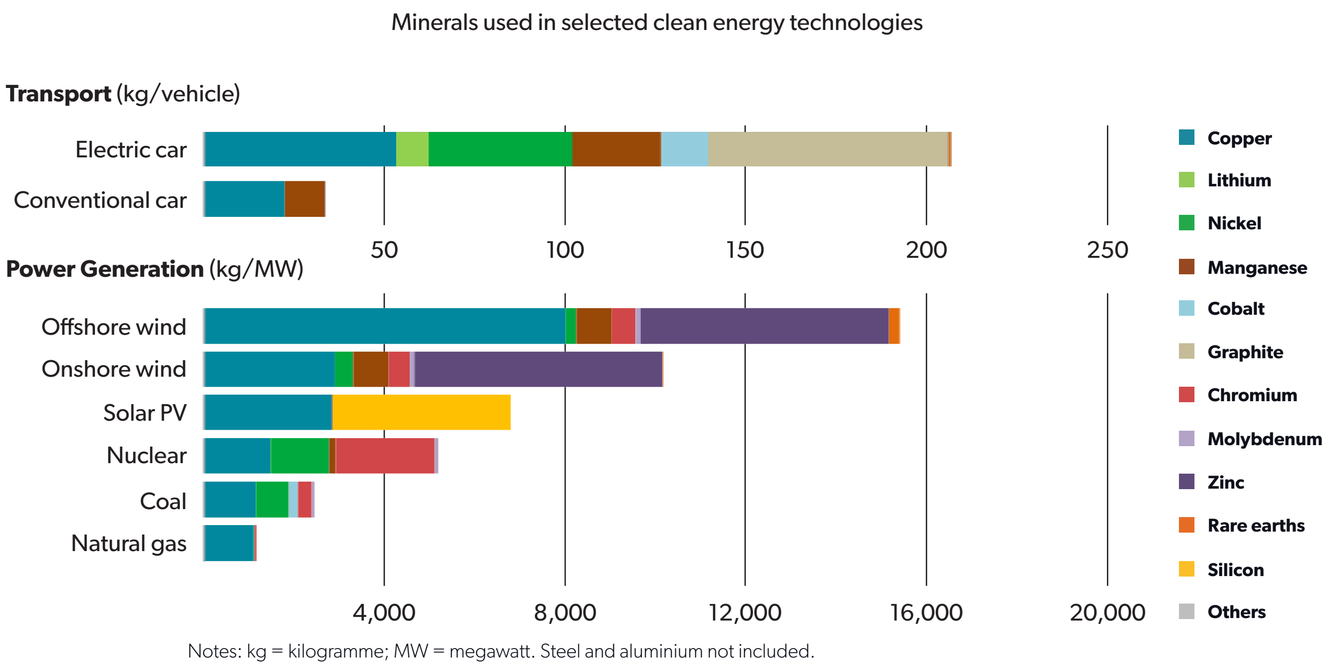
The chart below from IEA compares the materials requirements of EVs versus conventional cars and natural gas, coal, and nuclear with wind and solar.[97] As the chart shows, there are more than six times as many of these energy transition minerals in an EV as in a conventional vehicle.

This increase in materials required in EVs versus conventional cars and renewable projects versus natural gas demonstrates the massive amount of new mineral demand to meet climate goals such as net-zero by 2050.

As IEA shows below, their sustainable development scenario results in a 42-fold increase in lithium demand, 25-fold increase in graphite demand, 21-fold increase in cobalt demand, 19-fold increase in nickel demand, and 7-fold increase in rare earth demand by 2040.[98]

Not only are vast amounts of these energy transition minerals necessary, but current production of these minerals is far more geographically concentrated than that of oil or natural gas, as the next chart from IEA shows.

FIGURE 13: THE RAPID DEPLOYMENT OF CLEAN ENERGY TECHNOLOGIES AS PART OF ENERGY TRANSITIONS IMPLIES A SIGNIFICANT INCREASE IN DEMAND FOR MINERALS

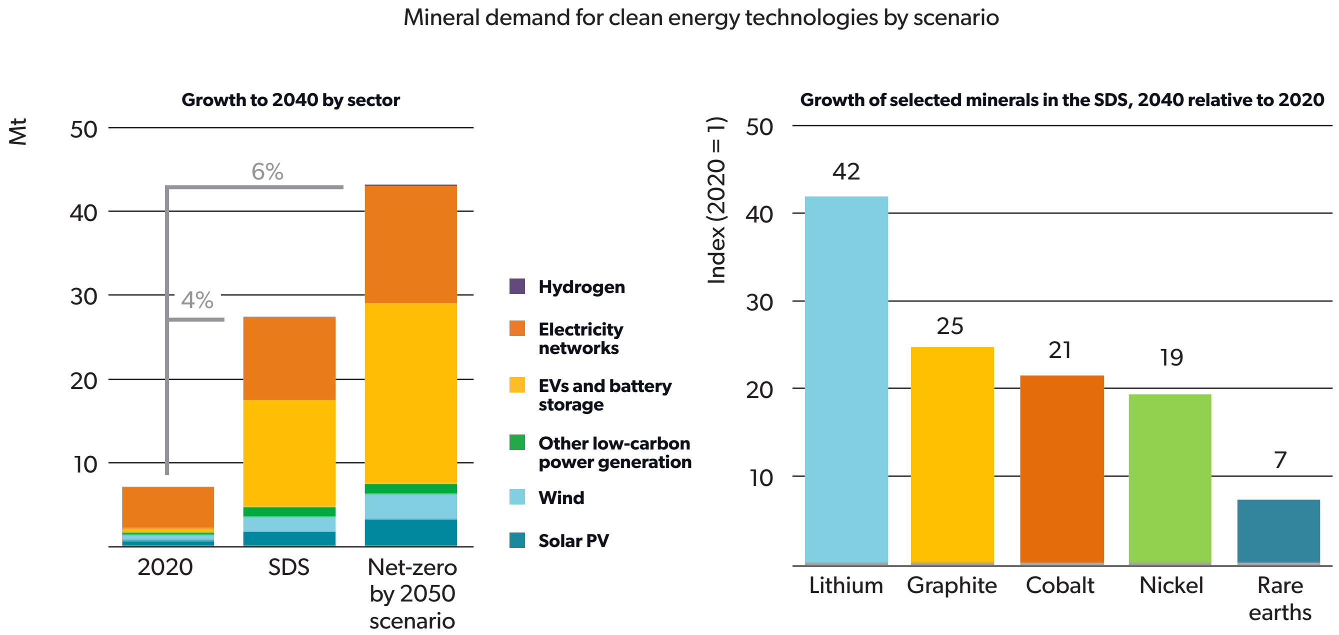


Source: International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

97 International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

98 International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

FIGURE 14: MINERAL DEMAND FOR CLEAN ENERGY TECHNOLOGIES WOULD RISE BY AT LEAST FOUR TIMES BY 2040 TO MEET CLIMATE GOALS, WITH PARTICULARYLY HIGH GROWTH FOR EV-RELATED MINERALS



Notes: Mt = million tonnes. Includes all minerals in the scope of this report, but does not include steel and aluminium.

Source: International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

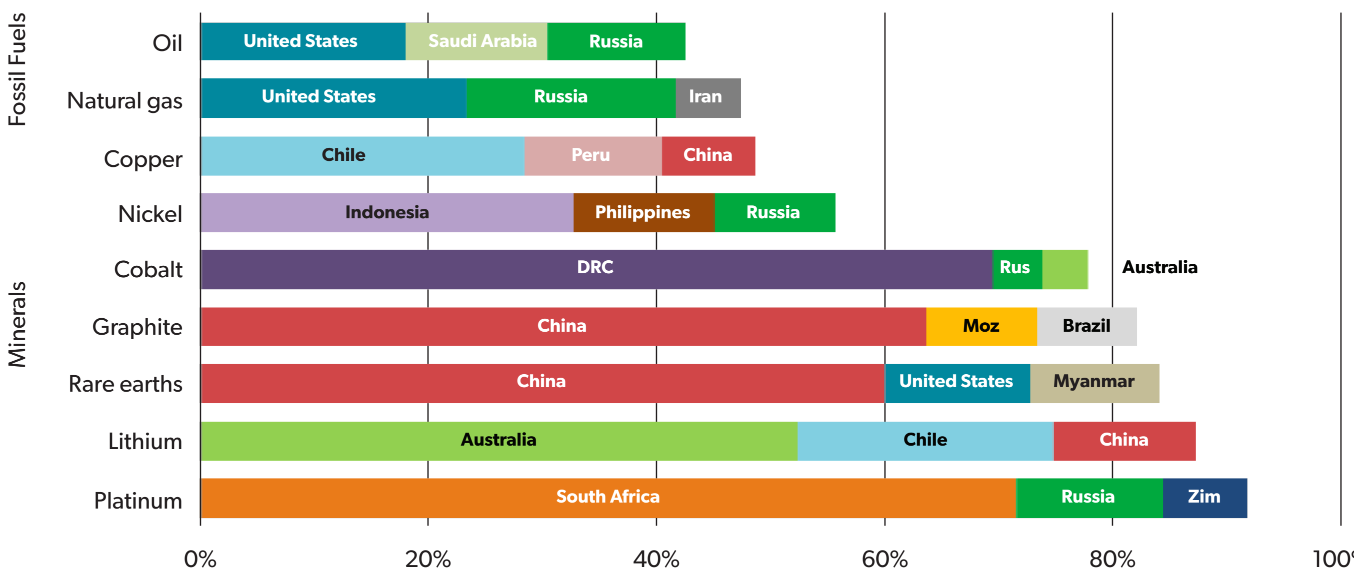
The Arab oil embargo of the 1970s demonstrated the vulnerability of having a strategic energy resource in a concentrated geographic location outside of the U.S. It also dominated our national energy strategy for decades with an eye towards reducing our dependence on the region. Many argued that the only way to do so was to consume less oil. Today, the U.S. has been effectively self-sufficient in oil production thanks more to large increases in domestic production than to reducing our use.[99] However, some of the same people and groups who argued that we should wean ourselves off of foreign oil now want the U.S. to move off of oil altogether by shifting from internal combustion engine (ICE) vehicles to EVs. But the sources of the materials used for EVs are far more concentrated than oil production ever was. As a result, disruptions in a single source of materials could have a much greater impact than Middle Eastern oil conflicts.

This situation is highlighted in the IEA chart below. While the mining of these energy transition minerals is more concentrated than oil or natural gas, we see an even greater concentration in processing. China dominates the processing of these important minerals—processing 40 percent of the world's copper, 58 percent of the world's

99 *See* Energy Information Administration, *4-Week Avg U.S. Net Imports of Crude Oil and Petroleum Products (Thousand Barrels per Day)*, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=wttntus2&f=4

FIGURE 15: CURRENT PRODUCTION OF MANY ENERGY TRANSITION MINERALS IS MORE GEOGRAPHICALLY CONCENTRATED THAN THAT OF OIL OR NATURAL GAS

Share of top three producing countries in total production for selected minerals and fossil fuels, 2019



Source: International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

lithium, 35 percent of the world's nickel, 65 percent of the world's cobalt, and 87 percent of the world's rare earths. To put this in context, at the height of our dependence, the U.S. imported 23 percent of our oil from the Middle East in 2001.[100] The gulf between oil dependence, and the much more intensive dependence on China for minerals is a significant one.

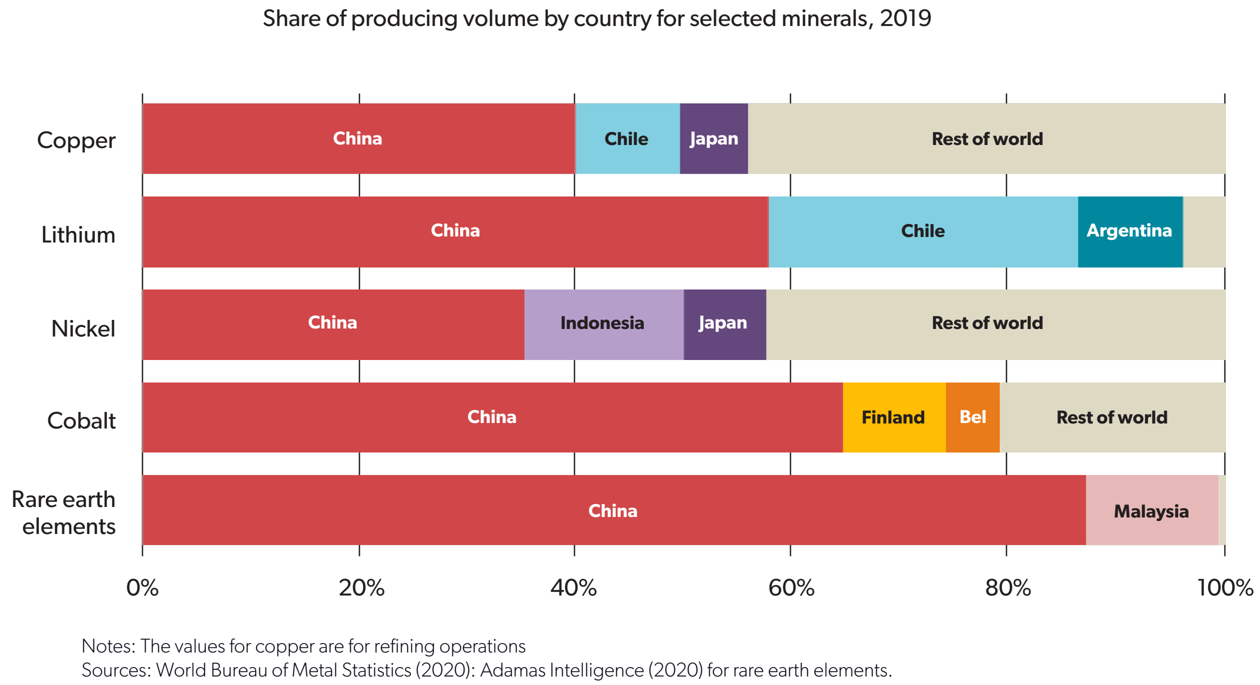
IEA is not the only organization expressing some concern about this concentration of mineral production and processing. President Biden's Department of Defense (DOD) recently released a report titled, "*Securing Defense-Critical Supply Chains.*"[101] *The report states:*

> China dominates the global advanced battery supply chain, including lithium hydroxide (94 percent), cells (76 percent), electrolyte (76 percent), lithium carbonate (70 percent), anodes (65 percent), and cathodes (53 percent). Even materials and components manufactured domestically often have reliance on China-produced precursors or are

100 IER, *China and the Rare Earth Supply Chain Policy Brief*, Feb. 23, 2021, https://www.instituteforenergyresearch.org/renewable/china-and-the-rare-earth-supply-chain-policy-brief/.

101 U.S. Department of Defense, *Securing Defense-Critical Supply Chains*, Feb. 2022, https://media.defense.gov/2022/Feb/24/2002944158/-1/-1/1/DOD-EO-14017-REPORT-SECURING-DEFENSE-CRITICAL-SUPPLY-CHAINS.PDF#:~:text=Securing%20Defense-Critical%20Supply%20Chains%20An%20action%20plan%20developed,in%20response%20to%20President%20Biden%27s%20Executive%20Order%2014017

FIGURE 16: THE LEVEL OF CONCENTRATION IS SIMILARLY HIGH FOR PROCESSING OPERATIONS, WITH CHINA'S SIGNIFICANT PRESENCE ACROSS THE BOARD



Source: International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

> fragile suppliers and single point failures within the supply chain. As electrification is expected to accelerate dramatically by 2030, reliance on China will grow, and China's relative cell dominance is projected to remain stable.

And this chart from Benchmark Mineral Intelligence provides one more way to look at the data on China's domination of key mineral processing.[102]

Even if China were a completely trustworthy trading partner, this amount of concentration would be concerning. Apple recently reported that supply constraints caused by China's COVID restrictions would cost between $4 billion and $8 billion in revenue.[103]

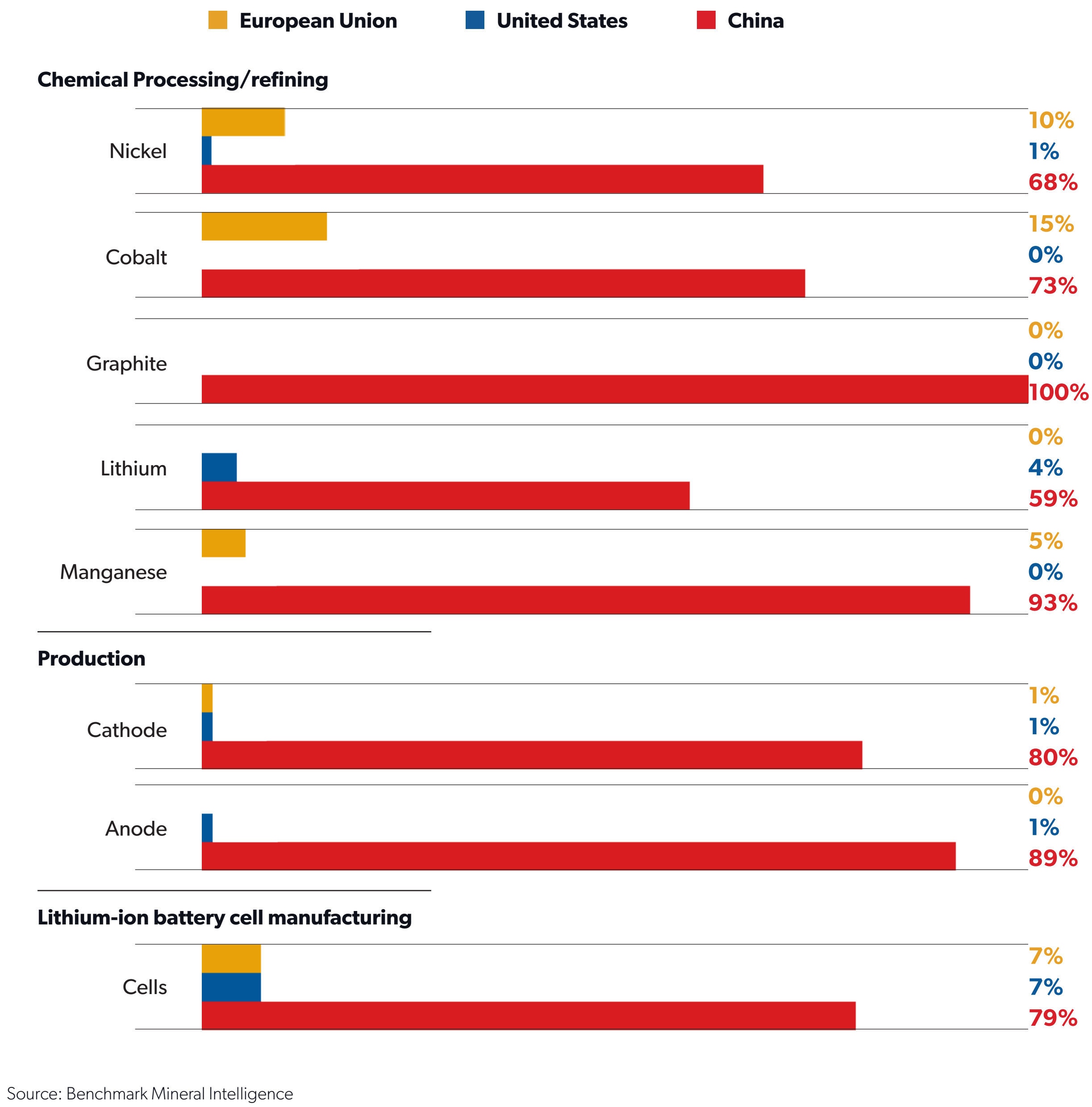
But China is not a completely trustworthy trading partner. Setting aside issues around human rights and the lack of intellectual property protections, China has already used its dominance in mineral processing as an economic weapon. In 2010, China banned the export of rare earths to Japan as part of another dispute, and this export prohibition caused rare earth prices to spike.[104]

102 Simon Moores, https://twitter.com/sdmoores/status/1520904149646417920?s=20&t=dtRyWIjBRtniDAUzfGXWCw

103 Mark Gurman, *Apple Expects Supply Shortages to Slash Sales by Up to $8 Billion*, Time, April 29th, 2022, https://time.com/6172193/apple-supply-shortages-slash-sales/

104 Keith Bradsher, *China Bans Rare Earth Exports to Japan Amid Tension*, CNBC, Sept. 23, 2010, https://www.cnbc.com/id/39318826

FIGURE 17: CHINA DOMINATES THE PROCESSING OF KEY MINERALS



Source: Simon Moores,
https://twitter.com/sdmoores/status/1520904149646417920?s=20&t=dtRyWIjBRtniDAUzfGXWCw

The U.S. could, of course, mine and process many of these materials. But mines typically take a decade or more to permit, and the Biden administration has been hostile to opening new mines. For example, the administration has either opposed or is delaying action on the Twin Metals, Pebble, Rosemont, Resolution, and Polymet mines. The Biden administration has even weighed in against the Alaska-sponsored infrastructure project in the Ambler Mining District to access rich potential mines.[105] Regulations that mandate the sales of EVs without allowing new mines to be built will make the U.S. more dependent on Chinese supply chains.

THE COST OF COMMODITIES ARE INCREASING

One challenge to the affordability of renewable energy, EVs, and batteries is that the cost of commodities has been rapidly increasing. According to Benchmark Minerals Intelligence, from April 2021 to April 2022, the raw materials that makeup nickel, cobalt, magnesium (NCM) lithium ion batteries with high amounts of nickel have increased in price by 164 percent, and the raw materials that make up lithium ion phosphate batteries have increased by 393 percent.[106]

Higher commodity prices make it harder to reduce the cost of EVs, and lower cost EVs are necessary to compete with conventional vehicles. For example, in 2016, Elon Musk unveiled the Model 3, and he said, "in terms of price, it'll be $35,000." Today, seven years later, the cheapest Tesla you can purchase is still over $40,000, and that doesn't include any upgrades, taxes, destination charges or other fees.[107] Elon Musk has succeeded in selling more EVs than anyone else, but he has not succeeded in driving down the price of EVs to parity with gas powered vehicles.

The same is true for other automakers. The average transaction price of a non-Tesla EV was $62,008 in January 2022 compared to $44,839 for all other vehicles—almost 40 percent higher.[108] When comparing the new Ford F-150 Lightning to a regular F-150, the starting price of the electric version is $9,500 more expensive.[109] The Hyundai Kona at the SEL trim level is $23,100, while the EV version with the SEL trim is $34,000.[110] Not only are the vehicles more expensive, insurance costs are higher as well. According to the online insurance brokerage Policygenius, EV insurance payments are 27 percent higher than for a combustion engine car.[111] The point is that EVs need to fall in price to be more cost competitive with vehicles with ICEs and the rising cost of commodities is making the needed cost declines difficult.

105 Liz Ruskin, Alaska Public Media, Biden administration deals setback to Ambler road, Feb. 22, 2022, https://www.alaskapublic.org/2022/02/22/biden-administration-deals-setback-to-ambler-road/ The right-of-way for the road to the Ambler Mining District runs across 25 miles of federal lands and the Bureau of Land Management suspended the right-of-way. See Institute for Energy Research, *Biden Invokes Defense Production Act to Boost Domestic Critical Minerals Production*, Apr. 6, 2023, https://www.instituteforenergyresearch.org/renewable/bidens-invokes-defense-production-act-to-boost-domestic-critical-minerals-production/

106 Simon Moores, https://twitter.com/sdmoores/status/1518680838057213952

107 Scooter Doll, *2023 Tesla prices: How much does your favorite model cost?*, May 2, 2023, https://electrek.co/2023/05/02/2023-tesla-prices-how-much-does-your-favorite-model-cost/

108 Ira Boudway, *Dealers Are Marking-Up EVs, Too*, Bloomberg, Mar. 5, 2022, https://www.bloomberg.com/news/articles/2022-03-05/hyundai-kia-price-mark-ups-test-consumers-purchasing-impulses?cmpid=BBD050722_GREENDAILY&utm_medium=email&utm_source=newsletter&utm_term=220507&utm_campaign=greendaily

109 Carbuzz, *Compare Ford F-150 vs Ford F-150 Lightning*, https://carbuzz.com/compare/ford-f-150-vs-ford-f-150-lightning

110 Carbuzz, https://carbuzz.com/compare/hyundai-kona-vs-hyundai-kona-ev#cars=i_84009-vs-i_84955

111 Nick Carey, Scratched EV battery? Your insurer may have to junk the whole car, Reuters, Mar. 20, 2023, https://www.reuters.com/business/autos-transportation/scratched-ev-battery-your-insurer-may-have-junk-whole-car-2023-03-20/#:~:text=It%20already%20costs%20more%20to%20insure%20most%20EVs,%24206%2C%2027%25%20more%20than%20for%20a%20combustion-engine%20model.

THERE ARE NOT ENOUGH MATERIALS IN THE MINING AND PROCESSING PIPELINE

An even bigger challenge than the increasing cost of battery materials is the fact that there are not enough of these materials in the development pipeline to meet the stated demand from automakers. EV expert Steve LeVine says, "the EV industry is in a decades-long battery metals crisis."[112] He goes on to explain that this year lithium and nickel production will be enough to produce 3.8 million EVs. However, automakers claim they want to make 7.7 million. He used major metals production forecasts and found that by 2030, there will only be enough metals for 15.6 million EVs, while automakers claim they want to produce over 40 million.[113]

To put these numbers in perspective, from 2010 to 2019, an average of 71 million cars worldwide were sold a year.[114] If car makers sell 15.6 million EVs in 2030, and assuming the conservative estimate of 71 million cars sold overall, EVs would only make up 22 percent of sales. IEA's net-zero by 2050 report calls for no sales of cars with ICEs by 2035. Without massive changes, there are not enough minerals and materials in the pipeline to quintuple EV production in only five years from 2030-2035. It is certainly possible to surprise to the upside, but a quintupling of mineral and material production is not realistic.

Without massive changes, there are not enough minerals and materials in the pipeline to quintuple EV production in only five years from 2030-2035.

112 Steve LeVine, Twitter, Apr. 26, 2022, https://twitter.com/stevelevine/status/1518913709397131264?s=20&t=VDBSMrbUvCUswbzKJGU_fQ

113 Steve LeVine, Twitter, Apr. 24, 2022, https://twitter.com/stevelevine/status/1518378692254310401. See also Steve LeVine, Just How Many EVs Can Be Made? Far Fewer Than Expected, The Electric from The Information, Apr. 24, 2022, https://subscriptions.theinformation.com/newsletters/the-electric/archive/just-how-many-evs-can-be-made-far-fewer-than-expected

114 Statistica, Number of cars sold worldwide between 2010 and 2021, Jan. 31, 2022, https://www.statista.com/statistics/200002/international-car-sales-since-1990/

SECTION 04

WHAT IS THE IMPACT OF NET-ZERO ON AMERICAN JOBS?

To understand the impacts of policies, economists typically do not try to explain the behavior of individual actors. Instead, they analyze how the interaction of these actors and policies change quantities and prices. An increase in the price of a commodity, say natural gas, motivates suppliers to supply more. This then works its way through the system as increased pressure to employ welders, drill-rig operators, along with encouraging engineers and designers to improve the technology for producing the gas and creating alternatives. At the same time, the higher price disciplines consumers to use less natural gas, which encourages behavioral and technical changes to economize on its use and to seek out appropriate alternatives.

Decades of data on these types of responses, along with trends in costs, economic growth, and preferences, inform the economic models used to make projections for variables of interest. DOE's NEMS is one such model. NEMS has been used to model the impact of various climate policies on aggregate economic output, prices, and employment.

A recent paper by The Heritage Foundation used the organization's clone of NEMS (the Heritage Energy Model, or HEM) to explore the economic impact of achieving the U.S.'s targets for the Paris Agreement.[115] Though less ambitious than those of a net-zero policy, the Paris Agreement's impacts provide a lesson for those casually mandating even stricter cuts to our energy system.

115 The Unsustainable Costs of President Biden's Climate Agenda, June 16, 2022. https://www.heritage.org/energy-economics/report/the-unsustainable-costs-president-bidens-climate-agenda. The particulars for the model are: U.S. Department of Energy, Energy Information Administration, "The National Energy Modeling System: An Overview," October 2009, http://www.eia.gov/oiaf/aeo/overview/pdf/0581(2009).pdf (accessed April 3, 2013). The model specifically altered the agency's codes for their carbon fee cases published in November 2021. US Energy Information Administration. "Annual Energy Outlook 2021," November 17, 2021. https://www.eia.gov/outlooks/aeo/emissions/carbon_fee/ (accessed February 4, 2022

The most sobering result from the HEM modeling is that the model crashes before it can even achieve the administration's net-zero's interim CO_2 reduction targets for 2030, which seeks to cut CO_2 emissions by 50 to 52 percent below our 2005 emissions. HEM could get no closer than a 44 percent cut resulting from a $300 per ton carbon tax. The emissions cuts do not get significantly better when a carbon tax is continued out to 2040, where the cuts are still less than 50 percent of the target. However, even these short-of-the-target efforts have extraordinary costs, while providing trivial moderation of climate impacts.

The most sobering result from the HEM modeling is that the model crashes before it can even achieve the administration's net-zero's interim CO_2 reduction targets for 2030, which seeks to cut CO_2 emissions by 50 to 52 percent below our 2005 emissions.

In the NEMS model and in economic theory, a carbon tax forces emissions cuts at the lowest cost.[116] A carbon tax makes actors in the theoretical economy of the HEM model treat CO_2 emissions just like any other input. All the inputs in this theoretical economy will be used perfectly efficiently. All the decision-makers in the complex energy web will act with perfect information and efficiency. Industry A will emit another ton of CO_2 only so long as emitting this ton provides production-cost savings or additional value to consumers that is at least as large as the carbon tax. The model also ensures that the emission of an additional ton of CO_2 in Industry A will provide at least as much benefit as the ton would provide for Industry B.

Modeling the carbon cuts becomes an iterative process of incrementally raising a carbon tax until the total cuts drop emissions to the target level. In economic modeling, no set of mandates or subsidies provides the CO_2 cuts with less harm to the economy than does a carbon tax. The HEM model (like NEMS) incorporates all current laws and regulations and cannot anticipate breakthrough technologies.

Reality is worse than this ideal model world precisely because there are mandates and subsidies. In fact, carbon tax revenues are often earmarked for subsidies under the misguided notion that this lowers the overall costs of emissions reductions. In addition, a carbon tax is government revenue for which political interests will compete. This sort of competition leads to further inefficiency. Heritage's model assumes all of the carbon tax revenue goes directly to the citizens, which allows them to spend their money most effectively. In the real world that outcome is highly unlikely.

The 44 percent CO_2 cut resulted from a carbon tax that started at $150 per ton in 2021 moved to $300 per ton in 2022 and rose 2.5 percent each year through 2030. All

116 One note about the NEMS model, it does not come up with a breakthrough technology that can meet the desired cuts. It also assumes current laws and regulations in the US are in effect.

prices are in constant 2017 dollars.[117] For the years 2022 through 2030, the carbon tax will reduce aggregate gross domestic product (GDP) by more than $4.3 trillion. This is almost $35,000 per household or almost $4,000 per year per household. By the end of 2040, the aggregate lost GDP will be $7.7 trillion, which is more than $54,000 per household.

For the years 2022 through 2030, the carbon tax will reduce aggregate gross domestic product (GDP) by more than $4.3 trillion. This is almost $35,000 per household or almost $4,000 per year per household.

These costs come in spite of the most cost-effective responses and adaptations. The model assumes people switch to energy-saving technologies wherever it is cost-effective to do so. There is an optimal amount of switching to wind and solar power. There is the optimal switching to more fuel-efficient cars. There is the optimal deployment of the most optimal heat pumps and induction cooktops. The perfectly efficient number of programmable thermostats are perfectly programmed. People drive less. They live in houses that are colder in the winter and hotter in the summer. In spite of all the new technology and behavioral change, the economy is worse, and people spend more for less energy.

All of these adjustments cause residential electricity consumption to drop 9 percent in 2030 (compared to the no-tax case). However, this is not enough to offset the 37 percent increase in electricity prices. On net, the average household will spend 25 percent ($570) more in total on electricity. That is, even after purchasing more efficient dishwashers, more efficient washing machines, more efficient water heaters, more efficient light bulbs, more efficient refrigerators, more efficient cooktops, more efficient heating and cooling systems, and adjusting their thermostats, households will still have to spend $570 more in 2030 for their electricity. This higher expenditure comes out of a lower income. Following this story for another ten years to 2040, the model finds the penalty is more than $840 per year per household, which does not count the additional cost of the new household technology.

The gasoline story is similar. The carbon tax forces adjustments all through the energy web. Vehicles will be lighter with better fuel efficiency. People will drive less, walk more, bike more, and take more public transportation. The myriad adjustments will cause gasoline consumption in 2030 to be 5.7 percent less with the carbon tax. However, all these energy-saving adjustments are swamped by the 140 percent increase in the price of gasoline compared to 2030 without a carbon tax. People will drive less but pay more. By 2040, the price of gasoline would rise 236 percent.

Simultaneously with these adjustments on the consumer side, businesses also adapt to the higher energy costs. Again, the HEM model assumes optimal adoption of efficient technology, optimal changes in production processes and optimal product mixes. But these optimal

117 U.S. Department of Energy, Energy Information Administration, "The National Energy Modeling System: An Overview," October 2009, http://www.eia.gov/oiaf/aeo/overview/pdf/0581(2009).pdf (accessed April 3, 2013). The model specifically altered the agency's codes for their carbon fee cases published in November 2021. US Energy Information Administration. "Annual Energy Outlook 2021," November 17, 2021. https://www.eia.gov/outlooks/aeo/emissions/carbon_fee/ (accessed February 4, 2022)

adjustments cannot undo the damage the carbon tax does to input costs. Less is produced and the economy shrinks.

Employment changes alone do not always give a clear picture of economic well-being. A policy that causes people to work six days per week for four days' pay is worse than a no-policy case where people work five days per week for five days' pay. That said, employment changes can be descriptive of the economic disruption from bad policies.

The HEM results show that forcing large cuts in CO_2 combines job losses with huge income losses. The impact varies as the economy tries to recover. The economic impact is not smooth over time and some years even have net increases in employment, but the average employment shortfall from 2022 through 2040 is 1.2 million jobs.

The economic impact is not smooth over time and some years even have net increases in employment, but the average employment shortfall from 2022 through 2040 is 1.2 million jobs

These damages (and likely more) do not depend on cutting CO_2 emissions via a carbon tax. There is some theoretical combination of regulations that, when perfectly implemented, would generate the same changes and adaptations throughout the energy system. Whether by regulation or taxation, cutting CO_2 imposes differential costs and benefits across the economy. Producers of carbon-free energy gain an advantage from the higher energy costs. Energy-intensive sectors of the economy are disproportionately harmed by higher energy costs. Mandates and regulations that can confer benefits on one industry or impose costs on competitors create a political environment ripe for lobbying and rent-seeking.

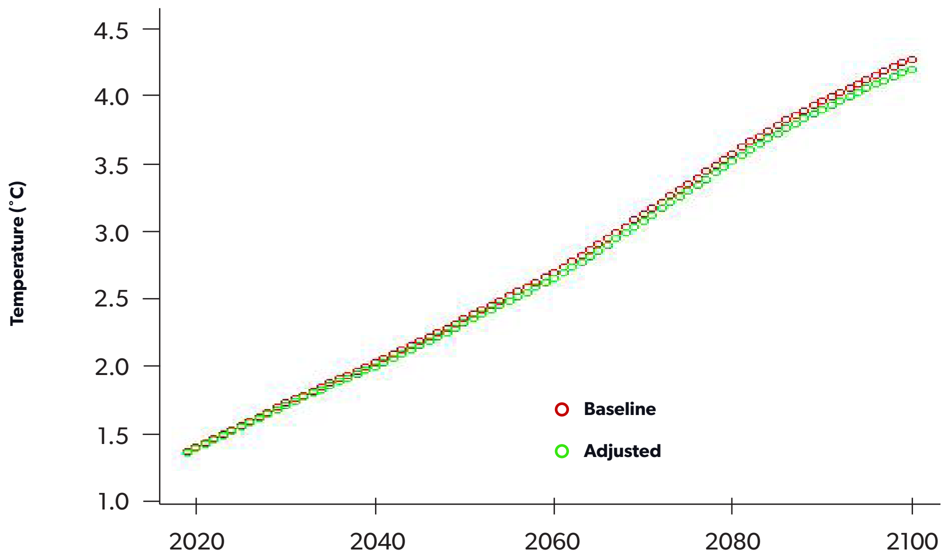
To get an idea of how much is at stake in terms of possible transfers, we can simply look at what would be the carbon tax revenue. The series of carbon taxes used start at $150 per ton in 2020, double to $300 per ton in 2021, and then increase by 2.5 percent each year until 2040, after adjusting for inflation. The carbon tax revenue would be more than $1 trillion each year from 2022 to 2040, with an average of $1.3 trillion per year. This is at least two-thirds above the 2023 budget request for the DOD.[118]

THAT IS THE PAIN. WHAT IS THE GAIN?

The Model for the Assessment of Greenhouse-Gas Induced Climate Change (MAGICC) is a standard model used to project the impact on global warming of changes in CO_2 levels. It has been employed by both the EPA and researchers at the Intergovernmental Panel on Climate Change (IPCC). Using the stream of CO_2 cuts from the HEM modeling, and assuming the cuts hold for the remainder of the 21st century, MAGICC projects a moderation in average world temperature of less than 0.07 degrees C in 2100 and about half that much by 2050. The chart below shows the temperature trajectory without any carbon tax (baseline) and the infinitesimally lower trajectory when the trillion-dollar-per-year carbon tax is implemented (adjusted).

118 Department of Defense, The Department of Defense Releases the President's Fiscal Year 2023 Defense Budget, Mar. 28, 2022, https://www.defense.gov/News/Releases/Release/Article/2980014/the-department-of-defense-releases-the-presidents-fiscal-year-2023-defense-budg/

FIGURE 18: SURFACE TEMPERATURE SHIFT FOR RCP6_(4.5 SENSITIVITY)



Source: MAGICC model output. See L. Wigley, "Emulating Coupled Atmosphere-Ocean and Carbon Cycle Models with a Simpler Model, MAGICC6–Part I: Model Description and Calibration," Atmospheric Chemistry and Physics, Vol. 11 (2011), pp. 1417–1456, https://www.atmos-chem-phys.net/11/1417/2011/acp-11-1417-2011.html

The projected change in temperature is trivial, even with a generous assumption regarding the sensitivity of temperature to CO_2 levels. This calculation assumes that a doubling of CO_2 leads to a 4.5 degree C increase in world temperature. As with much in climate science, there is much uncertainty regarding this sensitivity measure, but the IPCC's best estimate is 3.0.[119]

The net-zero policy proposed by the Biden administration would require unprecedented burdens on the energy market and energy consumers. The impacts would be so severe that the DOE's own model is unable to estimate the impacts. The model hits its limit when the cuts are less than halfway to the net-zero target. Even getting to this less-than-halfway point can be expected to impose high costs on the economy. By 2040:

- Aggregate GDP drops $7.7 trillion
- The employment shortfall averages 1.2 million jobs
- The average annual household electric bill increases by $840
- Gasoline prices rise 236 percent

Fully achieving the net-zero targets would involve much greater disruption and much higher costs, while still having a minor impact on global warming.

119 Intergovernmental Panel on Climate Change, https://www.ipcc.ch/report/ar6/wg1/#FullReport

WHAT IS THE BEST PATH FORWARD?

Many activists, both within and outside government, would like the U.S. to pursue a net-zero CO_2 emissions policy. As this paper shows, that will be very difficult. That said, the U.S. has a good record reducing CO_2 emissions—in some ways better than Europe's and with better economic performance.

While reducing CO_2 emissions may be an important goal, there are other important energy considerations that have been brought to light with recent events, including supply chain challenges during the COVID pandemic and Russia's invasion of Ukraine. In their pursuit of net-zero ambitions, Europe and Germany put themselves in a dangerous energy security situation that Vladimir Putin eventually exploited. The U.S., on the other hand, became more energy secure over the last decade due to the shale revolution. America's improved energy security over the last decade is a significant development, and we should allow it to continue.

As we consider the future of energy, a few things are clear. First, the U.S. will emit a smaller share of global CO_2 emissions over time. The rise of China's CO_2 emissions over the past 20 years is incredible.[120] Furthermore, India's CO_2 emissions will soon pass Europe's as hundreds of millions of Indians rise from poverty to the middle class and start using more energy.

Second, no one knows how to decarbonize certain parts of the economy at anything close to a reasonable cost. We should not predicate policy on the assumption that this decarbonization will magically occur. Consider the following account from Bloomberg:

> Stephen Trauber, co-head of [Citibank's] newly created natural resources and clean-energy transition group, said he met with the [ExxonMobil's] executive committee right after it lost three board seats in June. Activist investor Engine No. 1 ran a successful proxy campaign as it pushed for a net-zero target. Trauber said he urged the oil giant to reconsider its position.
>
> "They looked at me and said, 'That's great, but we don't know how we would get there. We can't commit to that if we don't have a plan to get there,'" he said Thursday during the webcast of an event hosted by Rice University's Baker Institute for Energy Studies and law firm Baker Botts LLP. "I assured them most companies today who have committed to net-zero don't have a plan on how to get there, but they're working to get there."[121]

It is disturbing that Citibank and other Wall Street firms like BlackRock are pressuring companies and politicians to commit to net-zero when they have no idea how to get there.

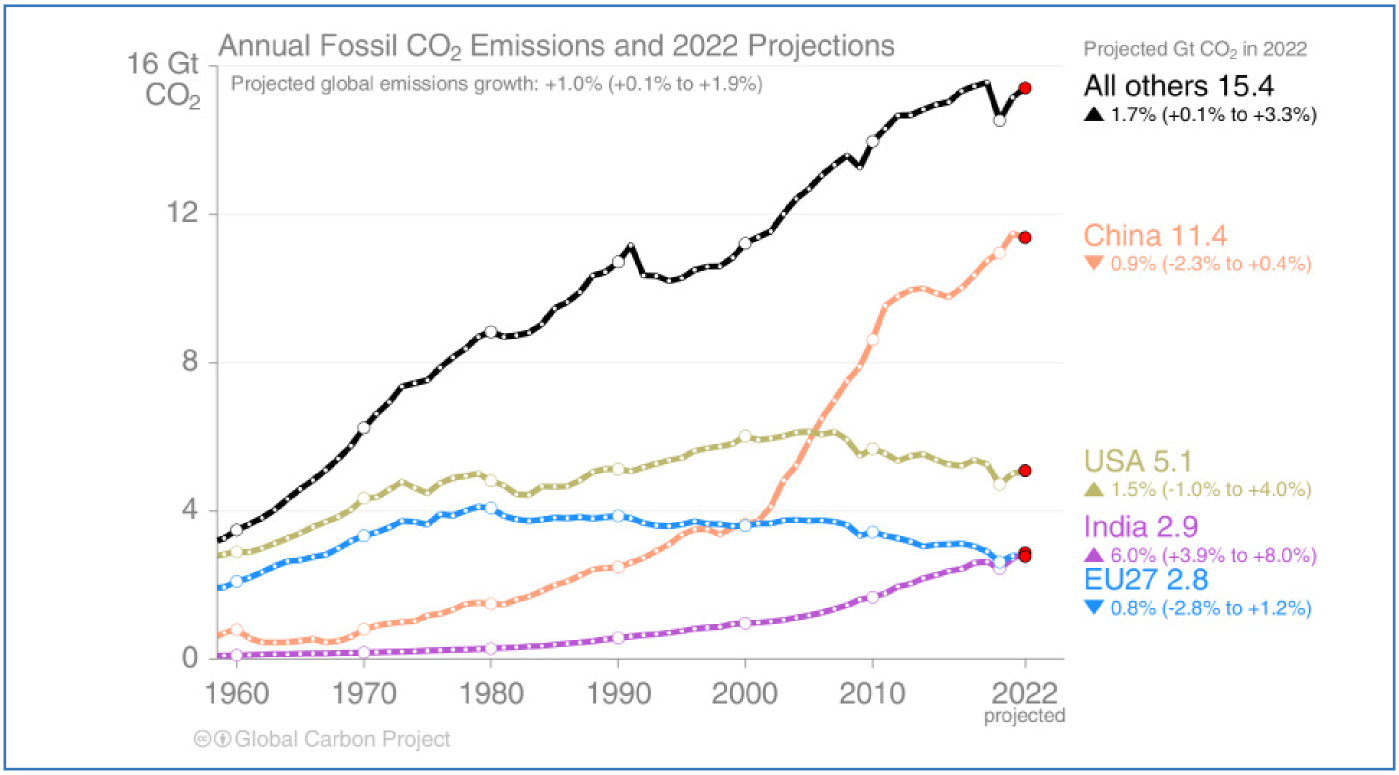
Europe's energy situation is an example of what can happen when countries try to achieve net-zero without a plan that can actually succeed. From 2010 through 2020, as Europe has aggressively promoted renewables and set net-zero goals, its natural gas consumption fell by 17 percent.[122] However, because Europe's natural gas production fell by nearly 30 percent over the same

120 Global Carbon Project, Global Carbon Budget 2022, p.7, https://www.globalcarbonproject.org/carbonbudget/22/files/GCP_CarbonBudget_2022.pdf

121 David Wethe & Kevin Crowley, Exxon Rejected Net-zero Pitch After Proxy Loss, Citi Banker Says, Bloomberg Quint, Sept 30, 2021, https://www.bloombergquint.com/business/citi-banker-says-exxon-rejected-net-zero-pitch-after-proxy-loss,

122 *See* BP, Statistical Review of World Energy 2021, p. 38, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

FIGURE 19: IN 2022 THE LARGEST INCREASES ARE IN INDIA, REST OF WORLD (PRIMARILY AVIATION), AND THE USA. EMISSIONS ARE PROJECTED TO DECLINE IN CHINA AND THE EU27. FOSSIL CO_2 EMISSIONS DECREASED IN 24 COUNTRIES DURING THE PAST DECADE



Source: Global Carbon Project, Global Carbon Budget 2022, p.7, https://www.globalcarbonproject.org/carbonbudget/22/files/GCP_CarbonBudget_2022.pdf

time period,[123] it became more reliant on Russian natural gas.

Government net-zero plans and mandates have failed Europe and increased its dependence on Russian energy. Instead of government mandates and corporate subsidies, we need innovation that improves all types of energy—reducing the cost of energy and improving energy security.

Forcing decision-making predicated on the future development of technology about which there is no certainty is not a reasonable way for countries or the world's largest companies to do business. As these countries and financial institutions push in this direction, it's unclear how severe the long-run effects will be.

As we look to the future, we need to consider how we got here. America has achieved impressive CO_2 emission reductions without damaging policies like a carbon tax or a cap-and-trade program. Unlike Europe, we have improved our energy security while reducing CO_2 emissions mainly through technology. We achieved these reductions by making all types of energy better and more cost effective instead of taking some forms of energy off the table. We should focus on these successes as we look to the future.

123 *See* BP, Statistical Review of World Energy 2021, p. 36, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

CONCLUSION

Since the oil embargo of the 1970s, our energy policy has been driven primarily by the threat of looming future crises, none of which have since come to pass. The threat of rising energy prices, resource depletion, and environmental collapse continue to prompt aggressive plans by policymakers to fundamentally reshape energy markets. Different elements of these plans have been passed into law over several decades and sometimes partially repealed or allowed to expire, leading to inefficient, contradictory, and self-defeating policies that place America's ability to access reliable and affordable energy at risk. As a result, the energy market is dominated by a complicated collection of subsidies, tax incentives, and regulations, which limit competition and stifle economic growth.

Over time, these policies have fundamentally changed the nature of the energy industry, creating a culture where economic and political elites advance their interests through the political sphere, while passing the costs of their policies on to everyday citizens. The federal government needs to get out of the way of all forms of energy, and pursue policies that enable market competition to drive the future of energy production and innovation.

Instead, the Biden administration has advanced a top-down approach, including net-zero carbon emissions. It has taken aggressive actions that make it harder to produce oil and natural gas in the U.S..[124] These actions are harming our economy by helping to drive up inflation due to increasing the cost of energy. Additionally, the Biden administration does not seem to appreciate that the U.S. has an exemplary record of reducing CO_2 emissions.

Using an energy-model created by the federal government shows that achieving net-zero will be incredibly costly. Instead of forcing this change with new federal mandates, regulations, and massive subsidies, a better way would be to harness our innovators and entrepreneurs to drive the next generation of energy technologies.

Instead of forcing this change with new federal mandates, regulations, and massive subsidies, a better way would be to harness our innovators and entrepreneurs to drive the next generation of energy technologies.

As with all energy and environmental challenges, the focus of public policy should be on maintaining the institutional framework that unleashes the creative powers of a free society: private property, competitive market exchange, and the rule of law. As we pursue the development of new energy breakthroughs, the U.S. should continue to provide domestic and international consumers with the abundant, reliable, and affordable energy produced within our borders. The other path, namely net-zero policies pursued by President Biden and other Western leaders, has proven to be much pain with little environmental gain.

124 Thomas Pyle, *150 Ways Biden and the Democrats Have Made it Harder to Produce Oil & Gas*, American Energy Alliance, https://www.americanenergyalliance.org/2022/11/125-ways-biden-and-the-democrats-have-made-it-harder-to-produce-oil-gas/

IER INSTITUTE FOR ENERGY RESEARCH®

www.instituteforenergyresearch.org