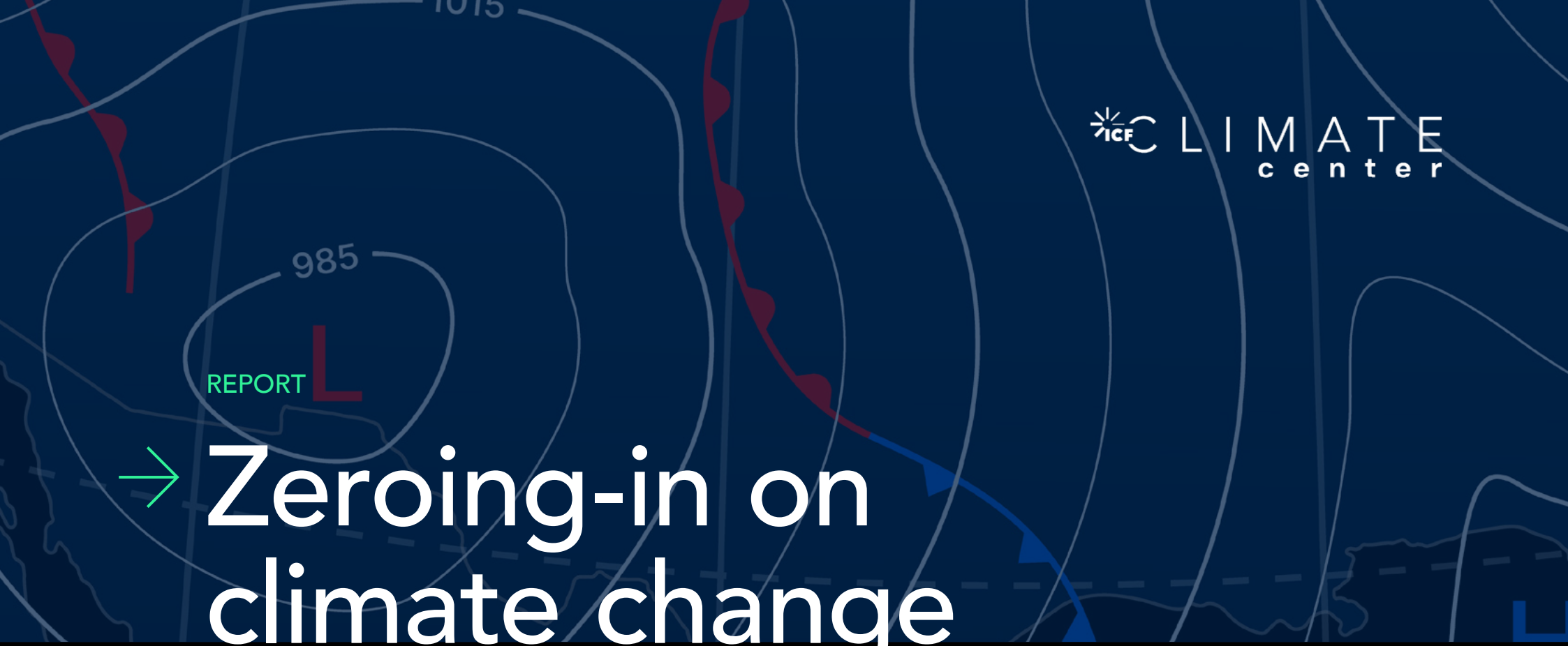


ICF CLIMATE center

REPORT

Zeroing-in on climate change

Three "super solutions" could put the US on a path toward a net-zero economy by 2050

By Adam Agalloco, Deb Harris, and Michael Jung, ICF

Introduction

Climate change is now touching every region of the United States. From heat waves to hurricanes, droughts to deluges, wildfires and more, extreme weather and other climate impacts are affecting lives and livelihoods of many Americans. To slow the impacts of climate change, and address its causes, the U.S. government has set ambitious climate goals[1] to reduce greenhouse gas (GHG) emissions 50%–52% by 2030, relative to 2005 and to be net zero by 2050.

The Bipartisan Infrastructure Law (BIL), passed in November 2021, and the Inflation Reduction Act (IRA), passed in August 2022, set a policy framework and provide funding that will advance the U.S. on its path to deep GHG emission reductions over the coming decades. Taken together, those two laws represent the largest investment of federal funding to advance clean energy and address climate impacts in U.S. history.

But will these laws get the U.S. far enough? What else is needed for the U.S. government to achieve its climate goals?

In this report from the ICF Climate Center, we leverage our decarbonization modeling platform CO_2Sight™ to show how the BIL and IRA could drive a 27% reduction in U.S. GHG emissions by 2030 and a 50% reduction by 2050 relative to 2005. While this represents significant progress toward U.S. decarbonization goals, additional measures would be needed to achieve a net-zero future.

We model a practical, but highly ambitious path toward achieving U.S. decarbonization goals, relying on three solutions that the BIL and IRA critically spur—transportation electrification, building decarbonization, and clean energy. With these three super solutions, the United States could eliminate more than 40% of GHG emissions by 2030 and nearly 90% of GHG emissions by 2050 relative to 2005.

While achieving these U.S. climate goals is possible, steep emission reductions will trigger complex challenges, financial costs, and trade-offs. The federal government, utilities, state and local governments, NGOs, community-based organizations, the American public, and the private sector would all need to play a role in achieving climate goals while also maintaining energy reliability, increasing energy resilience, mobilizing financing, and ensuring equity among other priorities for the country.

Decarbonization super solutions

Three super solutions that exist today have the potential to cut GHG emissions more than 40% from 2005 levels by 2030 and nearly 90% by 2050.

1. Transportation electrification
2. Building decarbonization
3. Clean energy

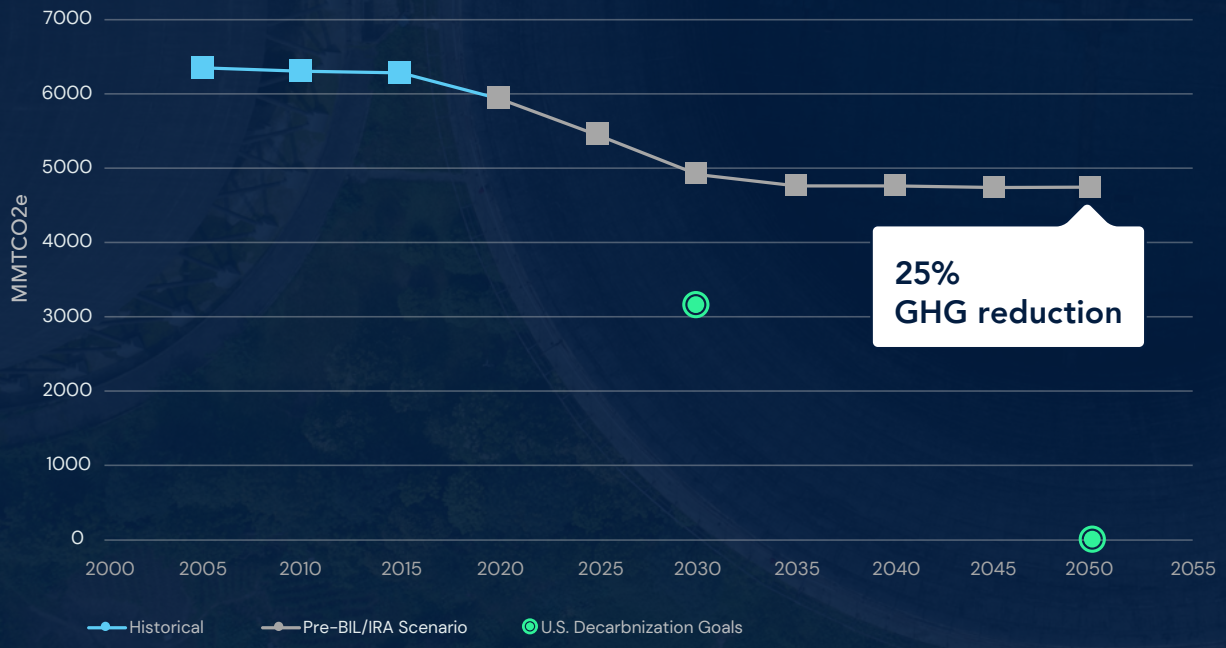
[1] https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

GHG emissions scenarios: GHGs projected to fall, but fall short of goals

It can be difficult to grasp the scale of the climate challenge. Prior to the passage of the BIL and IRA, government agencies at every level, utilities, and private companies had already invested hundreds of billions of dollars in clean energy infrastructure, energy efficiency, and sustainable innovation. Solar, wind, and battery storage accounted for 74% of new generating capacity installed in 2022.[2] The electric vehicle (EV) market and building decarbonization technologies have been quickly gaining momentum. And solutions for lower carbon fuels and more innovative technologies that capture and sequester carbon are being further explored. These actions have made a significant impact, but accelerated action would be needed to put the U.S. on a path to achieve its decarbonization goals.

This analysis finds that pre-BIL and IRA policies and actions like those described above, defined as the Pre-BIL/IRA Scenario, would have led to a 22% reduction in U.S. GHG emissions from 2005 levels by 2030 and a 25% reduction from 2005 levels by 2050 (Figure 1).

Figure 1: U.S. Pre-BIL/IRA Scenario



Source: ICF decarbonization platform (CO_2Sight™)

[2] https://www.eia.gov/todayinenergy/detail.php?id=50818

Understanding Decarbonization Pathway Scenarios

Our analysis presents three different scenarios to model the path of annual U.S. GHG emissions through 2050. Each scenario builds on the previous to show deeper decarbonization by modeling the impacts of additional policies and actions.

The Pre-BIL/IRA Scenario models U.S. GHG emissions through 2050 based on forecast impacts of policies and decarbonization efforts as they existed before the passage of the BIL and IRA.

The BIL/IRA Scenario models U.S. GHG emissions through 2050 based on forecast impacts of the BIL and IRA in combination with the policies and efforts included in the Pre-BIL/IRA Scenario.

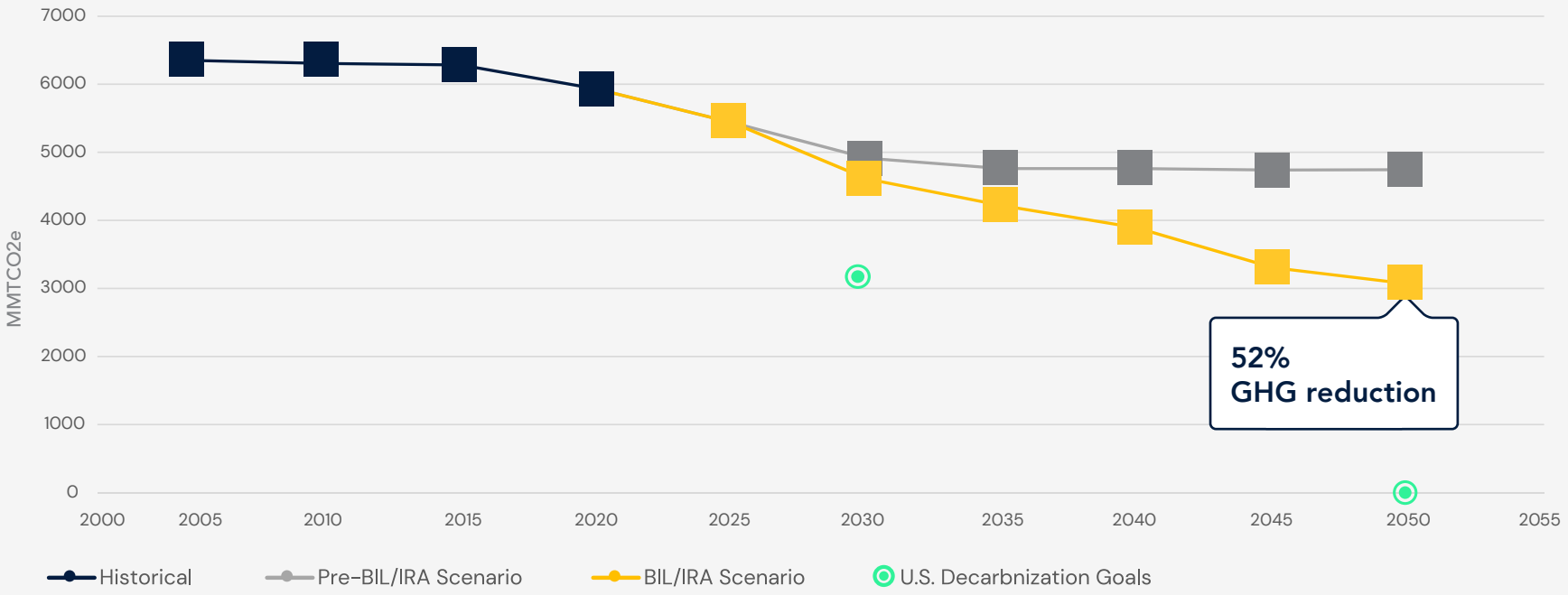
The Diversified Goal Scenario models U.S. GHG emissions through 2050 based on the forecast impacts of three currently-available solutions, in combination with the forecast impacts assumed within the BIL/IRA Scenario, that would align GHG emissions with U.S. GHG reduction goals.[3]

[3] The modeled outcomes embedded within the super solutions do not represent the only pathway toward achieving U.S. decarbonization goals. Rather, it represents an objective pathway that takes into account complex challenges and trade-offs. The diversified Goal Scenario leverages a range of diverse technologies to achieve U.S. climate goals.

Our BIL/IRA Scenario shows BIL and IRA investments are expected to bring GHG emissions to 27% below 2005 levels by 2030 and 52% below 2005 levels by 2050 (Figure 2). This represents more than double the reductions of the Pre-BIL/IRA Scenario by 2050.

Key BIL and IRA provisions drive the BIL/IRA Scenario projections of significant annual emission decreases below the Pre-BIL/IRA Scenario. The BIL is often described as an investment in the infrastructure needed to deploy clean energy technologies at scale. It provides[4] $90 billion for public transit funding, $65 billion for clean energy transmission and distribution grid projects, $9.5 billion to boost clean hydrogen production[5], and $7.5 billion to build a national network of EV chargers. The IRA invests upward of $400 billion in clean energy technologies directly[6], providing a mix of tax credits, rebates, and other incentives to businesses and consumers for EVs, solar, wind, battery energy storage systems, building decarbonization measures such as heat pumps, and energy efficiency projects. It also provides $19.5 billion to spur climate-friendly agriculture practices.[7]

Figure 2: U.S. BIL/IRA Scenario



Source: ICF decarbonization platform (CO_2Sight™)

[4] https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal/
[5] https://www.energy.gov/articles/doe-establishes-bipartisan-infrastructure-laws-95-billion-clean-hydrogen-initiatives
[6] https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/
[7] https://www.usda.gov/media/press-releases/2023/02/13/biden-harris-administration-announces-availability-inflation

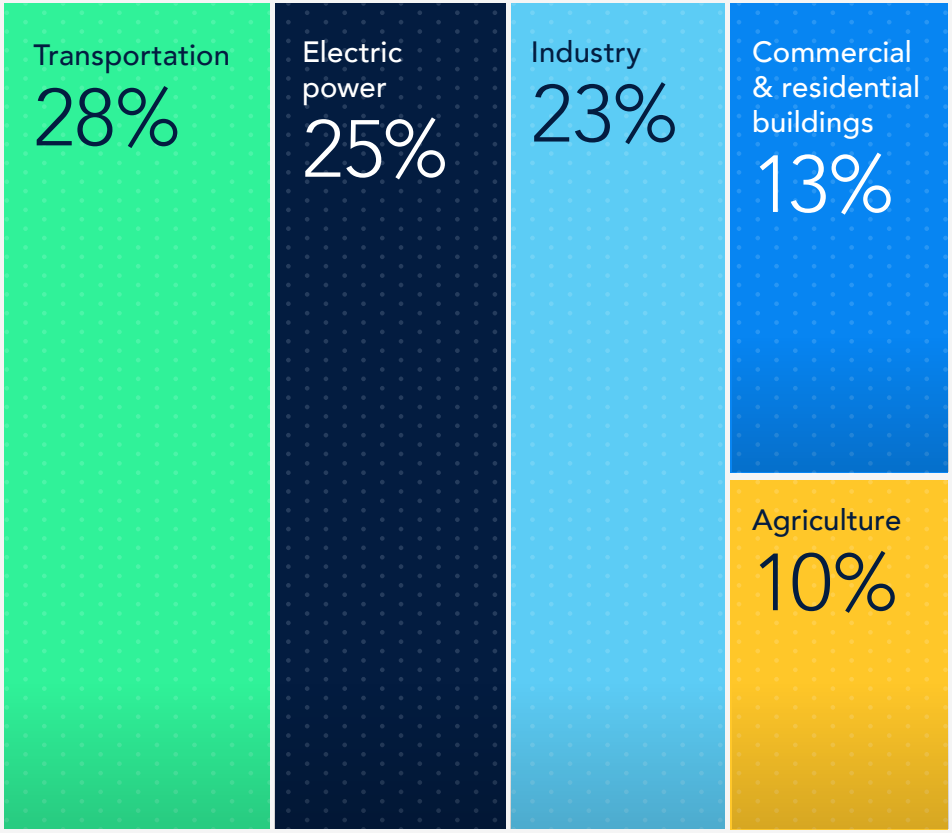
Between them, the two laws provide significant funding to advance decarbonization in five economic sectors that make up U.S. GHG emissions—transportation, electric power, industry, commercial & residential buildings, and agriculture—as indicated in Figure 3. Using an economic sector lens of emissions allows for a simplistic view of the U.S. GHG Inventory.

While successful implementation of the BIL and IRA objectives, as well as continuation of policies and efforts that existed before passage of the BIL and IRA, won't fully achieve the U.S. decarbonization goals, they are achievable.

Our Diversified Goal Scenario (Figure 4) shows that it is possible for the United States to cut GHG emissions more than 40% from 2005 levels by 2030 and nearly 90% by 2050 by aggressively pursuing three currently-available super solutions in combination with the outcomes forecast in the BIL/IRA scenario. These super solutions—transportation electrification, building decarbonization, and clean energy—are particularly significant for their potential to dramatically reduce GHGs.

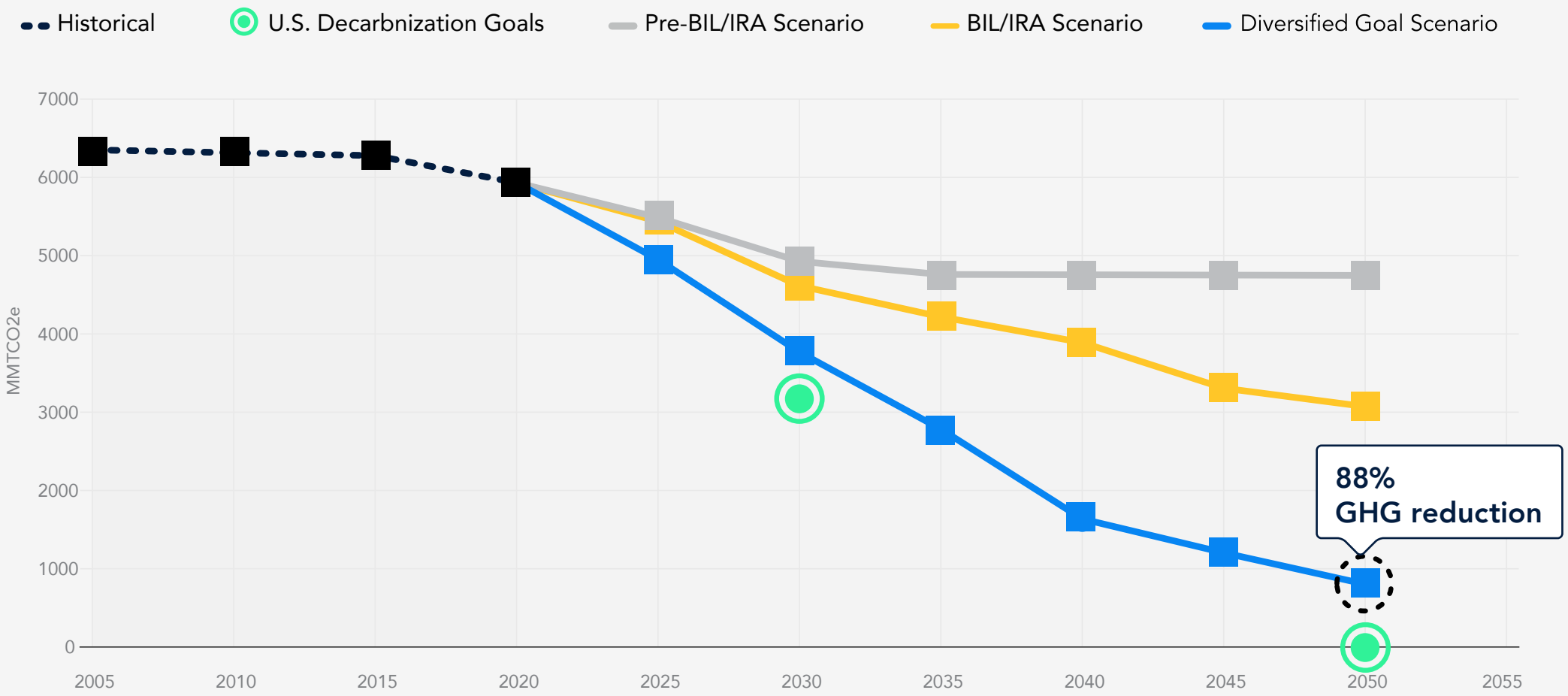
This scenario does not achieve net zero; residual GHG emissions remain as a result of hard-to-abate sectors for which solutions must be identified and deployed. While the ICF Climate Center did not model the elimination of those remaining emissions sources, accelerated technology innovations, a range of carbon sequestration methods, and other strategies in the coming decades could potentially get the United States to net-zero GHG emissions.

Figure 3: Sources of U.S. GHG emissions in 2021 (% of emissions in MMTCO2 eq)



Source: U.S. Environmental Protection Agency

Figure 4: U.S. Diversified Goal Scenario with three super solutions



Source: ICF decarbonization platform (CO_2Sight™)

Our Diversified Goal Scenario is one potential scenario that takes into account both existing and potential policies, technologies, and other factors to model the technically-achievable decarbonization these three super solutions could deliver, if fully implemented and as explored below.

Importantly, the Diversified Goal Scenario is far from a foregone conclusion. If the United States is able to overcome a host of challenges to scale three super solutions to their full potential, then the Diversified Goal Scenario would be possible.

Super Solution 1: Increase electric vehicles by 100X

CO_2Sight™, ICF's decarbonization modeling platform, helps localities, states, utilities, and other organizations to quantify potential GHG reduction pathway options to meet short-, mid-, and long-term GHG reduction targets.

ICF uses CO_2Sight™ tools and data to analyze specific sectors, compare multiple pathways to reach goals, assess relative costs of pathways, and visualizes results.

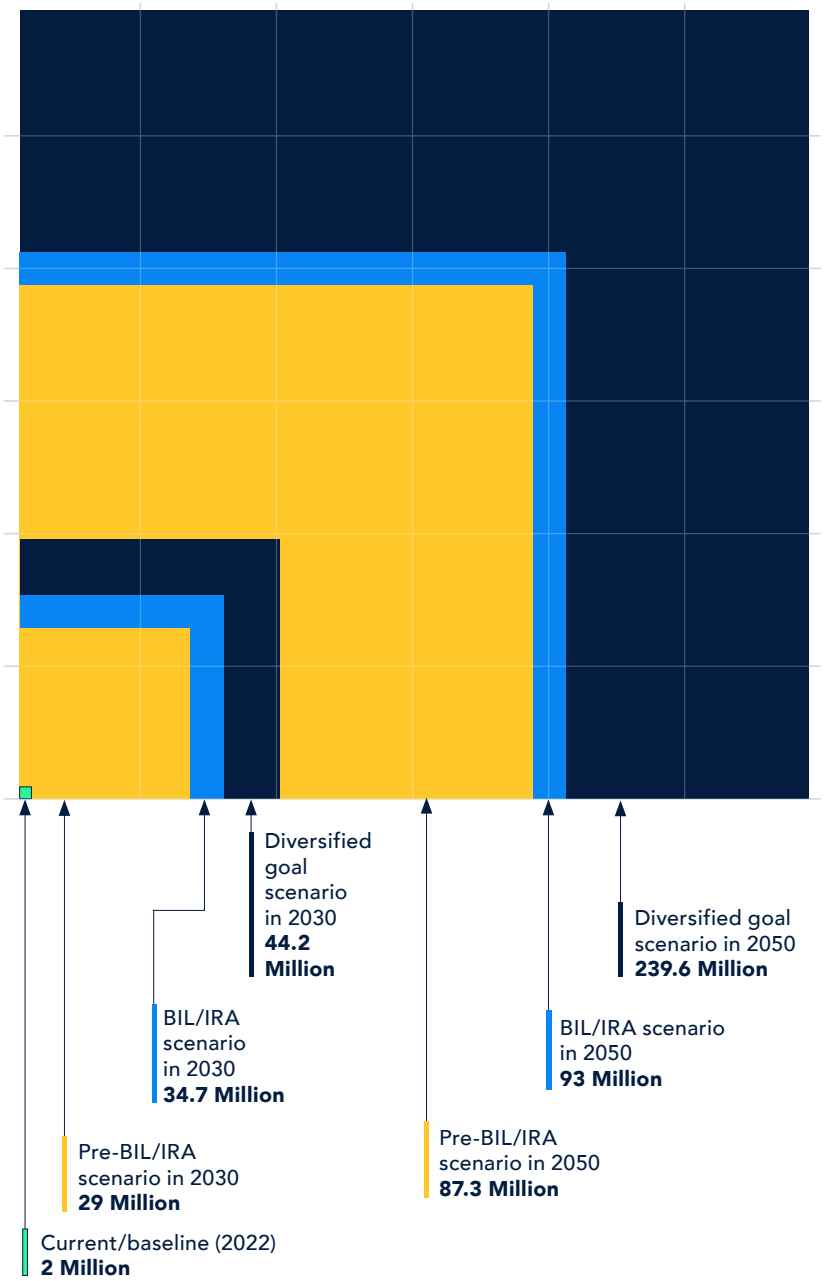
Around two million EVs were on U.S. roads at the end of 2022. Our Diversified Goal Scenario would require aggressive EV growth, more than 100X the current number of EVs on the road by 2050, including both the light-duty cars and pick-up trucks as well as heavy-duty buses and trucks. The United States would need to reach more than 44 million EVs on the road by 2030 and nearly 240 million by 2050 (Figure 5). According to the pre-BIL/IRA Scenario, the United States was already on track for about 29 million EVs on the road by 2030 before passage of the BIL and IRA. Those two laws, with their funding to build a national EV charging network and financial incentives to help consumers and businesses buy new and used EVs, could increase the number of EVs on the road by 2030 to nearly 35 million EVs. For transportation electrification to deliver the emission reductions modeled in the Diversified Goal Scenario, an additional 10 million EVs would need to be on the road by 2030, above the 34.7 million EVs in the BIL/IRA Scenario.

Our BIL/IRA Scenario shows that these laws will yield a total of 93 million EVs on the road by 2050, nearly 150 million less than the total modeled in our Diversified Goal Scenario. How might the U.S. make up a 150 million EV gap between the BIL/IRA Scenario and the Diversified Goal Scenario?

In 2022, the ICF Climate Center estimated[8] that an aggressive mandate for zero-emissions vehicles (ZEV), such as EVs, could drive the United States to reach 265 million EVs by 2050, of a total 310 million vehicles estimated to be in operation in that year. Combining a national ZEV mandate with the Biden administration's goal for a 100% clean power grid by 2035 would yield an 82% reduction in transportation sector emissions by 2050. Beyond a ZEV mandate, policies and funding to continue supporting EV charging infrastructure, electric grid capacity, and battery supply chain growth could all provide additional support to the widespread adoption of EVs modeled in the Diversified Goal Scenario.

[8] The impact of electric vehicles on climate change, ICF Climate Center

Figure 5: Transportation electrification scenarios



Source: ICF analysis using CO_2Sight™ decarbonization platform

Importantly, the pursuit of transportation electrification goes beyond simply replacing the internal combustion engine.

Given the potential for changes in land use, investments in public transportation are needed, such as system expansion, transit fare changes, as well as walk- and bicycle-friendly infrastructure in cities. In modeling the transportation electrification super solution, we assume complementary measures are implemented, such as vehicle mile traveled (VMT) fees for driving, and congestion pricing for specific zones, starting in 2030 and increasing in price through 2050. Through these measures, the ICF Climate Center estimates that a 10% decrease in VMT by 2030 and a 14% decrease by 2050 is feasible—contributing meaningfully to the Diversified Goal Scenario.

How to increase EVs by 100X

The U.S. will need to overcome many complex transportation challenges to achieve the levels of EV adoption modeled in the Diversified Goal Scenario.

Battery manufacturing would need to scale up. Building the battery supply chain will require new sources of minerals primarily available outside the United States. As one potential solution, U.S. manufacturers and automakers are attempting to expand mining operations for minerals in the United States. Streamlining the permitting process could accelerate and expand the availability of minerals domestically. U.S.-made component requirements in the IRA will make it critical for automakers to solve this challenge and source more battery materials in the U.S. to unlock IRA tax-incentive-driven demand.

Continuing consumer excitement for EVs would also need to remain a priority. Automakers in recent years have revised their EV sales projections downward and warned of slower-than-expected adoption in the U.S.[9] Slowing growth in U.S. EV sales in the first half of 2023[10] led to rising inventories and price cuts for many EV models, as automakers sought to spur the market and avoid heavy profit losses.[11] If consumer EV demand falls short in the years to come, transportation electrification will fall short as a decarbonization solution. Automakers and other stakeholder will need to find ways to continue to spur consumer adoption of EVs.

From remote rural areas to urban communities, the U.S. would need to scale public EV charging stations. The National Renewable Energy Laboratory estimates the U.S. needs a million publicly available Level 2 charging ports and 182,000 publicly available fast-charging ports to support a scenario with 33 million light- and medium-duty EVs by 2030.[12] By comparison, there were about 130,000 public chargers available in early 2023.[13] Aside from the obvious challenge of permitting and construction of so many chargers, utilities would need to expand the electric grid's capacity and implement sophisticated electric load management strategies to serve this wave of new chargers.

Finally, despite the potential benefits to disadvantaged communities, EV ownership today is much greater among higher-income households and in higher income communities. In recent years, EV costs and the lack of EV charging were contributing factors to lower levels of EV ownership in disadvantaged communities. The chicken-and-egg challenge of placing chargers in disadvantaged communities with low demand is not the only equity challenge surrounding EVs. The U.S. will also need to expand the electrification of public transportation, which will significantly benefit disadvantaged communities.

None of these transportation electrification challenges are insurmountable. The rapid growth in EV adoption over the past few years in combination with incentives and consumer demand can provide momentum needed to drive continued growth and help overcome many of these barriers. But additional investments, regulations, and policies for transportation electrification would be needed for the U.S. to achieve its decarbonization goals.

[9] https://www.cnbc.com/2023/07/27/ford-pushes-back-ev-target-warns-of-wider-losses.html
[10] https://www.bloomberg.com/news/articles/2023-07-06/electric-vehicle-sales-growth-slows-in-us-as-inventory-builds-up
[11] https://www.reuters.com/business/autos-transportation/slow-selling-evs-are-auto-industrys-new-headache-2023-07-11/
[12] https://www.nrel.gov/news/program/2023/building-the-2030-national-charging-network.html
[13] https://www.whitehouse.gov/briefing-room/statements-releases/2023/02/15/fact-sheet-biden-harris-administration-announces-new-standards-and-major-progress-for-a-made-in-america-national-network-of-electric-vehicle-chargers/

Building decarbonization measures

Measures modeled through the CO_2Sight decarbonization platform include a range of residential and commercial building energy efficiency and electrification measures including:

- Building control systems.
- High efficiency lighting and lighting control systems.
- High efficiency appliances, boilers, furnaces, hot water heaters, and air conditioning devices (including chillers, packaged units and other devices).
- Air and ground source heat pumps, HVAC variable refrigerant flow systems, and heat pump water heaters.
- Building envelope upgrades and deep energy retrofits.

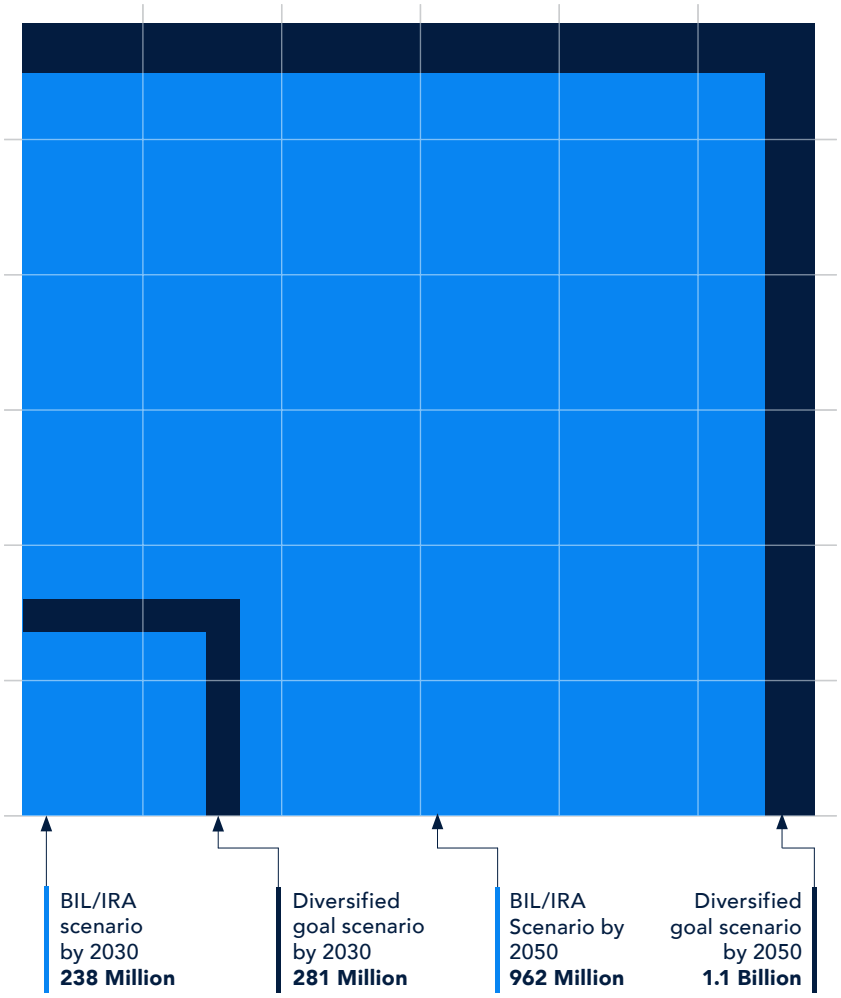
Super Solution 2: Install more than a billion decarbonization measures in buildings

There are roughly 110 million buildings in the United States[14], but they are certainly not created equal. About 90% of buildings, or 100 million units, are single-family homes. More than 5 million are multifamily residential buildings—containing 40 million housing units—and 5.5 million are commercial or institutional buildings.

BIL and IRA funding puts the U.S. on a path for additional decarbonization measures to be adopted in buildings, including energy efficiency (efficient windows, doors and insulation, and more) and electrification (rooftop solar, heat pumps, and more). The BIL and IRA could add an additional 238 million decarbonization measures in buildings by 2030 and an additional 962 million measures in buildings by 2050 (Figure 6). However, for building decarbonization to deliver the results modeled in our Diversified Goal Scenario, nearly 281 million additional measures would need to be implemented in buildings by 2030 and around 1.1 billion by 2050. In addition to the growth in the number of decarbonization measures installed, the types of measures would also have to evolve, including building envelope and shell improvements, electrification, and more holistic retrofits of buildings occurring. The Diversified Goal Scenario's results show that it will be necessary for nearly all U.S. buildings to undergo some type of energy efficiency and/or electrification measure by 2050.

[14] https://www.construction-physics.com/p/every-building-in-america-an-analysis

Figure 6: Building decarbonization scenarios



Source: ICF analysis using CO_2Sight™ decarbonization platform

The Diversified Goal Scenario's results show that it will be necessary for nearly all U.S. buildings to undergo some type of energy efficiency or electrification measure by 2050.

How to install more than a billion decarbonization measures in U.S. buildings

Building decarbonization requires multiple measures, starting with building envelope upgrades, insulating the interior of a building from the exterior, to reduce energy use and peak demand. "Plug loads," such as lighting and appliances that consumers plug into electrical outlets, need upgrading. Heating and hot water systems need low-carbon solutions in the form of electric technology or low-carbon fuels.

These measures all have different market cycles, supply chains, and installation contractors. Their economics also vary widely depending on location in the country, available rebates and incentives, financing options, and other factors. Some measures encounter technical challenges in some building types. When you look at all of these factors together, it is very hard to standardize and integrate decarbonization solutions across varying regional and local markets.

Building energy upgrade markets also face two high-level challenges: fragmentation and slow turnover. There are hundreds of thousands of building contractors, with little technical standardization and often limited capacity to diagnose and upgrade the wide variety of building conditions they find. Buildings turn over very slowly. While some 5% of cars on the road turn over each year, only a fraction of a percent of buildings undergoes major renovations or is demolished annually.

This means that decarbonizing existing buildings may naturally happen in a somewhat piecemeal fashion, whereas new EVs come fully equipped. Utilities and government agencies can structure building decarbonization programs by encouraging the bundling of energy efficiency upgrades and electrification during a single interaction with each building owner.

The IRA includes substantial building energy efficiency and electrification rebates, tax credits, and low interest financing, as well as investments in energy codes, state energy programs, training programs and other systems that support the deployment of these measures. State and local governments, along with utility partners, will be in prime position to help consumers retrofit their buildings and qualify for the incentives.

Many of the IRA incentives—from rooftop solar panels to heat pumps to induction cooktops and more—are designed to make it more affordable and accessible for consumers to voluntarily adopt these climate-friendly products. Lowering the financial cost of these technologies will certainly make them more attractive to consumers, but changing consumer purchasing decisions at scale is a complex and multifaceted challenge.

Fortunately, the federal government has a blueprint for achieving this sort of market transformation from the U.S. Environmental Protection Agency's ENERGY STAR® program. Recognized by more than 90% of American households, ENERGY STAR has motivated consumers to purchase energy efficient products like household appliances and light bulbs that reduce greenhouse gas emissions. Drawing from ICF's decades of work on the ENERGY STAR program, there are four essential elements of market transformation that every climate-friendly product must navigate to become mainstream.[15]

[15] https://www.icf.com/insights/market-transformation-climate-friendly-products

EPA's ENERGY STAR® program made energy efficiency mainstream

The ENERGY STAR label has become synonymous with cost savings and energy efficiency: 90% of American households recognize the ENERGY STAR brand.

For over 30 years, ICF has supported EPA by providing strategic, technical, analytical, and market engagement support to the ENERGY STAR program.

LEARN MORE

1. **Know the market.** It's important to understand every aspect of the market—all the way from the raw materials used in production to the consumer making the purchase to the disposal of the products it is replacing.
2. **Understand the barriers.** It's important to understand the likely barriers a climate-friendly product will face as it moves from research and development to prototype to demonstration to commercialization and eventually to mainstream market success.
3. **Embrace scalability.** Work with the early adopters first to gain momentum, but continually evaluate the market dynamics to determine the next level of stakeholders to engage. At each junction, scale up in order to expand markets and reach new customers while still being able to meet the demands for new climate-friendly products.
4. **Continue to improve and adapt.** Achieving market transformation requires agility to react to changes in the market and consumer demands.

Addressing these challenges will require substantial efforts. The U.S. would need to build the workforce and their technical capabilities to deliver building decarbonization upgrades. Improved diagnostic tools using data analytics would help identify the decarbonization upgrade opportunities that deliver the biggest bang for the buck. And, major financial incentives in addition to existing tax incentives and rebates through the BIL and IRA would accelerate building decarbonization. Finally, regulatory reforms that prioritize clean technologies over fossil fuel technologies would help accelerate the pace of turnover in key building systems.

Super Solution 3: Rapidly ramp-up clean energy

Electrifying transportation and buildings can reduce GHG emissions, even with the current mix of power generating resources in the U.S. However, electrification becomes much more effective at reducing emissions when paired with clean electricity. Put another way, a low- or zero-carbon power sector is a cornerstone super solution that amplifies decarbonization across the entire U.S. economy.

Much as a clean power grid serves as an essential ingredient enabling other super solutions, so, too, do low-carbon fuels. Low-carbon fuels in this analysis include emerging technologies such as renewable natural gas (RNG) from anaerobic digestion and thermal gasification, renewable hydrogen (formerly known as "green hydrogen"). These fuels can help decarbonize buildings, transportation, and industrial processes where electrification is not practical.

Increase renewables to 85% of total electricity generation

The U.S. would have to significantly increase renewable electricity generation to achieve its decarbonization goals. Our Diversified Goal Scenario models a rise in solar and wind from about 13% of total generation in 2022 to more than 80% by 2050. While renewable generation increases significantly over time, the sun isn't always shining, and the wind isn't always blowing. In order to create a balanced, reliable supply of renewable electricity, storage capacity from sources such as batteries would also need to rise from a negligible amount in 2022 to hundreds of gigawatts (GW) by 2050. In parallel with the increase in renewable electricity, the U.S. would need to reduce the share of generation

natural gas, coal, and other remaining unabated fossil fuels sources from 60% in 2022 to nearly zero in 2050. For the remaining low-carbon dispatchable resources that can be turned on and off on-demand, we model the use of carbon capture, usage and sequestration (CCUS) and RNG to reduce CO_2 emissions (Figure 7). While these resources comprise less than 10% of generation in 2050, they account for hundreds of GW of capacity, providing valuable reliability benefits, alongside storage, to the low-carbon system in 2050.

In total by 2050, over 85% of all U.S. generation capacity would come from renewable wind, solar, and hydro resources by 2050, with the remaining amount coming from low- or zero-carbon dispatchable resources.

Figure 7: Electric Generating Mix for Diversified Goal Scenario

Source: ICF analysis using CO_2Sight™ decarbonization platform[17]

Renewable natural gas

Also known as biomethane, RNG is a biofuel naturally produced from the decomposition of organic material.

[16]Based on EIA 2022 generation results

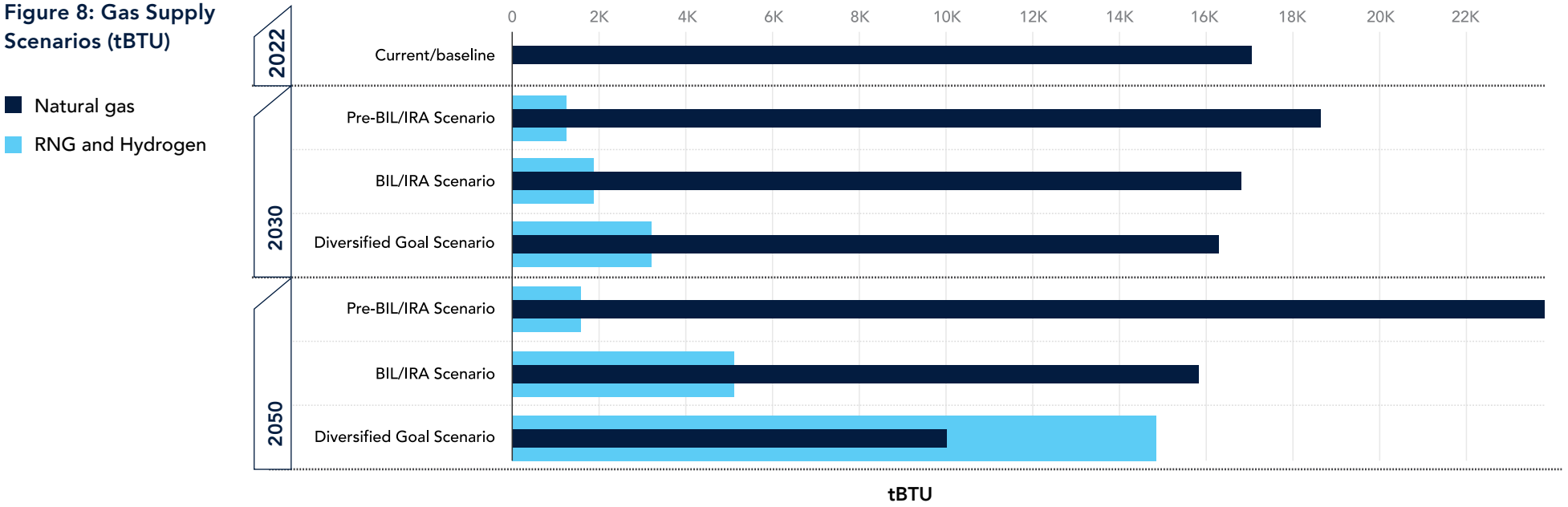
[17]This analysis did not consider emerging generation technologies, such as advanced nuclear, or new transmission capacity needed to support projected new generation sources.

Accelerate low-carbon fuels to surpass natural gas by 2040

In addition to replacing fossil fuels for generating electricity, fossil fuels are also used for heating and industrial applications. The United States used about 17,000 tBTU of methane-based fuel for non-power uses such as heating and industrial applications in 2020. The majority of this, 98%, was fossil fuel based, and a small percent is methane that comes from non-fossil sources including low-carbon fuels.

With BIL and IRA funding, our scenario projects that low-carbon fuels will grow to more than 1,800 tBTU by 2030 and more than 5,100 tBTU by 2050. However, for low-carbon fuels to reach their potential as a super solution as modeled in our Diversified Goal Scenario, low-carbon fuel supply would need to grow much faster, to 3,200 tBTU by 2030 and 14,850 tBTU by 2050. In our Diversified Goal Scenario, low-carbon fuels in total surpass natural gas, also known as fossil gas, as a fuel supply by 2040 (Figure 8).

Figure 8: Gas Supply Scenarios (tBTU)



Source: ICF decarbonization platform (CO_2Sight™)

RNG could become a key low-carbon fuel in the clean energy supply, leading the ICF Climate Center to project significant RNG supply growth by 2030 and 2050 in the BIL/IRA scenario. While the Diversified Goal Scenario calls for a modest increase in RNG supply—about 3,500 tBTU more by 2050—compared to the BIL/IRA scenario, the real challenge comes with a needed increase in renewable hydrogen supplies. We assume that renewable hydrogen supplies would rise from virtually zero today to almost 900 tBTU by 2030 and more than 6,100 tBTU by 2050, under the Diversified Goal scenario. The BIL provides $9.5 billion in funding for U.S. hydrogen hubs and other renewable hydrogen initiatives, which could yield early supply growth. In order for the availability of hydrogen to meet the levels projected in our scenario, the public and private sectors will need to substantially build on the momentum generated by the seed investment made through the BIL.

How to scale clean power and low- and no-carbon fuels

Electric grid readiness remains a major challenge to wide-scale clean energy adoption. Transmission expansion to decarbonize the grid would require a significant investment. Permitting[18], land rights, and regulatory approval for transmission projects are arduous processes that could be reformed, and are currently under consideration for areas of improvement by the federal government as a part of BIL/IRA, to significantly accelerate renewable energy adoption.

Identifying the optimal location, or sites, to build all of these new clean energy projects can help maximize the benefits of clean energy development while avoiding many challenges. When siting clean energy projects on undeveloped land, or greenfields, several critical factors impact the feasibility of the project:

- Grid access and available capacity
- Economic viability
- Land use and resource availability
- Policies and incentives

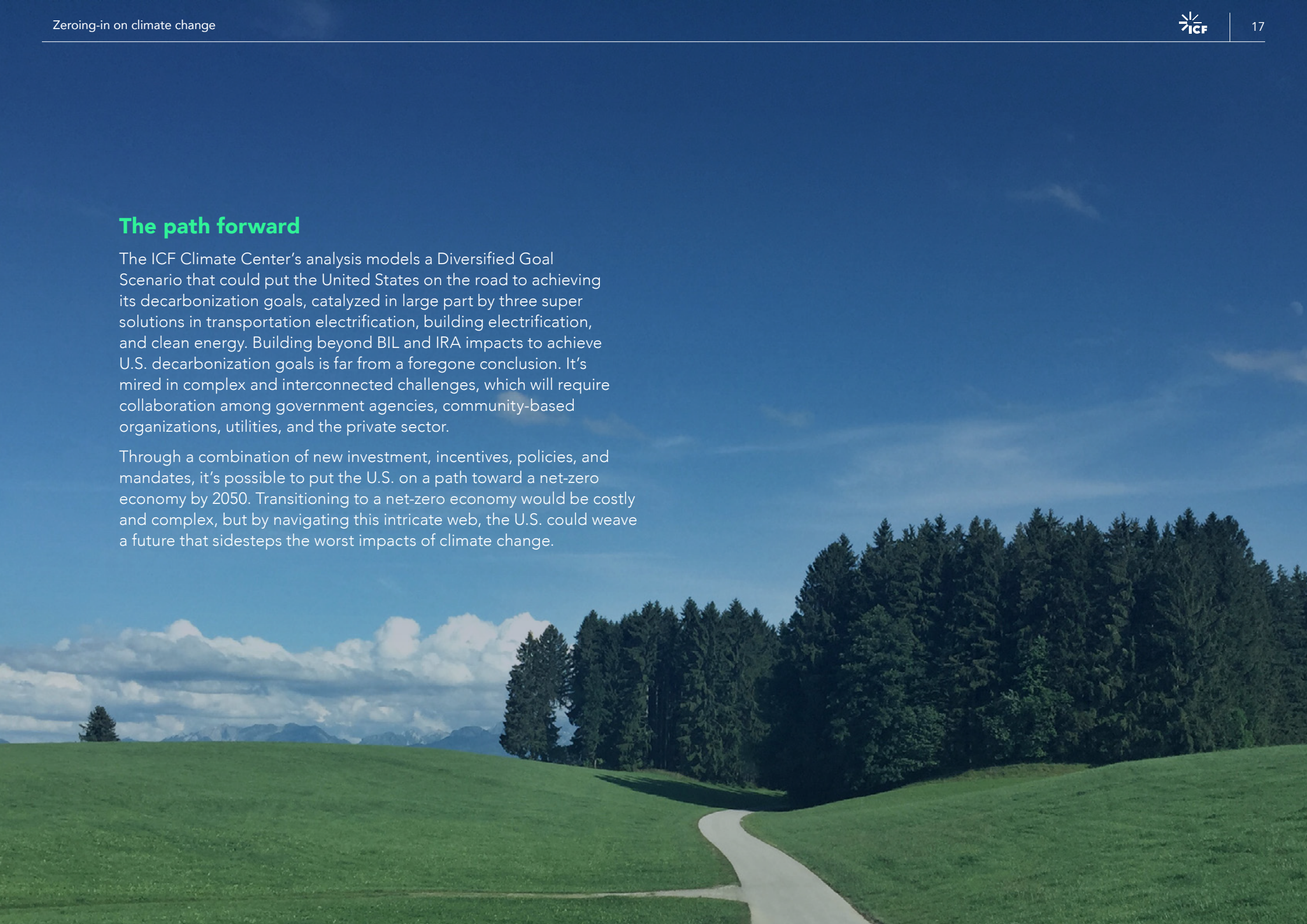
Clean energy developers, utilities, and other stakeholders can leverage technology[19] to perform due diligence around all these considerations simultaneously, maximizing their return on investment and accelerating clean energy development.

On the distribution side of the grid, customers are increasingly adopting distributed energy resources (DERs), such as rooftop solar and battery energy storage systems. As DERs rise as a proportion of generation on the grid, they can create a host of grid stability challenges. But DERs could also be a grid asset. Doing so requires significant investment in DER management systems, grid digitalization and automation, and data management and analysis.

Similar to EVs, scaling clean energy will require building out the supply chain of raw materials.[20] From copper to cobalt, manganese to molybdenum, and more, the U.S. needs new sources of minerals to manufacture clean energy technologies and integrate them into the grid. This will require investment to expand and diversify the supply of new minerals and recycle existing minerals.

Low- and no-carbon fuels challenges are primarily related to cost and supply. While BIL investments seek to accelerate renewable hydrogen production, sources today are both limited in the U.S. and more expensive than methane on a per unit basis. RNG production remains extremely fragmented across a patchwork of farms and landfills and must be scaled to become a significant fuel supply source in utilities' gas distribution systems. This effort would require investment in midstream infrastructure to connect upstream RNG sources with downstream distribution networks. Many of the challenges that persist in the clean energy sector can be addressed through relying on a diverse set of clean energy resources and updating and innovating existing policy, regulatory, and permitting frameworks to address a new clean energy paradigm.

[18] https://www.publicpower.org/streamlining-energy-infrastructure-permitting
[19] https://www.icf.com/insights/energy/clean-energy-project-sites-ira-benefits
[20] https://www.icf.com/insights/energy/securing-raw-material-supply-green-transition



The path forward

The ICF Climate Center's analysis models a Diversified Goal Scenario that could put the United States on the road to achieving its decarbonization goals, catalyzed in large part by three super solutions in transportation electrification, building electrification, and clean energy. Building beyond BIL and IRA impacts to achieve U.S. decarbonization goals is far from a foregone conclusion. It's mired in complex and interconnected challenges, which will require collaboration among government agencies, community-based organizations, utilities, and the private sector.

Through a combination of new investment, incentives, policies, and mandates, it's possible to put the U.S. on a path toward a net-zero economy by 2050. Transitioning to a net-zero economy would be costly and complex, but by navigating this intricate web, the U.S. could weave a future that sidesteps the worst impacts of climate change.

Methodology

ICF used a combination of in-house expertise and external sources (such as U.S. Energy Information Administration historical data and projections) to set parameters for the models used in this analysis. The analysis was then conducted using the ICF Climate Center's CO_2Sight™ analytical platform.

ICF's modeling approach in this study takes a restrained approach in its near-term modeling. For example, the electric power sector model uses a least cost approach to determine the deployment of electricity generation projects, which is informed in part by existing transmission constraints, supply chain delays, and permitting and interconnection concerns, all of which have been hampering renewable energy growth over the past couple of years and are expected to continue delaying and restricting project development in the near term (through 2030). Additionally, ICF's modeling approach to buildings and transportation accounts for IRA and BIL federal investments in energy efficiency and electrification but does not fully account for market transformation impacts on account of those investments or consider continued investment in either sector beyond the IRA and BIL.

The Diversified Goal Scenario provided in this analysis models a scenario in which future U.S. GHG emissions are closely aligned with GHG targets specified in the U.S. Nationally Determined Contributions made under the Paris Agreement. The GHG reductions are driven largely by technologies and strategies grouped into three super solutions, with outputs modeled by CO_2Sight™. The projections modeled within the super solutions in many cases relied on high-level, top-down modeling.

The methodology for transportation-based data relied on historical and projected sales curves for heavy- and light-duty EVs and electric buses derived from NREL Electrification Futures Study, as well as a proprietary vehicle stock turnover tool. Vehicle miles reduced assumptions were based on ICF modeling of strategies of focused land use changes, transit and mobility expansion and enhancements, as well as road pricing policies to be implemented through 2050. The methodology for low-carbon fuels-based data relied on information and estimates from several external sources. The methodology for power sector-based data used CO_2Sight's power sector modeling tool with an underlying assumption of net-zero emissions by 2040.

Hypothetical versus expected: The modeling in this analysis was different than that used for previous ICF projections. It is based on hypothetical policies and actions that could put the U.S. on a pathway to reach its decarbonization goals.

Costs: The analysis does not estimate cost. There is no doubt that reaching the full potential of these solutions is a heavy lift for the U.S. economy. The point of identifying the three super solutions is not to propose the only path toward net zero GHG emissions, but rather to demonstrate that a Diversified Goal Scenario is achievable using available super solutions.

Hard-to-abate emissions: As noted, the Diversified Goal Scenario does not address the final 12% of GHG emissions (based on 2005 levels) needed to bring the U.S. economy to net-zero GHG emissions. Emerging technologies and innovation in the industrial, agricultural, and aviation

industries would be necessary to eliminate emissions that are essentially "the last mile" to net zero. Many emerging industrial, fuel, and energy decarbonization technologies are in development, but not considered in this analysis due to their early stage. Improved land use policies could increase agriculture's ability to be a carbon sink. The prospects to find a path to net zero through early-stage technologies are promising, but not proven, and therefore not included in this analysis.

Local, state and regional forces: As decarbonization efforts happen in real-time, they happen from the bottom-up at the local and regional level. In a national level analysis such as this one, high-level estimates provide a feasible outlook for the future, but the ultimate outcome will be determined by realities at a local and regional level. This analysis does not explicitly account for potential changes in policies and measures at the state or local levels in the United States.

For example, the Diversified Goal Scenario models significant new renewable generation. Permitting and land availability is highly variable for generation projects, including renewables. The Diversified Goal Scenario assumes significant electrification. It assumes the U.S. electric grid will maintain the reliability and build the resilience to support the necessary level of electrification, but if utilities fall short on efforts to modernize the grid, there will be little choice but to slow electrification efforts. Permitting and land availability is also highly variable for much-needed new transmission projects. The success or failure of a few major transmission projects could significantly alter the U.S. path toward net zero.

Similarly, the analysis models significant growth in renewable hydrogen fuel supplies. Given that those supplies will likely come from a few major production hubs, the failure of a relative few production projects could severely limit hydrogen as a component of the low-carbon fuels super solution.

Contact us

Adam Agalloco
Director, Climate Change and Sustainability
Adam.Agalloco@icf.com

Deb Harris
Senior Director, Climate Planning +
ICF Climate Center Senior Fellow
Deb.Harris@icf.com

Michael Jung
Executive Director, ICF Climate Center
Michael.Jung@icf.com

ICF CLIMATE center

twitter.com/ICF
linkedin.com/company/icf-international
facebook.com/ThisIsICF
#thisisicf

icf.com/climate

The ICF Climate Center offers compelling research and unique insights that help organizations establish clear, practical pathways forward through the combination of climate science and predictive analytics.

The Center builds upon the work of 2,000+ climate, energy, and environment experts worldwide—making us one of the world's largest science-based climate consultancies. ICF works with business, government, and nonprofit organizations to design and implement programs and policies that drive low-carbon transitions and build resilience against the effects of climate change.