RMI

Realizing America's Clean Energy Opportunity

Accelerating Clean Regional Economies

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About RMI

RMI is an independent nonprofit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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Executive Summary

Energy, the input to every factor of economic production and backbone of modern life, is experiencing its greatest period of upheaval since Edwin Drake built the first oil well in 1859. The opportunities in this upheaval will be immense.

If the world aligns with a net-zero pathway, where total net carbon emissions are eliminated by 2050, investment into decarbonization ($785 billion in 2021) would triple by 2025 and double again by 2030.[1] These would be productivity-enhancing capital investments in technologies that create more jobs, support startups, drive innovation, modernize infrastructure, transform communities, and build advanced manufacturing capacity that otherwise will not exist in a fossil fuel–intensive energy system.

Clean energy is likely to become the cheapest source of energy in human history, opening countless possibilities in an era of energy abundance and economic dynamism.[2]

The United States can be a leader in this global energy transition, but to date it has not done enough to position itself for this opportunity. A growing number of countries are adopting ambitious clean energy policies and investing heavily in emerging technologies, raising the risk that the United States will be left further and further behind if it fails to take bold action.

Clean energy is likely to become the cheapest source of energy in human history, opening countless possibilities in an era of energy abundance and economic dynamism.

The United States needs a national strategy that focuses not on minimizing costs but maximizing the opportunities inherent in a clean energy transition. Above all, this strategy should prioritize accelerating investment in clean energy technologies, physical infrastructure, and vertical supply chains. In the process, the United States can support regional economies, accelerate growth, and promote a dynamic, inclusive society.

Although this issue is often thought of in terms of national competitiveness, many of the economic and social gains to be had in the US clean energy transition will be realized at the regional, or multistate, level and therefore call for a place-based approach to clean energy investment. A place-based approach should recognize the unique strengths, skills, and legacies of America's varied regions and develop targeted regional investment strategies that empower communities and build on local clean energy economic potential.

The Opportunity

With an unprecedented shift in the global energy system underway, the demand for clean energy technologies will continue to increase, as will the opportunities for regional specialization and integration. If governments and investors align their actions with their net-zero pledges, then this growth is just the beginning.

For too long, US policymakers and climate advocates have promoted the clean energy transition as an act of good will, prioritizing solutions that minimize costs but fail to capitalize on opportunities. Nor should the United States aim to catch up to the market leaders out of some sense of zero-sum competition and geopolitical rivalry. Rather, the transition is a once-in-a-generation opportunity to invest in good jobs, empowered communities, quality infrastructure, and game-changing technologies. As the domestic demand for clean energy technologies accelerates, new investments in infrastructure and clean energy supply chains can empower communities, drive productivity growth, create new export opportunities, and foster an inclusive industrial economy and American society.

Moreover, as the global disruptions of the COVID-19 pandemic and now the Russian invasion of Ukraine have laid bare, if the world is to create a more resilient global energy system, all countries will need to bolster their domestic contributions to the global supply chain for clean energy technologies. The United States is big and diverse enough to meaningfully contribute to this resilience by identifying regions that can accelerate investment in their industrial base, physical infrastructure, public works, and institutions of community empowerment.

The transition is a once-in-a-generation opportunity to invest in good jobs, empowered communities, quality infrastructure, and game-changing technologies.

The United States is in the midst of a historic clean energy transition that will only accelerate from here. A recent study estimates that embracing this transition will create positive gross domestic product (GDP) growth in every region of the country and more than $3 trillion in new economic value.[3] These benefits arise from investments in a more productive, modern, and dynamic economy, even as the costs of clean energy continue to fall exponentially. Clean energy is likely to become so cheap, in fact, that total expenditure needed to reach net zero will likely be a fraction of what the United States has historically spent on energy.[4]

Though the power sector has made the most progress toward net zero, more economic sectors and pieces of American life are following suit. The next most developed sector is transport, as electric vehicles (EVs) become more widely accepted and adopted. Meanwhile, new technologies are starting to revolutionize the buildings people live in, the cities people work in, and the industries that create the material foundation of modern life. The surge in investment is also translating into major shifts in the stock market, venture capital allocations, and asset managers' portfolios.

Although the clean energy transition is happening all across the United States, it is happening at varying speeds and scales. This diversity can be a source of strength. Different clean energy technologies will have distinct regional effects according to geographic, political, and economic factors. The Atlantic Coast, for example, is primed to benefit from a surge of investment in offshore wind. EV and battery manufacturing are already a major source of new investment in the auto manufacturing cluster known as Auto Alley that runs from Michigan to Alabama. The Gulf Coast has the potential to become a major global hub of clean hydrogen–related products and decarbonized industrial processes.

These emerging clusters reflect the fact that clean energy sectors are more manufacturing- and export-intensive than most industries, suggesting the clean energy transition could be a boon to US manufacturing and trade. Manufacturing of technologically complex products has historically been a major source of US exports, technological innovation, job growth, and regional development. A clean

energy transition that emphasizes domestic manufacturing of key technologies could bring these benefits back to American communities.

In response to shifting public opinion and technology improvements, institutions at all levels are increasing their ambitions to accelerate this clean energy transition, including the Biden administration and the 117th Congress. Despite some setbacks, both the federal executive and legislative branches are continuing to pursue the most ambitious climate agenda in US history — one that starts to recognize the opportunity to improve US clean energy competitiveness.

However, many roadblocks remain. This report lays out a vision for how a coordinated national strategy, championed by industry and government, and regional investment plans, driven by local institutions and investors, can accelerate the creation of America's clean regional economies.

The National Strategy

There is no guarantee that the clean energy technologies likely to define the 21st century will similarly define the landscape of American prosperity. In other words, the United States needs a strategy, and quickly.

The United States has the bulk of the technological solutions required to decarbonize, but these have not reached the scale to sufficiently drive down costs and reach widespread market diffusion.[5] The willingness of the private sector to invest in these technologies at the speed of US climate goals will require a national strategy with four main elements:

The National Strategy

1. **Driving domestic demand**
2. **Addressing barriers to private investment**
3. **Constructing new infrastructure and public works**
4. **Building secure and resilient supply chains**

1. Driving Domestic Demand

The primary barrier to new technology diffusion is higher costs, and the key to driving down costs is scale. It is well established that for every doubling in cumulative production, a technology's costs decrease at a predictable rate. Historically, this cost decline took place over two phases: the technology's emergence through publicly funded R&D, and its ongoing diffusion driven by market-stimulating, demand-pull policies.[6] Extending and expanding existing demand-pull policies, like clean energy tax credits, is therefore vital to accelerating investment in clean energy sectors, such as wind and solar, batteries and EVs, hydrogen and carbon capture, utilization and storage, public transit, and low-carbon buildings.

Growing and stable demand also provides a degree of certainty to investors in making decisions on future projects. Studies of the barriers to private-sector investment in clean energy show that many investors worry about insufficient scale in clean energy, risk in nascent technologies, limited projects with acceptable risk–return profiles, and demand uncertainty created by an unstable policy environment.[7] A robust domestic market also helps support industries as they become globally competitive and a source of future exports.

As a result, it is often up to government to provide subsidies and other demand-pull measures to overcome investor fears. Policymakers' appetite for subsidies is not limitless, however, so ensuring incentives are crafted to optimize the growth of strategically important clean energy technologies and industries is important.

2. Addressing Barriers to Private Investment

Creating a demand signal does not go far enough, however. Today's heightened policy instability, technological uncertainty, and the entrenched incumbency of fossil-fuel-intensive technologies mean the clean energy transition remains a high-risk proposition for many private investors. A combination of these risks, high up-front capital requirements, a lack of experience in new sectors, and high transaction costs has created a significant green finance gap between the needed investments and those forthcoming from the private sector.[8]

In particular, technology risks in nascent clean energy industries create what is often called the valley of death between new ideas and commercialized opportunities.[9] In general, there is a lack of available investment between high-risk venture capital and the lower-risk corporate financing of more mature solutions. The public sector can de-risk private capital through innovative public financing instruments, such as loan guarantees, or through dedicated financial institutions. Historically, these financially tailored solutions have catalyzed private investment in emerging technologies and helped novel solutions reach market maturity and widespread adoption.[10]

Connecting clean energy technology applications with the right financing instruments is difficult work that will continue to evolve and change as clean energy markets mature and new technologies enter the market. This will require sustained attention and clear communication between government, investors, and clean energy companies.

3. Constructing New Infrastructure and Public Works

A key piece in accelerating clean energy technology investment is building the infrastructure to scale at speed and public works to improve people's day-to-day lives. New technologies need to be linked to existing systems through physical infrastructure if they are to function, much as communities need to see material benefits if they are to support rapid change. In transitioning to a clean energy system, there is fairly strong agreement about what infrastructure and public works need to be built but considerable debate over how and where to build it.[11]

In the energy system, the United States needs to prioritize building power lines, charging stations, and pipelines for green hydrogen and captured CO_2 over the next 10 years. However, a complex web of procedural rules make it incredibly time-consuming and expensive to build large-scale infrastructure projects in this country.[12] In particular, environmental reviews have turned many parts of the United States into a "vetocracy" where bold action requires sign-off from a large number of actors, each with the potential to stymie progress.

The clean energy transition is also an opportunity to improve where people live, how people work, and the ways people travel. Through new housing, building retrofits, public transit, and other infrastructure construction, there is a growing variety of emerging technologies and business models for revitalizing cities, addressing cost-of-living constraints, boosting standards of living, and transforming urban landscapes. However, too much regulation and red tape, such as zoning rules, are constraining the supply of new assets that could accelerate the transition, lower costs, and improve lives.

4. Building Secure and Resilient Supply Chains

The successive shocks of COVID-19 and Russia's invasion of Ukraine have drawn attention to the importance of secure, resilient supply chains, particularly in the clean energy transition. Robust supply

chains are critical to deploying clean energy technologies at scale, and to capturing the economic opportunity inherent in the energy transition.

The United States needs to invest in the capacity to produce many of the necessary pieces domestically. Of course, none of these supply chains will be 100% domestically sourced, nor should they be if the cost competitiveness that drives clean energy deployment is to be maintained. Important steps include leveraging existing national manufacturing programs, expanding funding for applied R&D, investing in workforce development, creating new public–private partnerships, and establishing regional clean energy industrial clusters.

Regional Investment Strategies

A national strategy can only go so far. The United States is a complex assortment of cities, states, and regions, with varying histories, economic structures, local cultures, and political persuasions. The clean energy transition can be accelerated by not only recognizing but also embracing this geographic diversity.

The United States needs a series of regionally tailored investment strategies, designed explicitly according to a shared recipe for success that accelerates investment and promotes regional development. These strategies should be designed with regionally specific investment barriers in mind while capitalizing on local specializations and existing industrial clusters. Finally, community institutions and leaders should be embedded in this process from the beginning, helping clean energy investments meet local needs and concerns.

The United States needs a series of regionally tailored investment strategies.

Recipe for Success

Regional investment strategies should provide a tailored recipe for success that prioritizes new investments according to their contribution to (1) the clean energy industrial base and its supply chains, (2) the enabling infrastructure and public works, or (3) the institutions of community empowerment. Recognizing the regionally specific challenges and opportunities of investing in these three categories of investment is key to accelerating the national clean energy transition.

At a high level, identifying priority investments according to this rubric can help align policy and regulatory frameworks in pursuit of a common vision. This vision will be deeply informed by a multistate region's existing strengths. A regional investment strategy can take these strengths and identify which sectors to prioritize and what pieces of the clean energy industrial base and its supply chain to mobilize around.

Meanwhile, growth in these sectors can only be as fast as the infrastructure can facilitate and communities will support. These needs will be tied to the demands of a particular sector, such as high-voltage transmission infrastructure in the power sector or hydrogen-ready pipelines in the industrial sector. Furthermore, the tools to accelerate investment are often shared among multiple state and local decision makers, creating a need for an institutionalized structure of planning and coordination, such as a regional investment strategy process.

Barriers to Investment Are Regionally Specific

Effective regional investment strategies would identify specific barriers to investment in the clean energy industrial base, its enabling infrastructure, and the spillovers to community empowerment. The multistate lens is critical here because many of these barriers are specific to the political economy and regulatory landscape of these regions.[i] Though Americans share many common values, this is a country that celebrates and encourages diversity in cultures, economies, and, of course, politics. This diversity can be a headache for investors because the success or failure of a given project can vary from county to county, state to state.

Addressing these barriers is particularly important in accelerating the clean energy transition because clean energy technologies are not competing on a level playing field. Instead, they operate in an environment of skewed incentives, uneven policy, and asymmetric information. As ambitious as some states and cities are in their clean energy deployment strategies, none are currently providing a sufficiently strong market signal to invest at the scale or speed required.

In accelerating clean energy investment, the general investment environment is just as important as specific climate mitigation policies.[13] This environment can include factors such as the overall ease of doing business, regulatory quality, investment facilitation, and competition policy. Economic development organizations (EDOs) understand these nuances and can therefore play a particularly important role in facilitating investment and implementing regional investment strategies.

Clean Energy Clusters and Regional Economic Development

Regional investment strategies can also help deliver inclusive economic development throughout America as part of a strategic cluster framework that reflects the unique competitive advantages of the varied regions.[14] Clusters are geographically localized concentrations of firms, suppliers, support services, and specialized institutions in related sectors that operate in an active web of collaboration and higher performance.

A strategic cluster framework reflects the unique competitive advantage of America's varied regions.

A core advantage of the cluster framework is the ability to use it as a means for organizing and framing disparate local and regional economic development policies and as a pragmatic way of capitalizing on existing strengths and resources, whether through dedicated cluster initiatives or cluster-oriented economic development plans. Regional investment strategies should therefore build on existing cluster initiatives and regional development strategies across multistate regions of the United States. Appropriately targeted multistate regions would be large enough to capture multiple clusters of varying industrial specializations and promote coordination between state and local actors while working at a scale commensurate with the challenge of rapid decarbonization.

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i Multistate regions have no widely agreed-upon definition, but are often associated with terms like the Midwest, South, or Gulf Coast. The term is left purposefully vague throughout the report to allow for future research into appropriate multistate groupings.

Not only can clusters help attract investment to a region, but they also offer a range of economic and social benefits.[15] They create jobs in high-wage industries and boost demand in related goods and services industries, offering a path out of unemployment for workers in hard-hit areas. As clusters grow, they can also help stabilize communities by repurposing idle assets and providing quality jobs. Clusters also typically evolve around tradable goods whose export revenue can deliver higher value to local communities, injecting more spending into local businesses and creating higher tax revenue for public services.

Embedding Institutions of Community Empowerment

Regional development takes leadership. The institutions providing that leadership will vary, as will the manner in which it is demonstrated. These institution can include EDOs, research universities, community colleges, startup incubators, business alliances, public–private partnerships, and non-governmental organizations. Furthermore, the market for clean energy industries is global, increasingly competitive, and subject to first-mover advantages and returns to scale that will leave slow movers behind. Seizing the opportunities of this growing market requires investing in the institutions that build local capacity.

Regional investment strategies should embed these institutions and leaders in an accountable process that represents where people are from and their values. This representation includes providing a just transition for communities that rely on fossil fuel industries, as well as accounting for historical environmental injustices in regions where pollution, strip mining, deforestation, and other environmental impacts have disproportionately affected low- to moderate-income workers, people of color, and other underserved groups. A multistate approach would be broad enough to flexibly accommodate perspectives across different regions of the country while remaining targeted enough to address real-world investment barriers and facilitate tangible investments in local communities.

Introduction

The world stands on the brink of a new industrial revolution, one where clean energy technologies are forming the basis for a more secure and resilient energy system. Countries around the world are competing to invent, manufacture, and sell these technologies using the power of their domestic markets, institutional manufacturing and innovation capacities, and increasingly sophisticated export strategies.

At current rates of growth, global revenues from clean energy technologies will double to nearly $3 trillion by 2030.[16] If the world aligns with a net-zero pathway, investment in decarbonization, already $785 billion in 2021, needs to triple by 2025 and double again by 2030 to well over $4 trillion annually.[17] This growth is driven by the economic and security benefits of cheap, stable, and plentiful clean energy and the global imperative to reach net-zero greenhouse gas emissions by midcentury.[18]

The United States can be a leader in this global energy transition, but to date it has not done enough to position itself for this opportunity. Part of the problem is that the United States has traditionally thought of the clean energy transition as a cost to be minimized, not an economic opportunity to be captured. The literature is replete with examples of least-cost decarbonization pathways and notably lacks studies offering scenarios that maximize possible benefits. This thinking has shaped the US national approach to climate policies, incentives, and regulations. It has also shaped how various states and regions approach clean energy investments. All that is changing.

Many of the economic and social gains to be had in the US clean energy transition will be realized at the regional level. The United States is made up of unique subregions, each with its own economic strengths, culture, history, natural resources, demographics, and political and regulatory structure. Techno-economic analysis of cost-minimizing deep-decarbonization pathways, although important, can be blind to these factors. In practice, regional political economy differences are critical components of transitioning communities, restructuring industrial sectors, and accelerating the speed of the energy transition.

The United States can compete in the creation, manufacturing, and deployment of clean energy technologies in a way that not only puts us on a path to decarbonization but drives regional economic development. Regional investment in clean energy technologies, physical infrastructure, and supply chains can support regional economies, accelerate growth, and promote a dynamic, inclusive society.

This report charts a course for promoting regional development and accelerating the clean energy transition through widespread investment. It first describes the global and national economic opportunities available in the clean energy transition, illustrating the once-in-a-generation opportunity to create dynamic, vibrant communities by tapping into clean energy supply chains. Next, it examines the progress the United States has made to date, illustrating the unprecedented yet uneven characteristics of the US clean energy transition. The following section explains what the United States needs to do to take advantage of these opportunities and accelerate progress at a national level, outlining a four-pronged approach of demand-pull, de-risking, infrastructure deployment, and supply chain resilience. Finally, the last section proposes an integrated strategy for place-based economic development through clean energy investment, aligning the strategic industry cluster framework with clean energy supply chains whose development also serves to empower regional communities.

The Economic Opportunities of the Clean Energy Transition

A growing number of countries are adopting ambitious clean energy policies and investing heavily in emerging technologies, raising the risk that the United States will get left further and further behind if it fails to take bold action. The nation needs to rapidly accelerate investment in clean energy technologies, physical infrastructure, and vertical supply chains if it is to capitalize on this moment, in the process supporting regional economies, accelerating growth, and promoting a dynamic, inclusive society.

With specialization and heightened competition at home, more and more US-based firms will be pushed to the technological frontier, boosting innovation and productivity growth throughout the economy.[19] Furthermore, in industries where the United States has already developed competitive strengths, its firms will be able to take advantage of an expanding international market and global clean energy transition.[20]

The Global Opportunity

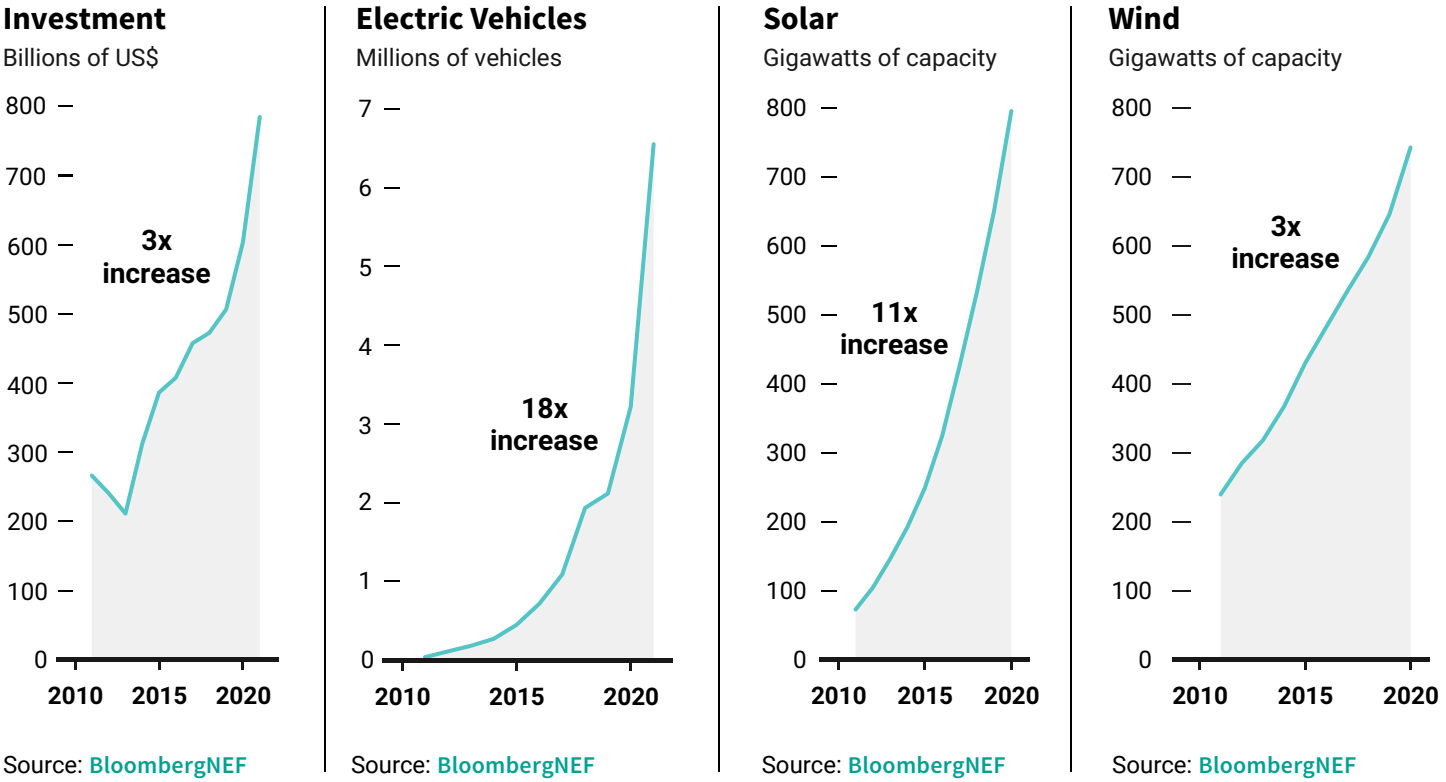
Much of the economic opportunity afforded to American workers, businesses, and communities will depend on how competitive US clean energy industries are in the global marketplace. The United States needs to learn from early market leaders while bringing its own unique advantages to bear.

The Accelerating Transition

To say clean energy is booming globally would be an understatement. In 2021, global investment in the energy transition stood at $784.4 billion, three times its size a decade earlier and more than 25 times that of 2004.[21] Whereas this investment used to be almost entirely in the power sector, today there are rapidly growing markets in electrified transport and heat, energy storage, green hydrogen, sustainable materials, and more.

All this investment has seen the deployment of clean energy technologies explode (see Exhibit 1, next page). Global solar power–generating capacity increased from just 5.5 GW in 2005 to 789 GW by the end of 2020. Wind capacity experienced only slightly less spectacular growth, increasing from 58 GW in 2005 to 743 GW by the end of 2020.[22] In 2021, 6.55 million electric vehicles (EVs) were sold worldwide, a 103% increase from the year before, and 6.51 million more than were sold in 2011.[23]

Exhibit 1 **Clean Energy Technologies Are Booming**



If governments and investors align their actions with their net-zero pledges, then this growth is just the beginning. In a scenario consistent with net-zero emissions by 2050, the world will install 630 GW of solar and 390 GW of wind power a year by 2030, four times the rate of deployment today.[24] Annual investment in power-line infrastructure will nearly quadruple to $820 billion by 2030, 40 million EV chargers will be installed, and annual battery production will climb to 6,600 GWh from just 160 GWh in 2020. The deployment of electrolyzers for green hydrogen production is expected to grow by a factor of 1,000 by 2040.[25] The upstream effects will be similarly dramatic, with the market for critical minerals like copper, cobalt, and manganese likely growing by over 700% in the next decade, surpassing revenues in the coal industry.[26]

The United States, however, is not currently prepared to seize this opportunity. It is home to relatively few global leaders in clean energy technology production and lags far behind in global market share of major clean energy technologies, like solar power, EVs, and batteries. None of the top 10 global solar manufacturers are American, and only GE is among the top manufacturers of wind turbines. Tesla is by far America's best-performing clean energy manufacturer, sitting among the top five battery producers globally, and the largest EV manufacturer both by market capitalization and annual sales. In a global index of clean energy companies with the greatest potential to benefit from the transition, US firms make up just 1.3% by market capitalization and many sectors do not feature a single US company.[27]

China accounted for more than a third of total installed capacity for wind and solar power in 2020, installing roughly as much as Spain's entire electricity-generating capacity.

Falling Behind and Catching Up

This historic transition to clean energy was built on a few key success factors, all of which extend beyond environmental regulation. Far-sighted policymakers saw that creating demand for new technologies helps drive down their prices, financial tools and policy stability can de-risk novel solutions, growth is facilitated by infrastructure construction, and resilient supply chains are a source of competitive strength.

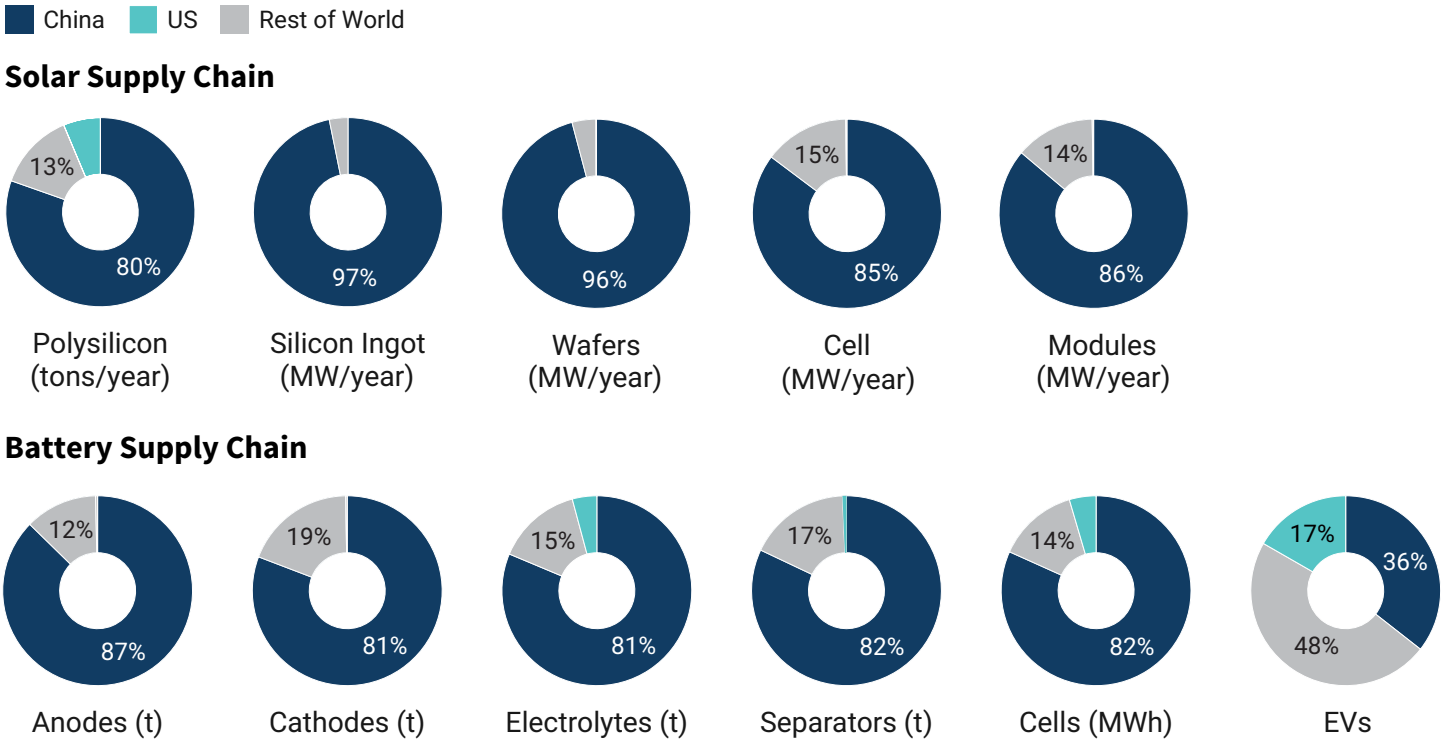
In many respects, the fight against climate change did not begin with the first UN Conference of the Parties in 1995, but with Germany's feed-in tariff for the production of solar energy in 1990.[28] By 2004, Germany accounted for two-thirds of global demand for solar panels and for the first time there was an economically significant market for a clean energy technology. This changed everything.

Though at first countries with the largest domestic markets had the highest market share in manufacturing, this changed rapidly as countries like China saw new opportunities for exports and innovation in clean energy markets. Whereas Germany and the United States were more committed to free trade than they were to retaining manufacturing jobs, China aggressively pursued market share by scaling its domestic market, providing cheap credit to local and national champions, investing heavily in infrastructure, and bolstering production throughout the supply chain.[29] In just one decade, Chinese manufacturing of solar and wind equipment boomed and its market share grew dramatically.

After originally pursuing an exports-oriented strategy, China's dominance in clean energy technologies today is built on its domestic market. Unsurprisingly, domestic manufacturers respond to domestic market signals. China accounted for more than a third of total installed capacity for wind and solar power in 2020, installing roughly as much as Spain's entire electricity-generating capacity. China built more offshore wind in 2021 than every other country built in the previous five years. China sold more than half of all EVs in 2021, or about 3.1 million, a 169% increase over 2020 and more than three times the number of EVs sold in the United States.[30]

As a result, China holds overwhelming market share in most areas of the supply chains in solar and EVs. Wind manufacturing is more dispersed globally because it is often located closer to the point of installation due to high transportation costs.[31] In the solar power supply chain, China is the leading manufacturer of every segment, including polysilicon, silicon ingots, wafers, cells, and photovoltaic (PV) modules.[32] Wholly owned Chinese companies or Chinese joint ventures manufactured around 36% of all EVs produced in 2021. China is the leading manufacturer of battery cells, packs, cathodes, anodes, separators, electrolytes, lithium refining, cobalt refining, manganese refining, and spherical graphite refining for lithium-ion batteries, the critical input for EVs (see Exhibit 2, next page).

Exhibit 2 China Dominates Every Segment of the Solar and Battery Supply Chains



Source: BloombergNEF

One particularly important lesson from Chinese dominance in these supply chain segments is how it facilitated regional specialization as a means of economic diversification and greater technological innovation. China included renewable energy and EV manufacturing among the list of strategic emerging industries that would help the country move past its history as a low-cost manufacturer and embrace a more durable growth model.[33] This national vision is implemented through regionally specific strategies, which have allowed China to capitalize on local specializations and foster emerging clusters, like Jiangsu Province, where most solar PV manufacturing is located.[34] Provincial or local policies were instrumental in this process, including dedicated land-use rights, energy subsidies, and loan guarantees, as well as public and private financing institutions, including banks and public investment funds.

Global Clean Energy Competition Picks Up the Pace

The clean energy transition is growing in scope, scale, and speed. Whether it is enough to avoid the worst impacts of climate change remains an open question, but whether it overhauls the geoeconomics of energy is not.

This era of a few large players dominating clean energy technologies is ending. In many respects, solar and batteries are particularly suited to China's low-cost manufacturing advantage, even as its state-driven economic model allowed it to take early risks other countries avoided. COVID-19 and the war in Ukraine have exposed vulnerabilities in global supply chains, fostering an upsurge in reshoring strategies.[35] Meanwhile, the degree of risk and uncertainty surrounding a clean energy vision is falling as policymakers, financiers, companies, and the public unite behind a net-zero future.[36]

The clean energy transition is growing in scope, scale, and speed. Whether it is enough to avoid the worst impacts of climate change remains an open question, but whether it overhauls the geoeconomics of energy is not.

Fossil fuel energy systems are at an inflection point as Europe and other countries call into question the benefits of relying on energy sources that pollute the air and support corrupt, extractive regimes.[37] As fossil fuel production declines, clean energy industries will rapidly expand to fill its place, creating enormous opportunities for innovation, supply chain production, and global competition. This creates opportunities for US firms in areas that are more likely to be internationally competitive, yet to date US companies are trailing their European counterparts in adjusting to a net-zero future.

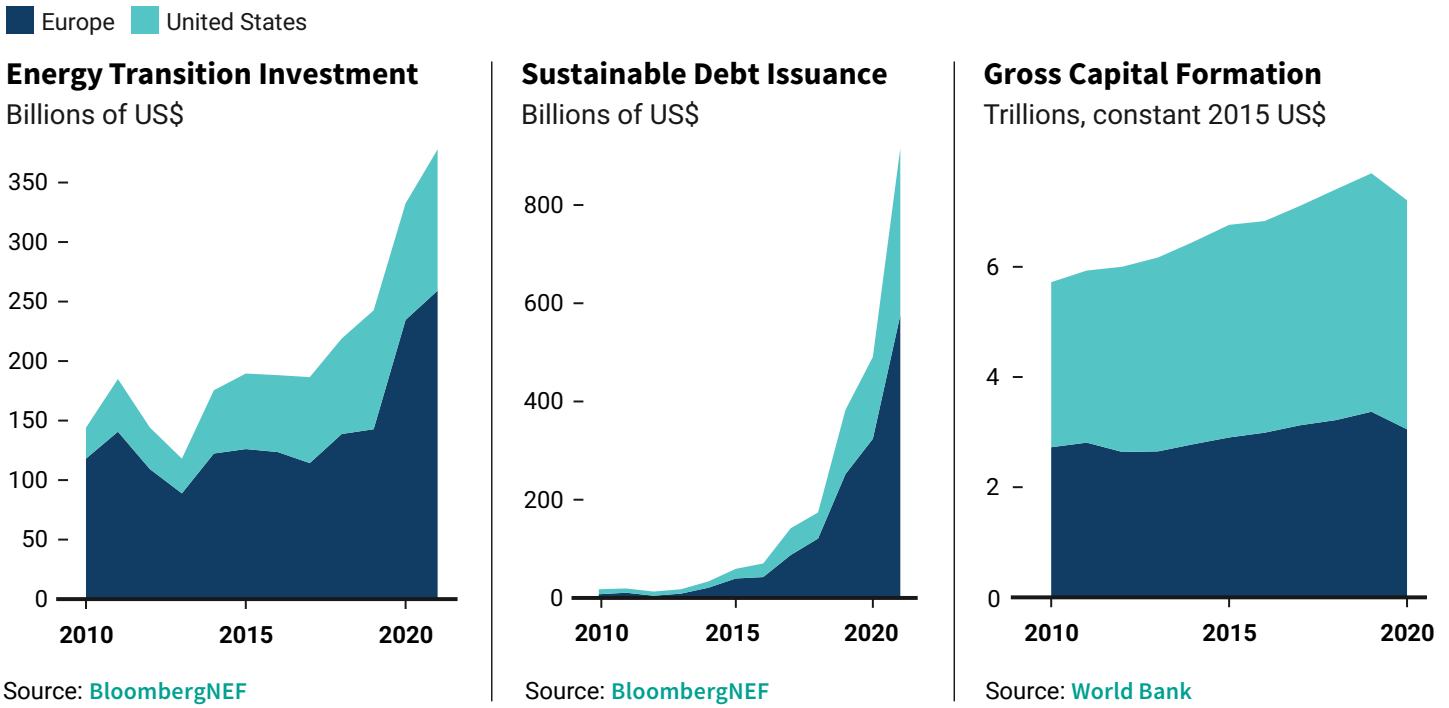
Europe is setting a blistering pace in the race to decarbonize, one that is only accelerating as tensions with Russia force countries to imagine a future free of energy dependence on fossil fuels. In May 2022, the EU's executive arm announced a $205 billion plan to end oil, gas, and coal trade with Russia by 2027, raising its clean energy target for 2030 to 45% of its total energy mix.[38] This is on top of the EU's already highly ambitious policies, which include an emissions trading system for high-emitting sectors; the European Green Deal, which plans to mobilize $1.1 trillion in sustainable investments by 2030; and its Fit for 55 strategy, which, among other provisions, will require all new cars in the EU to be zero emission by 2035.

An ambitious policy environment is helping Europe catch up to China and other early leaders in key emerging markets. In EV and battery manufacturing, for example, manufacturing investment is following sales. Over 20% of European car sales in the first quarter of 2022 were plug-in EVs, compared with just 5% in the United States, attracting new manufacturing facilities to the region, including Tesla, and convincing major European automakers to accelerate their transition to EVs.[39] Europe has also set up public–private institutions to accelerate progress, such as the European Battery Alliance, which brings together industry, government, and the scientific community to turn Europe into a global leader in sustainable battery production while addressing disruptions to supply chains.[40]

An important area where Europe's lead is growing is the financial sector, which is driving change throughout the continent's economies. For example, 65% of large European financial institutions have net-zero commitments, compared with just 39% in North America.[41]

Between 2011 and 2021, Europe cumulatively invested $1.1 trillion in the energy transition, 43% more than the United States, and issued nearly twice as much sustainable debt, despite 27% more capital formation across the US economy as a whole during that period (see Exhibit 3, next page).[42] This disparity is driven in part by policy pressures, such as climate-related financial disclosure rules, which the EU has mandated for years, as well as broader policy signals, such as its decades-old carbon market. US regulators, on the other hand, only released proposed rules earlier this year and have historically sent few clear signals to financial markets that investing in the energy transition is in their long-term interest.[43]

Exhibit 3 Green and Climate-Related Investment in Europe Is Far Outstripping the United States



Source: BloombergNEF

Source: BloombergNEF

Source: World Bank

These disparities could become a real issue for the United States in attracting foreign direct investment (FDI). Regions with high renewable energy penetration and supporting energy infrastructure will be better able to attract investments from companies that have pledged to green their industrial processes and supply chains. To date, 111 of the 167 largest greenhouse gas–emitting companies tracked by Climate Action 100+, a coalition of large investors pushing for climate action, have pledged to reach net-zero emissions by 2050, as have 70% of the 641 large industrial companies tracked by BloombergNEF.[44]

Europe is the largest FDI partner of the United States, accounting for roughly two-thirds of the total FDI stock in the country, or about $2.8 trillion as of 2019.[45] Similarly, the EU is the largest destination for US foreign investment and a major source of sales for many US multinationals.[46] If US regions and companies do not keep up with the clean energy transition, they risk both not attracting some of this FDI in the future and not remaining competitive with European companies in international markets.

US companies will also encounter new risks and opportunities in the event that Europe, and potentially other like-minded countries, implements what is known as a carbon border adjustment mechanism (CBAM) or other forms of climate-related trade measures. In July 2021, the European Commission adopted a CBAM proposal that would require importers of carbon-intensive products — initially aluminum, cement, iron, steel, and fertilizer — to report the embedded emissions in these products and pay a carbon price accordingly. Although it remains unclear whether the commission will be able to overcome the arduous implementation challenges of a CBAM, the approach could be highly disruptive for many US companies competing in the European market.[47]

However, with the right policy signals and investment decisions, measures like a CBAM could be a source of opportunity for leading US companies and communities. Already, the Climate Leadership Council estimates

that the United States has a 300% carbon advantage over China and 400% over India in carbon-intensive industries, which is only expected to grow as the United States continues to decarbonize.[48] The carbon intensity of US steel production, for example, is half that of China or India and easily the lowest of the world's major steel producers.[49] This advantage could create new opportunities for these sectors in Europe, and, if a future CBAM were to be introduced in the United States, domestically as well.[50]

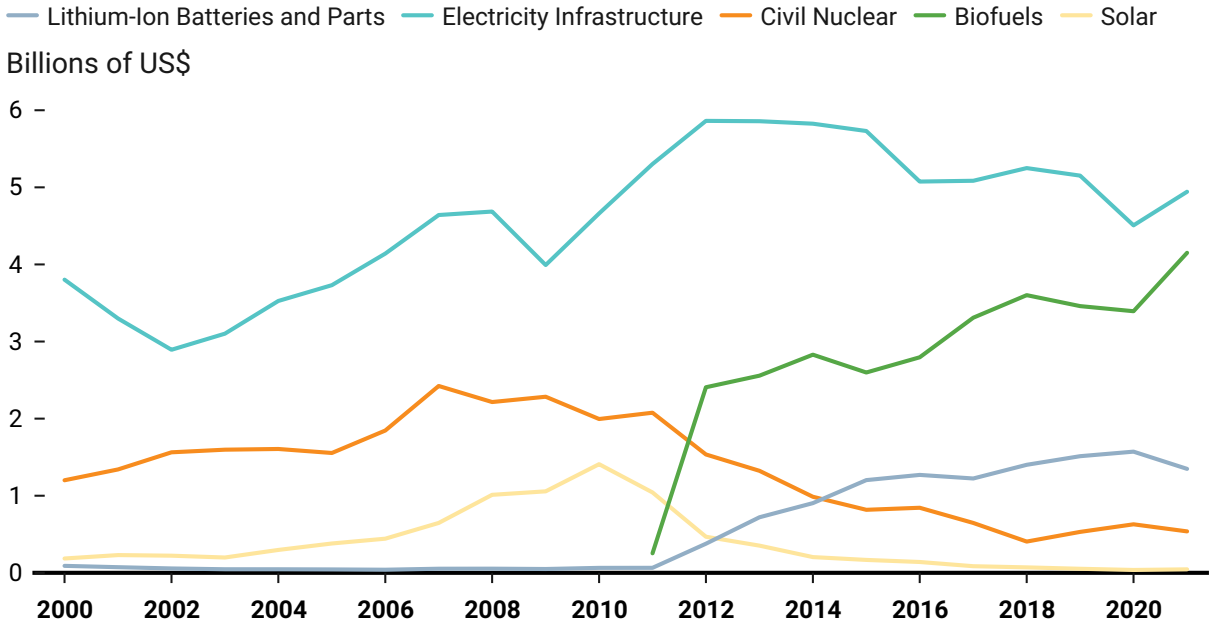
These trends speak to the latent potential for sectors throughout the US economy to take advantage of growing global clean energy markets. The United States is among the top 10 countries in terms of economic complexity, which is a measure of the technological sophistication of exported products and their value-added contribution to economic growth.[51] Building on this measure, one Oxford University study ranked the United States eighth among large trading nations in terms of its potential to export a technologically sophisticated range of green products if it invests in that capacity.[52]

The United States is already a large and growing exporter of many clean energy technologies. As of 2016, it was the third-largest exporter of environmental goods as measured by the Organisation for Economic Co-operation and Development (OECD). However, as a share of total exports, the United States remains well below its competition, including Germany, Japan, South Korea, and China, suggesting there is significant room for growth.[53]

One study found that in the solar PV, wind, LED, and lithium-ion battery markets, the United States has the second-highest trade value added of all major economies, with particular strengths in wind and battery manufacturing.[54] The United States also exports a lot of electricity infrastructure goods and biofuels but has seen persistent declines in civil nuclear and solar exports (see Exhibit 4). With the clean energy transition only recently accelerating, only so much can be inferred from these trends, with the real action expected to play out over the course of the coming decade.

Exhibit 4

US Exports of Clean Energy Technologies



Source: US Energy Trade Dashboard

The window for making this choice is closing quickly, however. Clean energy industries are prone to a first-mover advantage effect that makes the next few years critical to future success. In wind manufacturing, for example, early support in Denmark gave the small Nordic nation a big lead in wind power manufacturing, which its large firms, such as Vestas, continue to maintain.[55] The United States, on the other hand, has made an unfortunate habit of giving up its early leads in clean energy sectors.[56]

The United States should not aim to catch up to the market leaders out of some sense of zero-sum competition and geopolitical rivalry, but because this is a once-in-a-generation opportunity to invest in good jobs, empowered communities, quality infrastructure, and game-changing technologies. As domestic demand for clean energy technologies accelerates, new investments in infrastructure and clean energy supply chains can empower communities, drive productivity growth, create new export opportunities, and foster an inclusive industrial economy and American society.

Moreover, as the global disruptions of the pandemic and now the Russian invasion of Ukraine have laid bare, if the world is to create a more resilient global energy system, all countries will need to bolster their domestic contributions to the global supply chain for clean energy technologies. The United States is large and diverse enough to meaningfully contribute to this resilience by identifying regions that can encourage accelerated investment in the clean energy industrial base, enabling infrastructure, public works, and community institutions.

The National Opportunity

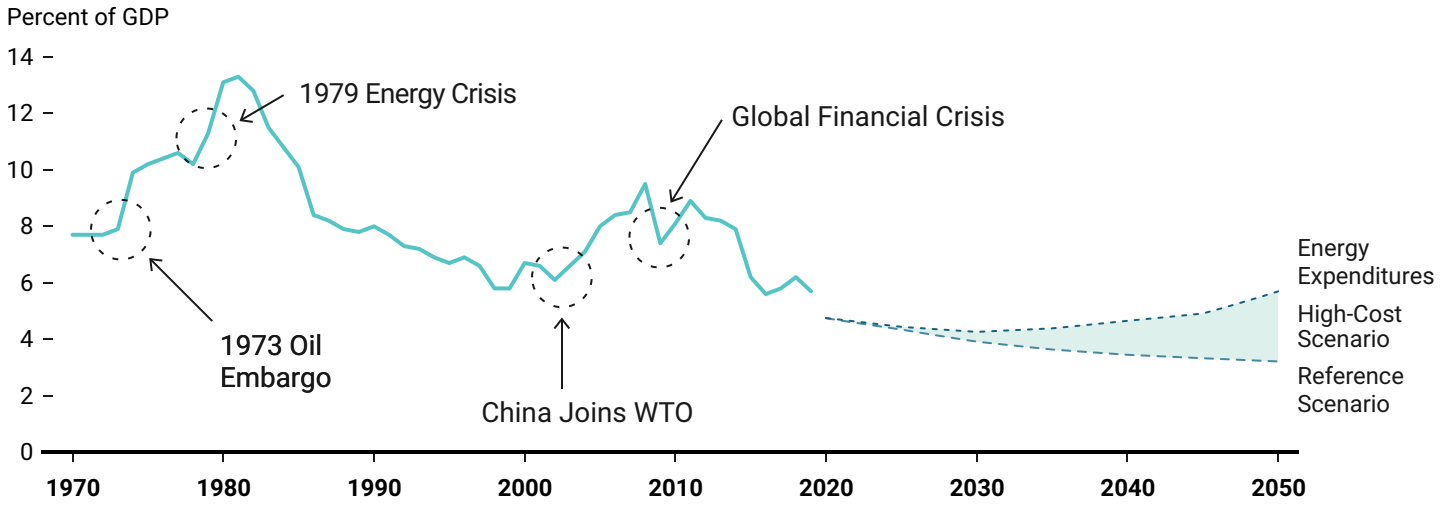
The United States now faces a choice between embracing change or missing out. As investment moves to clean energy, multiple sectors, including electricity, transportation, and, in the not-too-distant future, heavy industries like steel, cement and chemical production are all rapidly evolving. These transitions are affecting regions of the United States differently, forming clusters of new opportunity according to their economic strengths and industrial specializations. These clusters are reinvigorating American manufacturing, offering a clean energy future that bolsters international exports and local job creation. At the same time, US policymakers at every level of government are becoming more ambitious and strategic in their approach to accelerating the clean energy transition.

Cheap and Abundant Energy

Clean energy is likely to become the cheapest source of energy in human history, opening countless possibilities in an era of energy abundance.[57] Energy is an input to every sector, underpinning productivity growth and economic dynamism.[58] The United States should approach the coming transition not as a chore or act of goodwill, but as a chance to reinvigorate important sectors like manufacturing, create new businesses, foster new innovation clusters, and export cleaner American goods to the world.

Clean energy is likely to become so cheap, in fact, that a recent Princeton study estimates that the total expenditure needed to reach net zero will be a fraction of what the United States has typically spent on energy costs (see Exhibit 5, next page).[59] With the war in Ukraine reminding Americans how quickly geopolitical instability can lead to high gas prices and inflationary pressures, the urgency of transitioning to cheaper, domestically produced sources of energy has rarely been so keenly felt.

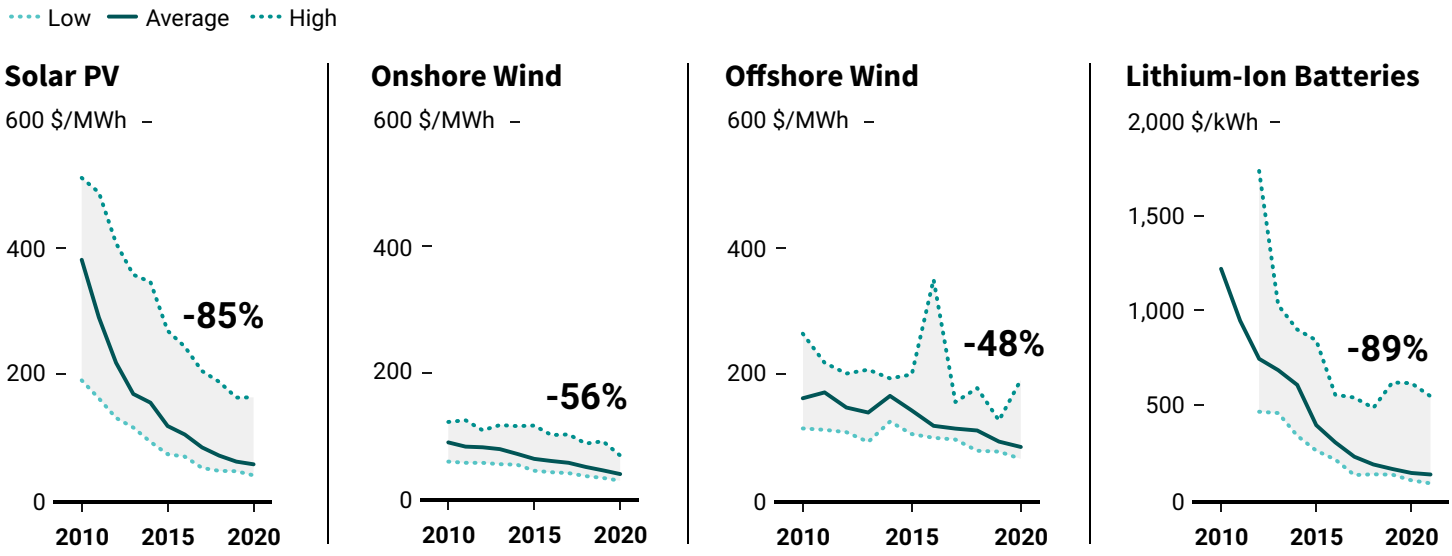
Exhibit 5 **Energy Expenditures Fall as the Economy Transitions to Clean Energy**



Source: Energy Information Agency; Princeton Net Zero America; Jenkins et al., 2022, *Summary Report: The Climate Impacts of Congressional Infrastructure and Budget Bills,* REPEAT Project, https://doi.org/10.5281/zenodo.6311986

This shift is due in large part to the dramatic decline in the costs of clean energy technologies. As the capacity of solar, wind, and batteries installed globally has increased, manufacturers have seen the benefits of growing economies of scale. Since just 2010, there has been an 85% decrease in the cost of solar, a 55% decrease in the cost of onshore wind, and an 89% decrease in the cost of batteries (see Exhibit 6).[60] With growth in renewable energy expected to shatter records in 2022 and beyond, the trend toward cheaper energy will continue. This in turn will increase demand for renewable energy, leading to further deployment and declining costs in a virtuous cycle of ever-decarbonizing energy supply.

Exhibit 6 **Costs of Clean Energy Technologies Have Plummeted over the Past Decade**



Source: International Renewable Energy Agency; BloombergNEF

Regions of the United States are also likely to enjoy distinct benefits from cheaper energy and less price volatility over time based on local climate and energy needs. Over the past 10 years, the inner Mountain West states have paid, on average, 72% more for energy than the cheapest regions of the country, and in the South it is over 50%.[ii] Households in the Northeast pay an average of 78% more than Western states,[iii] in part because of the high and volatile prices of natural gas for heating during the winter.[61]

Clean energy sources offer a solution to high and volatile energy prices and are already reaching and beating cost parity with their fossil fuel counterparts. They are also less likely to be subject to the wild price fluctuations that have caused significant costs at various times, including recent spikes in response to Russia's invasion of Ukraine.

Massive Capital Investment

If the world is to reach net-zero emissions by 2050, the International Energy Agency estimates that total investment in the global energy system needs to double by 2030, focused particularly in electrification, such as EVs, infrastructure, and renewable energy.[62] BloombergNEF estimates that investment in clean energy technologies specifically needs to grow nearly sixfold between 2022 and 2030.[63]

Although the capital outlays required to meet net zero are significant and the practical impediments are daunting, it is important to remember that these are technology investments, not energy imports. If done correctly, the investment will contribute to the productive capacity of the US economy, rather than sending money overseas to fund corrupt regimes and environmental degradation.

If the world is to reach net-zero emissions by 2050 … total investment in the global energy system needs to double by 2030.

This need for technology investments is also a huge market opportunity for US firms. Already, annual revenue in advanced energy industries is about $240 billion,[iv] which is 16.5% of the world total (see Exhibit 7, next page). If the United States' share of advanced energy revenue was the same as its share of world gross domestic product (GDP), it would be a $1 trillion domestic industry by 2030.[64] The domestic advanced energy sector is already larger than many primary commodities industries, including agriculture and mining, and some service industries, such as food and beverage stores.[65] The sector has grown well above average GDP growth, at around 5% a year, with the highest growth coming in transportation, which grew 16% year over year in 2021.

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ii Inner Mountain West states in this definition include Montana, Nebraska, North Dakota, South Dakota, and Wyoming. The South includes Arkansas, Kansas, Louisiana, Missouri, Oklahoma, and Texas.

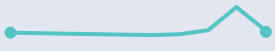
iii Northeast includes Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. The West includes California, Idaho, Oregon, and Washington.

iv The group Advanced Energy Economy defines "advanced energy" as being 52 technologies across the sectors of electricity generation, electricity delivery and management, fuel production, fuel delivery, building efficiency, transportation, and industry. For more details, see the report *This is Advanced Energy* (**https://www.aee.net/aee-reports/this-is-advanced-energy**).

Exhibit 7

Advanced Energy Revenue in the United States

Billions of US$

	2011–2020	2020	Global Share
Transportation	8.7  37.6	$37.6	**11.8%**
Fuel Production	31.1  33.6	$33.6	**18.3%**
Fuel Delivery	0.3  0.5	$0.5	**5.8%**
Building Efficiency	35.3  94.5	$94.5	**27.6%**
Industry	4.2  11.6	$11.6	**18.1%**
Electricity Generation	34.7  39.8	$39.8	**10.4%**
Electricity Delivery and Management	12.2  22.2	$22.2	**15%**
Total	**126.5**  **239.9**	**$239.9**	**16.5%**

Source: Advanced Energy Economy

Different regions will be able to capitalize on different aspects of this investment boom. For example, the 2009 American Recovery and Reinvestment Act helped create roughly 900,000 jobs in clean energy sectors between 2009 and 2015, but job growth was stronger in areas with preexisting green skills or related industries that could best take advantage of government spending.[66] The Princeton Net-Zero America study, for example, estimates a range of 0.5–1 million jobs created by 2030 and 1.2–6 million by 2050, but the distribution of these jobs will vary significantly by region.[67] The authors estimate that 25% of manufacturing jobs created in a zero-carbon scenario will be in the Midwest, 20% of solar jobs in the Western states, and 20% of jobs in utilities in the Northeast.[v]

Regional Clusters and Inclusive Growth

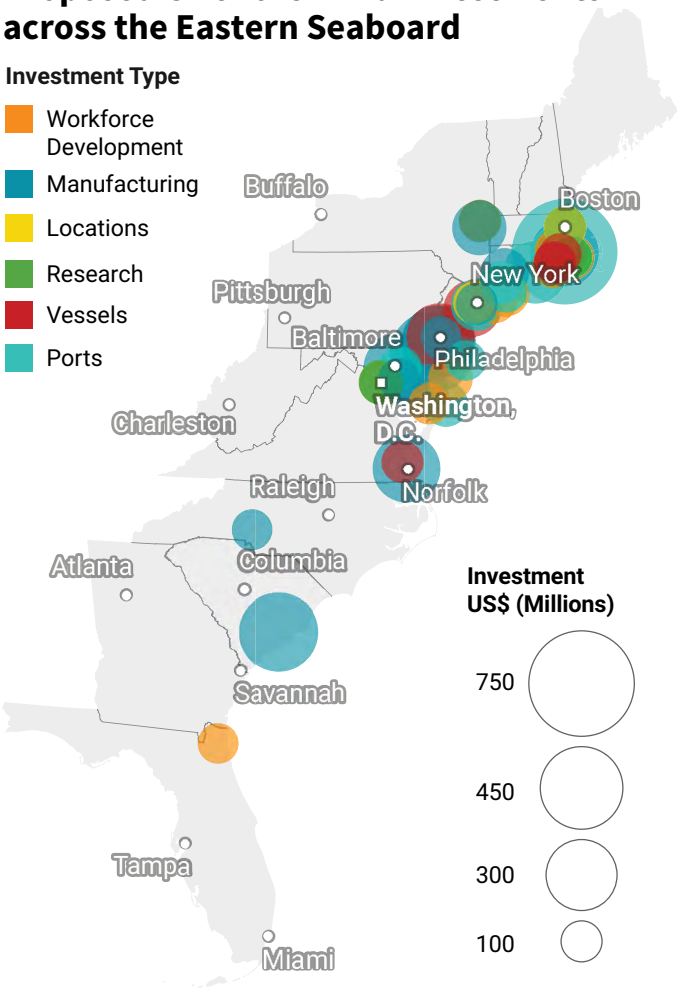
In short, the clean energy transition will affect geographies and sectors differently. Firms within similar industries tend to cluster geographically because of access to shared labor, capital, and expertise, so the clean energy transition will likely affect regions depending on where clean energy clusters develop over time. Clusters have been shown to increase innovation activity, competitiveness, job creation, and local economic growth.[68] Therefore, those states or regions that are most able to attract and sustain clean energy industrial clusters are more likely to enjoy the fruits of the energy transition.

v The Midwest includes the states of Illinois, Michigan, Wisconsin, Ohio, Minnesota, Iowa, and Indiana.

The clean energy transition will affect just about every industry and, in turn, could reshape and reinvigorate just about every existing cluster. This potential for all regions to take advantage of the transition is important in the context of widening regional divergence across the country. Where regions across the United States used to converge in income and well-being, since the early 1980s, the gulf between the richest and poorest parts of the country has either remained the same, or in many instances, is headed in opposite directions.[69]

Exhibit 8

Proposed Offshore Wind Investments across the Eastern Seaboard



Source: American Clean Power

Interactive version

Different clean energy technologies will have distinct regional effects according to geographic, political, and economic factors. The Atlantic Coast, for example, is primed to benefit from a surge of investment in offshore wind. BloombergNEF expects the US offshore wind industry to expand by several orders of magnitude over the next 15 years, reaching 50 GW of cumulative installed capacity by 2035, up from just 42 MW today.[70]

One study conservatively estimates only 18 GW of offshore wind installations across the mid-Atlantic coast and argues this presents a $70 billion opportunity for businesses throughout the offshore wind supply chain by 2030.[71] A recent National Renewable Energy Laboratory report estimates that building 30 GW of offshore wind by 2030 will require an annual average buildout of "$12.2 billion in capital expenditures, manufacturing and installation of more than 263 12- to 15-megawatt wind turbines, 886,000 tons of steel, 10,100 tons of permanent magnets, 979 miles of electrical cable; 4–6 Jones-Act-compliant turbine installation vessels . . . and a minimum of $375–$500 million in port upgrades."[72] The authors estimate further that reaching the target would create 77,300 new jobs, support 5–10 new manufacturing plants, and employ a further 31,300 people per year in construction and supply chain jobs.

According to American Clean Power, at least $2.9 billion of capital investments have already been proposed across the offshore wind supply chain, mostly in manufacturing, ports, and vessels (see Exhibit 8, at left).[73] In February, the Bureau of Ocean Energy Management held an auction for six offshore wind leases in the New York Bight, off the coast of Long Island, resulting in a record $4.4 billion in new leases.[74] Notably, European companies dominated the auction, with only one lease going to US-headquartered offshore wind producers. This reflects the first-mover advantage, which often gives European and Chinese companies a considerable leg up over US firms.

The clean energy transition offers a chance to embrace a broad, regionally inclusive growth model by attracting investment to regionally specific clean energy clusters. Cluster formation is already apparent in various regions of the United States, creating increased job growth, investment, and productivity spillovers. In the United States, green cluster formation has been shown to increase with greater access to capital, government protection, and the level of sociopolitical legitimacy achieved by the emerging industry within the region.[75] Regional economies stand to benefit if they can encourage entrepreneurs to commercialize their ideas locally.

Revitalized Manufacturing Base

These benefits often reflect the fact that clean energy sectors are more manufacturing- and export-intensive than the national average, suggesting the clean energy transition could be a boon to US manufacturing and trade. One estimate suggests 26% of all clean energy jobs in the United States are in the manufacturing sector and that clean energy jobs create twice as much export value as typical employment options.[76]

Sustained investment in infrastructure and clean energy not only promotes decarbonization, but also causes a surge in US manufacturing exports and jobs. The Economic Policy Institute modeled a scenario with $2 trillion of public and private investment, finding it could create on the order of 6.9–12.9 million jobs within five years, a third of which would be in the manufacturing sector.[77] A more expansive policy approach could create as many as 15.5 million jobs over 10 years, including an additional 600,000 jobs in EVs alone as part of 1.6 million jobs across all manufacturing sectors.

These estimates speak to the outsized role manufacturing plays in the US economy more generally. Manufacturing is particularly important for job creation because of where firms tend to sit in the supply chain, creating additional jobs downstream of the production process. Every job in durable goods manufacturing is estimated to create an additional seven jobs among suppliers and through induced spending.[78] Two-thirds of industrial R&D spending takes place in manufacturing firms, helping generate more innovation across the US economy than any other sector.[79] Reshoring American manufacturing through local clean energy production would therefore have an outsized impact on job creation and technological innovation.

However, US manufacturing has been in decline over the course of the 21st century. Real manufacturing value added as a share of national output fell by 20% between 2007 and 2019, the impact of which has been felt in job growth, capital investment, innovation, and a burgeoning trade deficit. The United States has lost roughly 5 million manufacturing jobs since the beginning of the century in addition to losing much of the applied R&D capacity to make the advanced technologies that were first invented in this country.[80]

This decline had very different effects in different regions. The Midwest was hit particularly hard, with studies showing that manufacturing job loss is correlated with lower lifetime incomes in these areas, more disability benefit recipients, and even declining marriage and fertility rates among men.[81] The effect on local communities was particularly pronounced in areas that had little industrial diversity, leaving unemployed workers with scarce options for new job opportunities.[82] Clean energy manufacturing, therefore, should only be one pillar of a regional economic strategy that catalyzes new investments and economic dynamism.

Manufacturing of technologically complex products has historically been a major source of US exports, injecting external demand into the economy and playing an important role in closing America's trade deficit with the rest of the world. The total value of US manufacturing exports, however, has not grown in a decade, and although manufactured goods remain about 80% of total exports, this share has fallen by 10 percentage points over the course of the 21st century.[83] The US share of global manufacturing has halved over the same period.[84]

Greater domestic production will also increase the demand for upstream commodities and components, further spreading the economic opportunities of the transition. The demand for critical minerals, such as copper, nickel, cobalt, and various rare earth elements, will rise significantly as production of clean energy increases. An EV requires six times the mineral input of a conventional car, for example, and onshore wind nine times the mineral resources of a natural gas power plant.[85] Already, there is a "gold rush" in critical minerals mining across the United States, with the Biden administration issuing a series of executive orders to boost domestic production and investors responding with a suite of new projects.[86]

Urban Transformation

Finally, the clean energy transition is an opportunity to improve where people live, how people work, and the ways people travel. Reaching net-zero emissions requires replacing around 130 million heating units and 95 million stoves, electrifying 275 million vehicles, and installing rooftop solar panels on as many as 55 million homes.[87] America is an increasingly urban society, but its cities have not kept up with this transformation to urbanity. Through new housing, building retrofits, public transit, and other infrastructure construction, there is a growing variety of emerging technologies and business models for revitalizing cities and transforming urban landscapes.

Housing production in cities is a prime example of an investment that can create wealth, ease the burden on lower-income households, and lower emissions in parallel. Cities account for the bulk of US emissions but have a much lower carbon footprint per person, although the suburbs surrounding city centers undermine these benefits.[88] Enabling and encouraging high-density housing production, particularly through zoning reform, is therefore a critical clean energy solution.

Further, a significant shortage in housing production over the past decade has seen costs of living spiral in coastal cities, even as wages among lower-skilled workers have not kept pace. As housing costs have increased and wages have remained stagnant, low-income residents in these cities have a real level of consumption 74% lower than in more affordable parts of the country.[89] Addressing these disparities through a major housing production push could boost the real incomes of Americans across the country, creating growth and reducing emissions.

Retrofitting the existing stock of buildings is another significant opportunity for job creation and new investment across the country. The energy efficiency sector is already the largest clean energy employer in the United States, at around 2.5 million jobs nationwide. As more residential and commercial buildings electrify and improve their energy efficiency, this sector will only grow. The US also has a vast and largely untapped potential for rooftop solar installations, which would help reduce energy prices, increase resiliency, and add further jobs in this sector.[90] Additionally, the growing significance of clean and sustainable building materials and household appliances can support a variety of new businesses throughout their supply chains. New sustainable and low-carbon construction methods also offer an opportunity to boost productivity in the construction industry, which has famously lagged behind other sectors of the US economy.[91]

Urban transformation can also help attract investment and industrial clusters to particular regions. Amazon, for example, decided in part to place its second headquarters in Arlington, Virginia, because of its public transit options, the livability of its communities, and access to nearby solar energy.[92] Many of the attractive features of these "consumer cities" align with the urban transformations required to meet US climate goals.[93] These changes include higher-density housing (which is more likely to be low-cost housing), lower air pollution, and more green space and mobility alternatives, including bikeshare programs, expanded public transit, and cyclist- and pedestrian-friendly streets.[94]

None of these opportunities are guaranteed to come to fruition, nor does this cover the complete variety of ways in which the clean energy transition could reshape and revitalize regions across the United States. But with the right policy tools and investor incentives, America can create a "New Climate Economy" that generates good jobs, accelerates investment in productivity-enhancing infrastructure and technologies, and closes the gaps in wealth and opportunity that exist throughout the country.[95] This economy is already taking shape as investors, companies, communities, and governments mobilize the resources and effort necessary to reshape the country.

Progress to Date

The United States is already in the midst of a historic clean energy transition. Though the power sector is farthest along its journey to net zero, more economic sectors and areas of American life are following suit. The next most developed sector is transport, as EVs become more widely accepted and adopted. Meanwhile, new technologies are starting to revolutionize the buildings in which people live and the cities in which people work. Likely to be the final piece of the puzzle, heavy industry is also seeing the beginning of what a decarbonized future will look like, from hydrogen production to new technological manufacturing processes to carbon capture, utilization, and storage (CCUS).

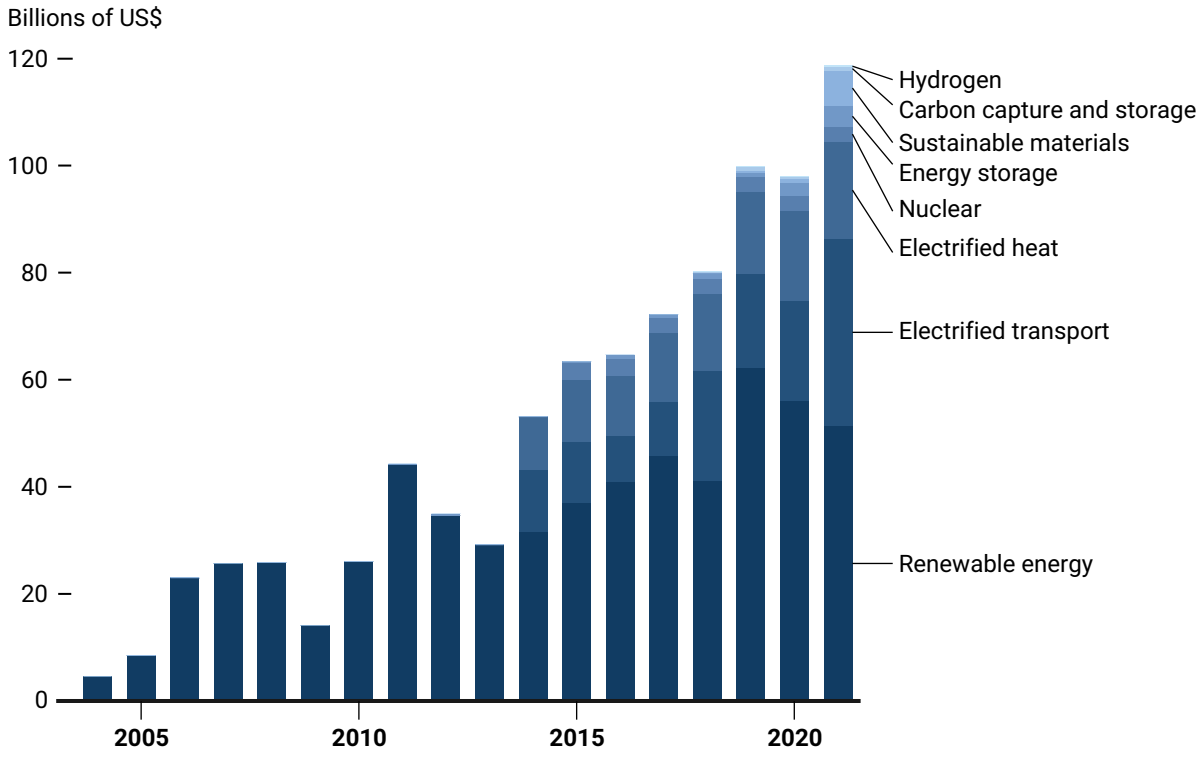
Accelerating Investment

Already, annual US investment in the energy transition has nearly tripled over the past 10 years to $118 billion in 2021, growing at an average rate of over 10%.[96] The largest share of this investment is renewable energy, at around 43% of the annual total, but electrified transport and heat are growing rapidly, reaching shares of 29% and 15%, respectively (see Exhibit 9).

Exhibit 9

US Energy Transition Investment

Annual capital spent on deploying low-carbon technologies in the United States



Source: BloombergNEF

Further signs of an accelerating transition are also coming out of the venture capital (VC) sector. Investment in climate tech has grown 3,750% over the past seven years, reaching a cumulative $60 billion between 2013 and 2019 — even before the pandemic spending spree that lasted much of 2020–2021.[97] For this famously high-risk/high-reward industry, VC funding has already spawned 43 climate unicorns, or startups surpassing $1 billion in value.

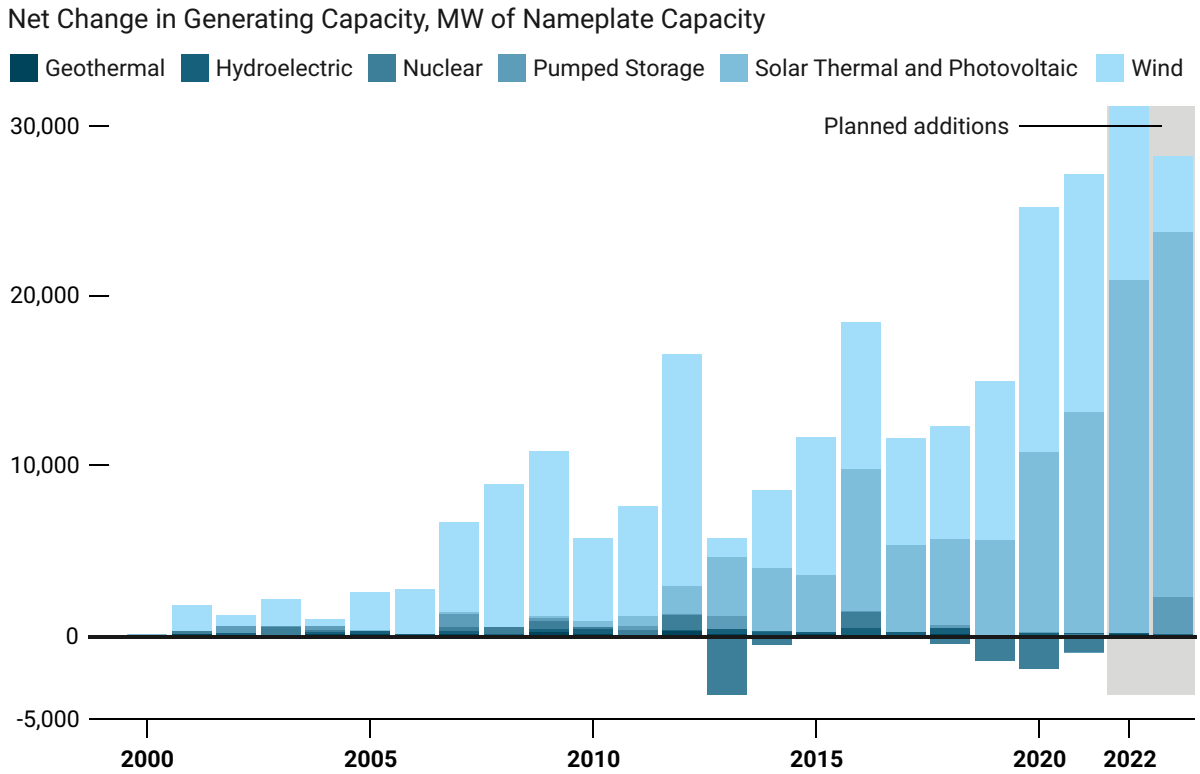
Major investors are also beginning to put increased pressure on companies to address existing sources of emissions. Climate Action 100+, a coalition of large investors pushing for climate action, has over 600 signatories representing more than $65 trillion in assets under management. Of the group's 167 focus companies, which together are responsible for more than 80% of global industrial emissions, 111 have net-zero targets, up from just five when investor pressure first began in 2018.[98] Other major initiatives include the Net-Zero Banking Alliance and Paris Aligned Investment Initiative, each with tens of trillions of dollars under management now pledged to climate-aligned investment strategies.

Powering Ahead

The major story in America's accelerating clean energy transition is the rapid expansion of renewable energy technologies in the power sector. Although nuclear and hydro continue to be the largest sources of clean power in the United States, combined solar and wind power generation has grown from a fraction of a percent of total generation in 2001 to around 11% today, averaging more than 20% annual growth since 2009.[99] In 2022, nearly half of all new electricity-generating capacity will be solar power and a further 28% is set to be wind or batteries.[100] There is currently zero new coal generation planned to be built (see Exhibit 10).

Exhibit 10

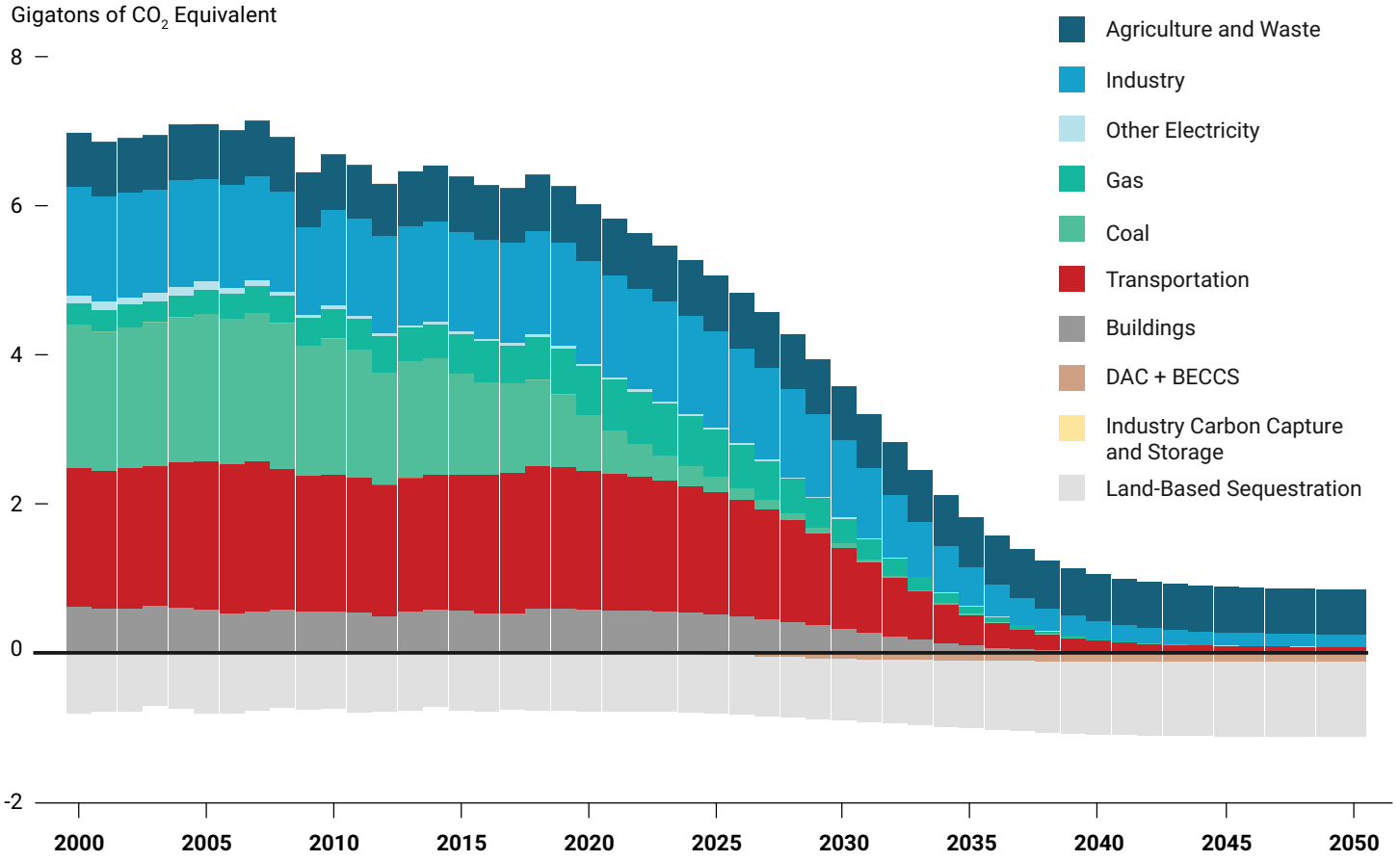
Electricity Capacity Additions in the US by Clean Energy Technology



Source: Energy Information Agency

Meanwhile, US emissions from coal power generation have fallen more than 40% over the past two decades and total coal consumption is down 60% from its 2007 peak to levels not seen since the mid-1970s.[101] As a result, emissions from the entire US power sector have fallen by a third. According to RMI modeling, coal use must be eliminated by 2030 if the United States is to reach its decarbonization goals (see Exhibit 11). This elimination is not a foregone conclusion, however. The US Energy Information Administration forecasts that coal consumption will remain unchanged between now and 2050 under existing policy and technology conditions.[102]

Exhibit 11 **US Emissions in a 1.5°C Scenario**

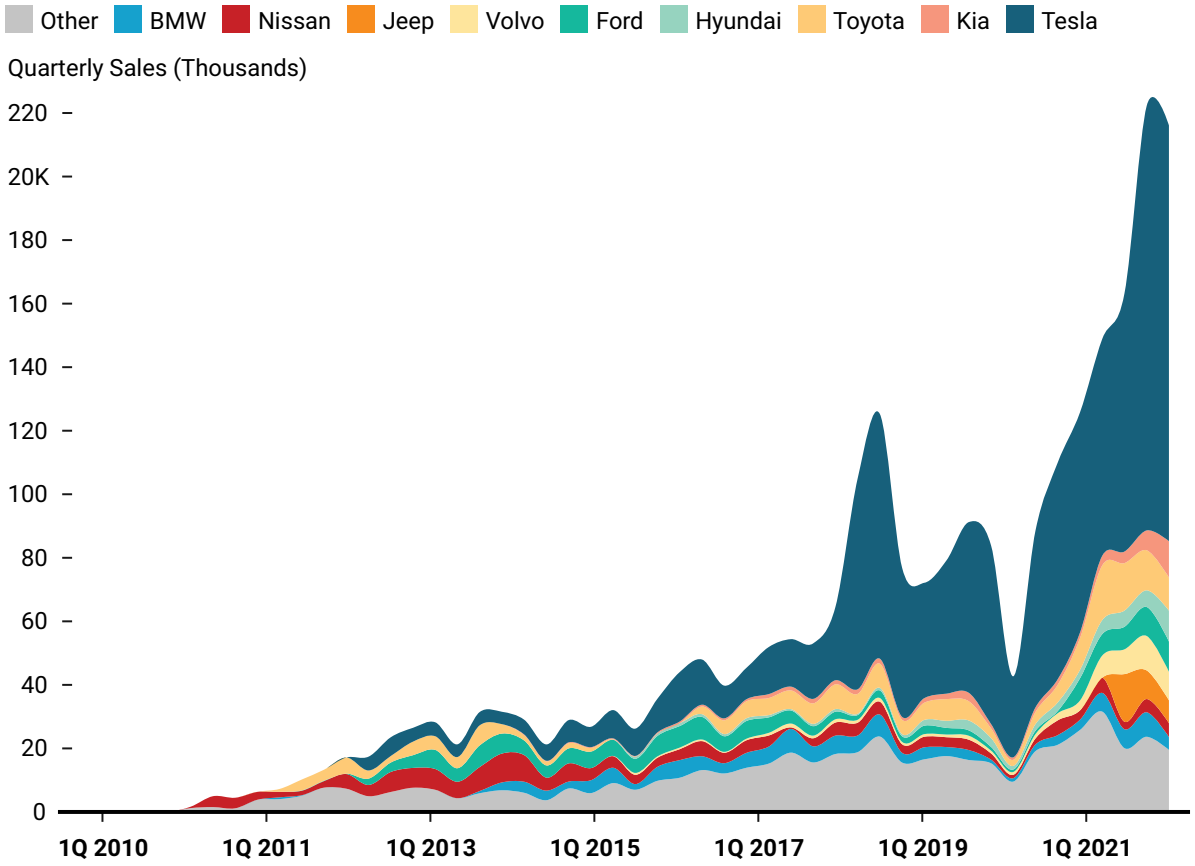


Source: RMI

These dynamics are true across a growing number of clean energy sectors, such as the rapid uptake of EVs. The number of EVs sold in the United States doubled in 2021 to more than 650,000 as prices of new EVs come closer to reaching cost parity with internal-combustion vehicles.[103] BloombergNEF expects EVs to cross that threshold by around 2025.[104] Tesla remains the dominant automaker in the US market, accounting for more than half of all EVs sold in 2021 vehicles (see Exhibit 12, next page). To put the dramatic change in EV and battery costs in perspective, a Nissan Leaf, which today sells for around $28,000, would cost more than $300,000 if battery prices had remained at 1990 levels.[105] The rapid fall in the cost of EV batteries is quickly shifting consumer preferences and automaker priorities.[106]

Exhibit 12

EV Sales in the United States by Automaker



Source: BloombergNEF

Perhaps an even greater factor than price declines has been changing perceptions of EVs in the marketplace.[107] This market disruption was driven first by Tesla, which now has two of the 20 highest selling car models in the country, including the Model Y, which accounted for nearly 30% of EV sales in 2021, and the Model 3, which accounts for a startling 21% of all EVs sold in the US over the last 10 years.[108] Other automakers are following suit, releasing electric versions of some of their best-selling vehicles, such as the Ford F-150 Lightning, not as gimmicks but as flagship products with new features, greater performance, and decades of brand equity behind them.[109] More than 60 new EV models could be released in the US market over the next five years.[110] However, many manufacturers' long-term production plans remain inconsistent with their stated ambitions, reflecting the need for greater policy and financial pressure.[111]

The list of rapidly growing clean energy technologies is getting longer by the year. For example, the global production of green hydrogen, which is set to play a significant role in decarbonizing heavy industry and transport, is estimated to grow by more than 600% in 2022, and the amount of new production capacity installed each year is expected to increase more than 78 times by 2030 and 1,000 times by 2040.[112] Similarly, the amount of CCUS capacity is expected to triple over the next five years, offering further opportunities for heavy industry to decarbonize and expanding the market opportunities of the clean energy transition.[113]

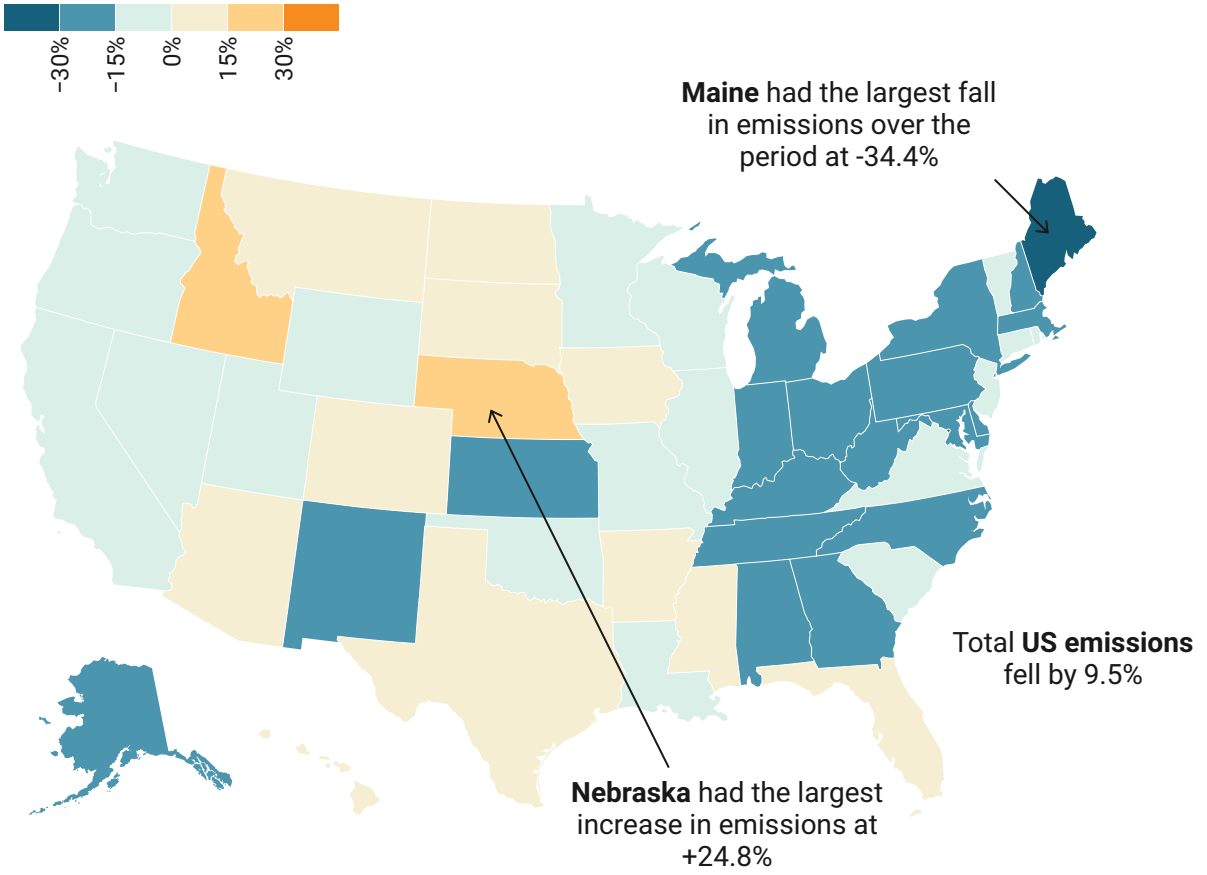
Regions Experience the Energy Transition in Different Ways

The clean energy transition is happening all across America, but at varying speeds and scales. Total carbon emissions in the United States fell by 9.5% from 2000 to 2018, even as 13 states recorded emissions increases over the same period and 12 experienced reductions of greater than 20% (see Exhibit 13).[114] National GDP also increased by 41% over the same period with no statistical relationship between state-level GDP and emissions changes.[115]

Exhibit 13

Change in State-Level Emissions in the United States

Percentage change in annual CO_2 emissions, 2000–2018



Source: Energy Information Agency

Interactive version

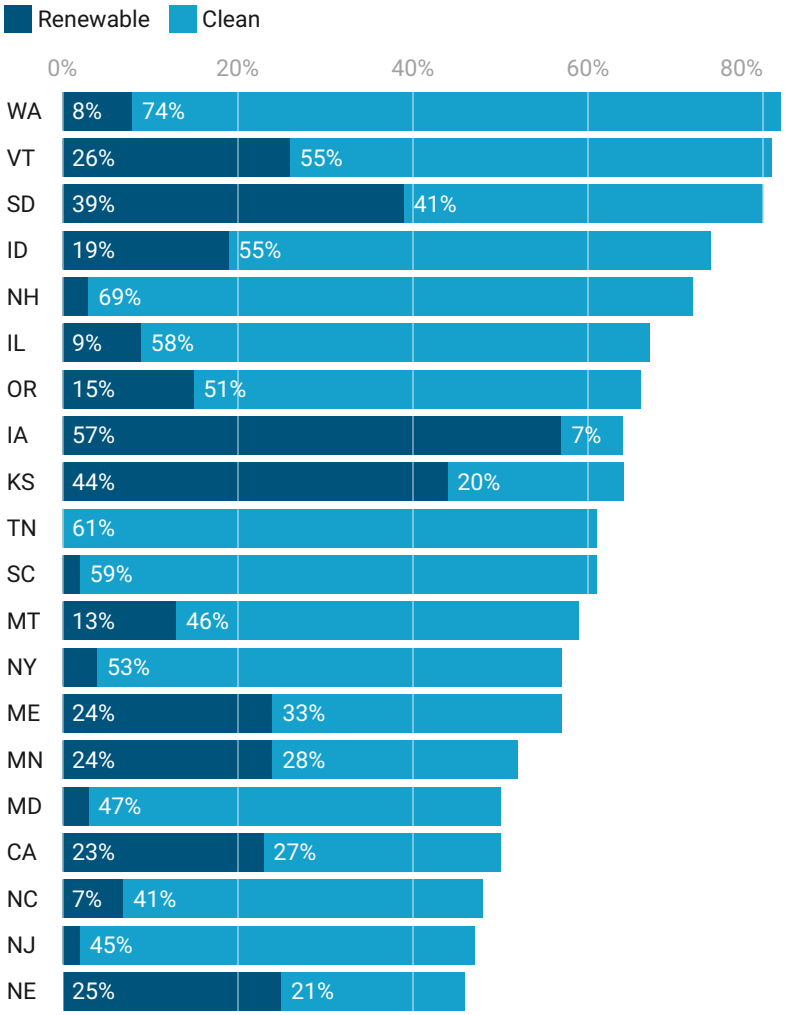
Similarly, the pace of renewable energy adoption has varied considerably. Texas and California are comfortably the national leaders in renewable electricity generation, though as a share of their respective totals each falls comfortably outside the top 10 states (see Exhibit 14, next page). What is notable about states with the largest growth in clean energy is how little they correlate with climate or emissions reduction ambitions.[116] Many of the states witnessing the fastest adoption are those without net-zero goals or climate strategies, such as Texas, Kansas, and South Dakota. Several states have begun pursuing clean energy adoption for reasons entirely unrelated to climate change mitigation, such as industrial transformation, existing resource endowments, and taking advantage of declining costs.

Exhibit 14

Renewable Energy Adoption Varies by State, with Some Surprising Leaders and Laggards

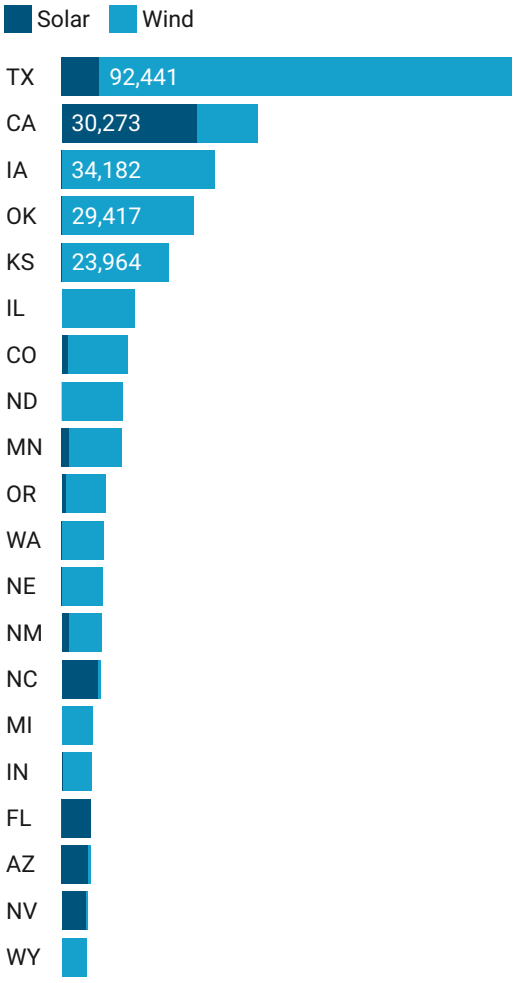
Share of Renewable and Clean Energy by State

Share of total electricity generation in 2020



Total Wind and Solar Generation

GWh of solar and wind generation in 2020 by state



Note: Renewable refers to solar and wind generation. Clean includes nuclear, hydroelectric, geothermal, other biomass, and pumped storage.

Source: EIA

Source: Energy Information Agency

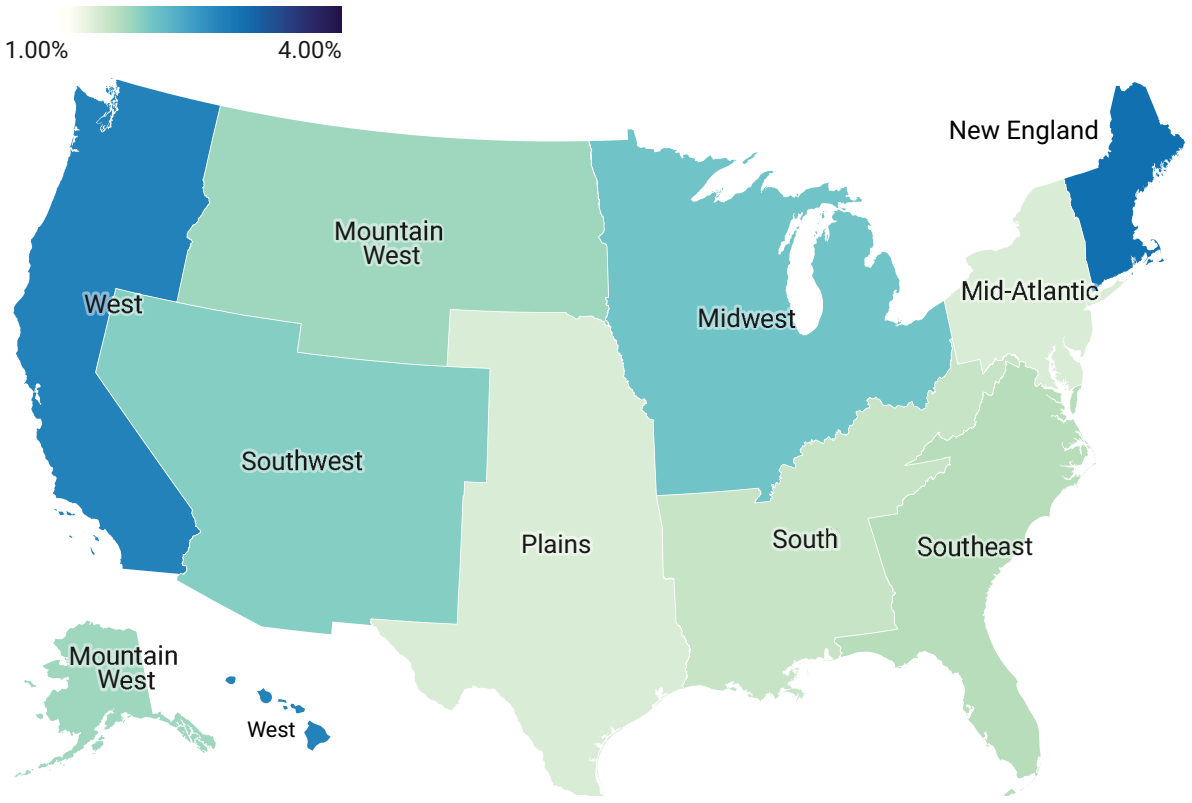
The distribution of EVs nationally is even more skewed than that of electricity generation: 42% of all EVs are registered in California, and a further 16% in Texas, Florida, and Washington. In 2021, 13% of all passenger vehicles sold in California were electric, easily the most of any state; it accounted for 36% of all EV sales in the United States.[117] One important reason for the discrepancy is investment in EV charging infrastructure. States with the densest charging networks, which are mostly on the West Coast or in the Northeast, are those with higher EV adoption. New York and California, in particular, "rival leading nations in government incentives and charging infrastructure" that help advance EV adoption.[118]

Unsurprisingly, the largest states have the most clean energy jobs — a quarter of all cleantech jobs are in California, Texas, and New York — but many smaller states, particularly in the Northeast and West, are developing specializations and industrial clusters that set them up for future success.[119] Vermont and Michigan have the highest share of clean energy jobs: 5.3% and 3.3%, respectively. Vermont has a relatively high degree of specialization in solar, storage, and woody biomass, whereas Michigan has specialized, perhaps unsurprisingly, in advanced and motor vehicle manufacturing. At the regional level, New England has the greatest share of clean energy jobs (3.1% of the combined total), followed closely by the West at 2.9%. The Plains and the South are farthest behind, at just 1.8% and 1.9% of all jobs in clean energy sectors (see Exhibit 15).

Exhibit 15

Green Jobs by Region

Jobs in renewable energy, clean vehicles, clean fuels, and energy efficiency



Source: E2

Interactive version

Specialized clean energy clusters are emerging across the country. These include EVs and battery manufacturing throughout Auto Alley, which runs from Michigan to Alabama. America's largest auto companies are planning at least a dozen new battery and EV manufacturing facilities, clustered almost exclusively in the region, investing half a trillion dollars in those state economies over the next five years.[120] While many of the upstream segments of the battery supply chain are dispersed across the country, downstream components, such as battery component manufacturing and equipment manufacturing are more clustered in the Midwest (see Exhibit 16).

Exhibit 16

Battery Supply Chain Facilities around the Country

Location of North American companies in the lithium-ion battery supply chain

Supply Chain Segment

Battery Grade Component Manufacturing | Distributors | Electrode and Cells Manufacturing | Equipment Manufacturing | Modules and Packs Manufacturing | End of Life/Recycling | Raw Material Manufacturing | Other Battery Components and Materials Manufacturing

Source: NREL

Interactive version

Other examples include solar generation and associated industries in the Southwest, cleantech startups along the West Coast, advanced battery manufacturing in upstate New York, and clean energy innovation in Colorado.[121] Over time, the benefits of clustering should help these industries become increasingly internationally competitive, creating new export opportunities and sources of FDI.

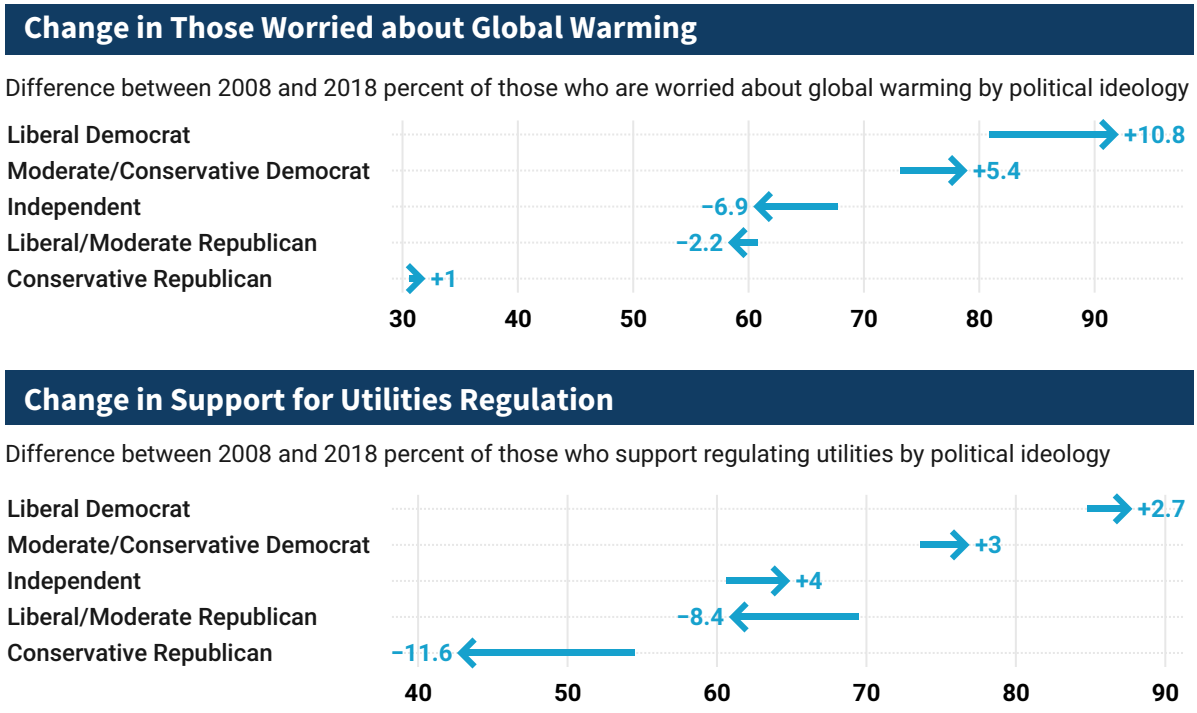
Public Policy Is Growing More Ambitious and Sophisticated

Public policy and consumer attitudes also play a key role in the energy transition and capitalizing on the opportunities it affords. Many US jurisdictions, from cities to the federal government, are taking dramatic steps toward decarbonization, reflecting changing public attitudes to climate change. Many of these policy changes are moving toward a sectoral approach that emphasizes technology transitions over pollution reduction, creating stable domestic markets and providing a degree of certainty to future investors.

A record number of Americans today believe both that humans are responsible for global warming and that a range of policy solutions is required to address it. The degree of concern and willingness to act, however, remains starkly divided along political party lines (see Exhibit 17). Younger generations tend to be more concerned about climate change and are much more likely to support relatively stringent measures, such as phasing out fossil fuels and gas-powered vehicles.[122] There are few differences in climate attitudes by region, and while people who live in cities are more likely to be concerned about climate change than rural Americans, this is most likely a function of the rural–urban split in partisan preferences.

Exhibit 17

Support for Climate Action Has Increased but Remains Starkly Divided by Political Ideology



Source: YPCC, Mason 4C, Ballew et al.

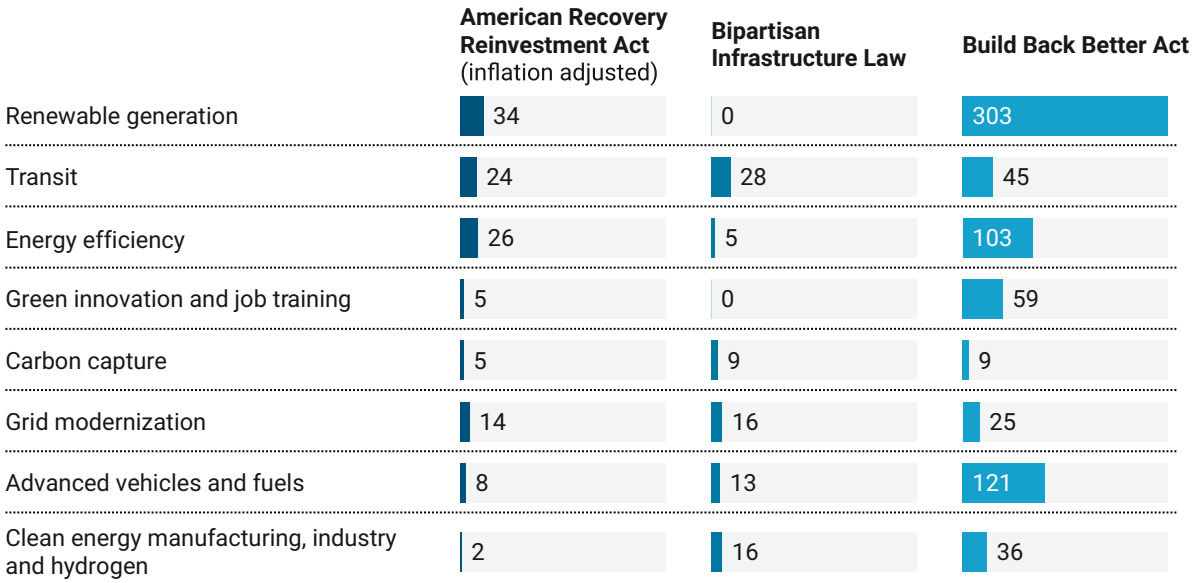
In response to shifting public opinion and technology improvements, institutions at all levels are becoming more ambitious in addressing climate change, including the Biden administration and the 117th Congress. Despite some setbacks, both the federal executive and legislative branches are continuing to pursue the

most ambitious climate agenda in US history. The bipartisan infrastructure bill, which Biden signed into law in November 2021, included more than $100 billion of clean energy or low-carbon initiatives (see Exhibit 18). This amount is just shy of the total investments included in Obama's 2009 stimulus package (adjusted for inflation), which was at the time the "largest single investment in clean energy in history."[123]

Exhibit 18

Biden Administration Climate Plans in Context

Billions of US$ in government expenditure



Note: Time frame of spending differs by bill. Build Back Better Act numbers reflect the November 2021 version of the proposed bill, which did not pass the Senate.
Source: Author calculations

To put this in perspective, the climate spending in the infrastructure bill alone is larger than the GDP of 134 of the 195 countries represented at the 2021 Glasgow Climate Conference.[vi] Although this injection of federal funds could go a long way toward pushing down the price of emerging technologies, like green hydrogen, or facilitating further growth in EVs and renewable energy with improved infrastructure, the impact from an emissions standpoint will be limited.[124]

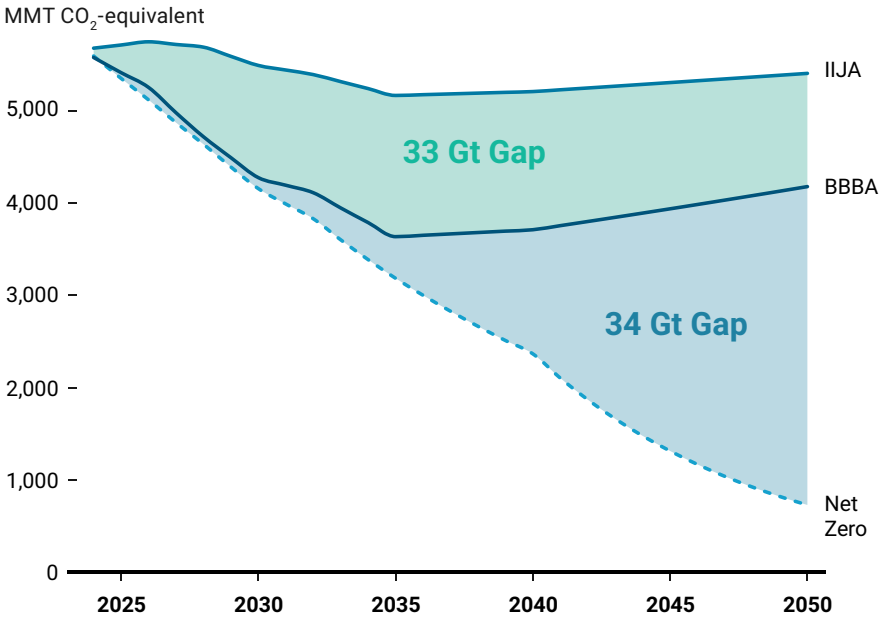
The climate provisions included in the Build Back Better Act (BBBA), which never passed the US Senate, would have put the United States on track to reach its net-zero targets in the near term and catalyzed almost an additional $6 trillion in capital spending by 2040 (see Exhibit 19, next page). The BBBA included approximately $645 billion in climate-related spending — more than five times the size of Obama's clean energy spending as a share of economic activity and more than seven times the share of US government spending. According to Princeton modeling, the BBBA would cut US emissions by a cumulative 5.2 billion tons between 2022 and 2030.[125] The clean energy tax credits included in the bill would, on their own, reduce power sector emissions by a fifth between 2022 and 2050 at the remarkably low cost of about $33–$50 per ton according to the Rhodium Group.[126]

vi This compares GDP, an annual figure, to government expenditure, which occurs over several years.

Exhibit 19 The Build Back Better Act Would Have Put the US on a Path to Net Zero Emissions through Investments in Infrastructure and Power Generation

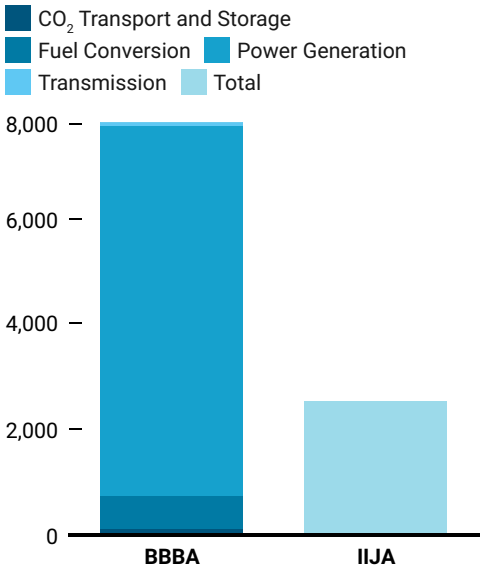
Greenhouse Gas Emissions Trajectories by Policy

There is as much of a gap between the infrastructure bill (IIJA) and Build Back Better Act (BBBA) as there is between BBBA and net zero.



Difference in Capital Investments Catalyzed by the BBBA and Bipartisan Infrastructure Law (IIJA)

Projected cumulative investment (Billions of US$) in decarbonization between 2024 and 2040



Note: MMT CO_2-equivalent under different policy scenarios.

Source: REPEAT Project

The federal government is also providing more ambitious goals for its sectoral strategies, particularly in batteries and EVs.[127] Among other policy proposals, the Biden administration published a National Blueprint for Lithium in 2021, which outlines its demand-pull and supply-push approach.[128] The demand-side focus is to increase the sales of EVs across the United States through a combination of tax credits, expanded EV charging infrastructure, and fuel economy standards to reach the administration's official goal of 50% EV sales by 2030. On the supply side, the administration and Congress are actively promoting critical minerals mining in the United States as well as developing new substitutes and improving reuse and recycling.[129] The Bipartisan Infrastructure Law also included $6 billion to go toward battery manufacturing and processing, some of which is already being distributed to US companies.[130]

The Biden White House also issued its "Executive Order on America's Supply Chains" to add more specificity to some of the most important clean energy supply chains.[131] In 2021, the US Department of Energy (DOE) published a review of the supply chains of large-capacity batteries, followed by deep-dive reports in 2022 on the supply chains of carbon capture, the electric grid, energy storage, fuel cells and electrolyzers, hydropower, neodymium magnets, nuclear energy, platinum group metals, semiconductors, solar PV, wind, and cybersecurity.[132] These reports review the raw materials, processed materials, subcomponents, final products, and end-of-life management for each of these technologies, providing a deep base of knowledge and data for future investors.

The federal government is also sending a strong signal that now is the time to invest in these efforts across the United States. The Biden administration's BBBA would have included more than 30 place-based economic programs, including funding for research universities, bolstering supply chain resilience, and establishing incubators for small businesses in underserved communities.[133] The Bipartisan Innovation Law, formerly known as the Endless Frontiers Act, includes $10 billion to establish regional technology hubs across the country, and a further $3.6 billion for the Manufacturing USA and Manufacturing Extension Partnership programs, which provide place-based collaboration for small and medium-size manufacturers.

This funding would come on top of the $8 billion allocated for regional hydrogen hubs, and a further $10 billion for investments in carbon capture, direct air capture (DAC), and industrial emissions reduction projects in the Bipartisan Infrastructure Deal.[134] In June 2022, the Loan Programs Office (LPO) issued its first loan guarantee since 2014, supporting the world's largest clean hydrogen energy storage facility, and is promising to approve further guarantees and direct loans over the coming years.[135] Congress also included $1 billion in the American Rescue Plan Act to launch the Build Back Better Regional Challenge, which will provide grant funding to 20–30 regions for innovative approaches to economic recovery from COVID-19.[136]

RMI has identified six states — California, Colorado, Illinois, New Jersey, New York, and Washington — that are leading the way to complete decarbonization by 2050.

State policies are also advancing. Twenty-four states have implemented greenhouse gas emissions targets,[137] 38 have renewable portfolio standards,[138] and every state has implemented some combination of financial incentives to encourage the growth of clean electricity, EVs, and other decarbonization technologies.[139] The ambition of these initiatives varies considerably, as does the range of sectors covered by new policies.

RMI has identified six states — California, Colorado, Illinois, New Jersey, New York, and Washington — that are leading the way to complete decarbonization by 2050.[140] These states have moved the needle substantively on US emissions while showing other states how to do so. These six frontrunner states, along with numerous other states taking ambitious steps, have made clear progress using a diverse set of policy instruments. The size of these six states, in terms of population and economy, also means their clean energy investments have played a major role in shifting the national landscape.

A wide array of policies is also being implemented at the local or city level. Climate Mayors, for example, is a coalition of roughly 500 mayors from across the country who have committed to meaningful climate action in their communities. In 2021, US cities purchased a record amount of renewable energy through power purchase agreements, utility programs, and on-site solar installations.[141] More than 180 communities around the country have committed to 100% renewable electricity by 2050, 50 of which have already reached this goal.[142] A growing number of American cities are thinking beyond electricity and looking at how to invest in green spaces, encourage more bicycling or walking, invest in public transit, and phase out fossil fuel use in residential and commercial buildings.[143]

Despite all this action and momentum, there is still a long way to go. Congress has been unable to pass a climate agenda that, while flawed, would have provided an unprecedented signal to companies and financiers that there is a clear road ahead for clean energy investment. Progress at the state level is more

heterogeneous, with some clear leaders and all too many laggards. The overlapping, intermingling policy instruments and market signals from America's many state and local policymakers are muddying the waters for new investment, particularly FDI.

The United States needs a vision for its clean energy future, one that puts communities and their interests first by building on their existing strengths and designing incentive structure to facilitate investment and inclusive growth. Although this vision must start at the national level, it will be acted upon region by region, state by state, town by town.

National Strategy – Building the Backbone of Opportunity

Maximizing the economic opportunities afforded by the clean energy transition will not be easy. There is no guarantee that the clean energy technologies likely to define the 21st century will similarly define the landscape of American prosperity. In other words, the United States needs a strategy, and quickly.

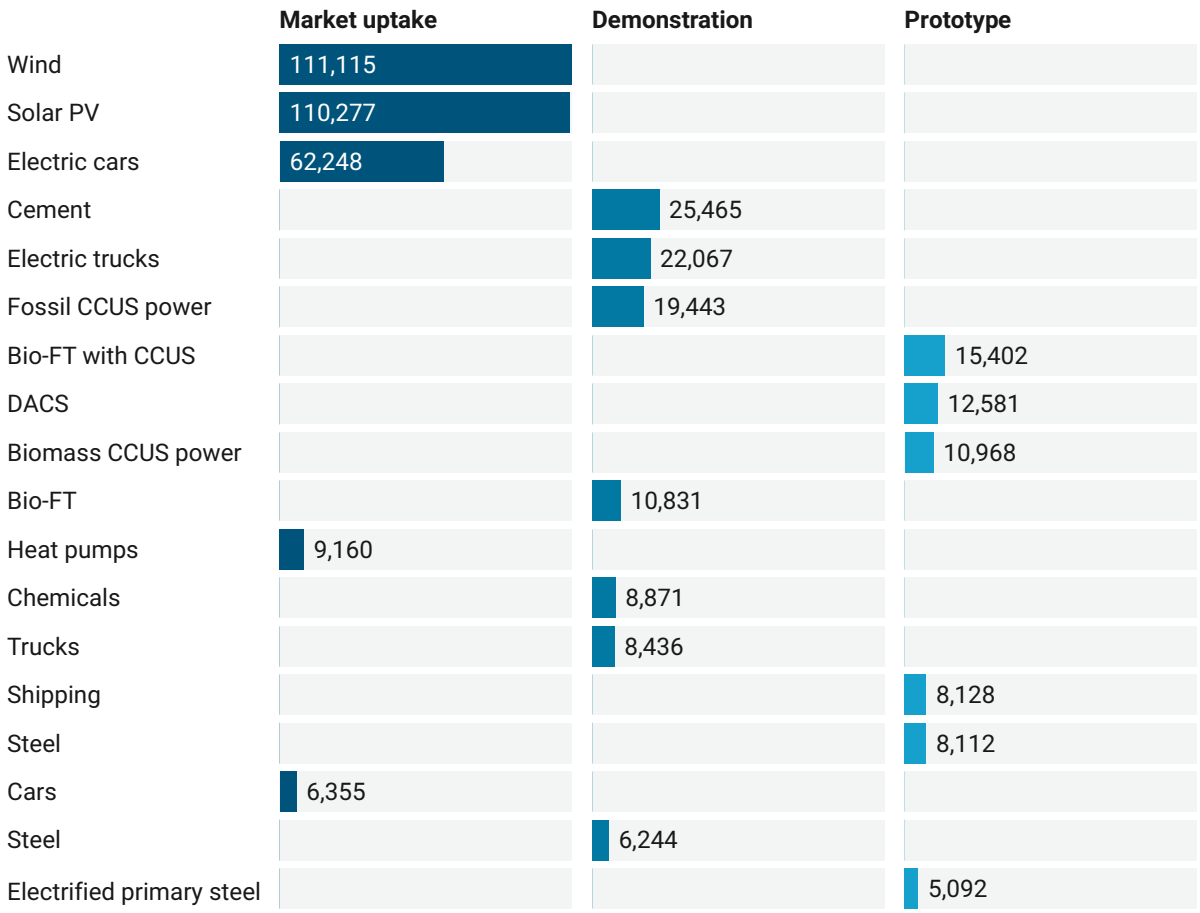
Becoming a net-zero economy by 2050 means that clean energy technologies need to go from niche applications to dominant solutions. This will require the combined force of public investment and private capital markets.[144] The US private sector needs to invest, at a minimum, an additional $220 billion per year until 2030, and a further $410 billion per year in the 2030s to cut emissions economy-wide by 80% by 2050.[145] Unfortunately, although private investment is growing at a record pace, it remains woefully insufficient, particularly in hard-to-abate sectors like heavy industry, shipping, and aviation, where technological solutions remain in very early stages.

The United States has the bulk of the technological solutions required to decarbonize, but they have not yet reached the scale to sufficiently drive down costs and reach widespread market diffusion.[146] According to the International Energy Agency's *Net Zero by 2050* report, approximately half of the emissions reductions required by 2050 will come from technologies with existing market uptake.[147] Most of the remaining early innovation required is concentrated in the industrial sector (see Exhibit 20, next page).

Exhibit 20

Most Emissions Reductions Will Come from Technologies Already on the Market

Cumulative CO_2 emissions reductions for selected technologies by maturity category in the IEA's *Net Zero by 2050* scenario



Note: Bio-FT = biomass gasification with Fischer-Tropsch synthesis; CCUS = carbon capture, utilization, and storage; DACS = direct air capture and storage.

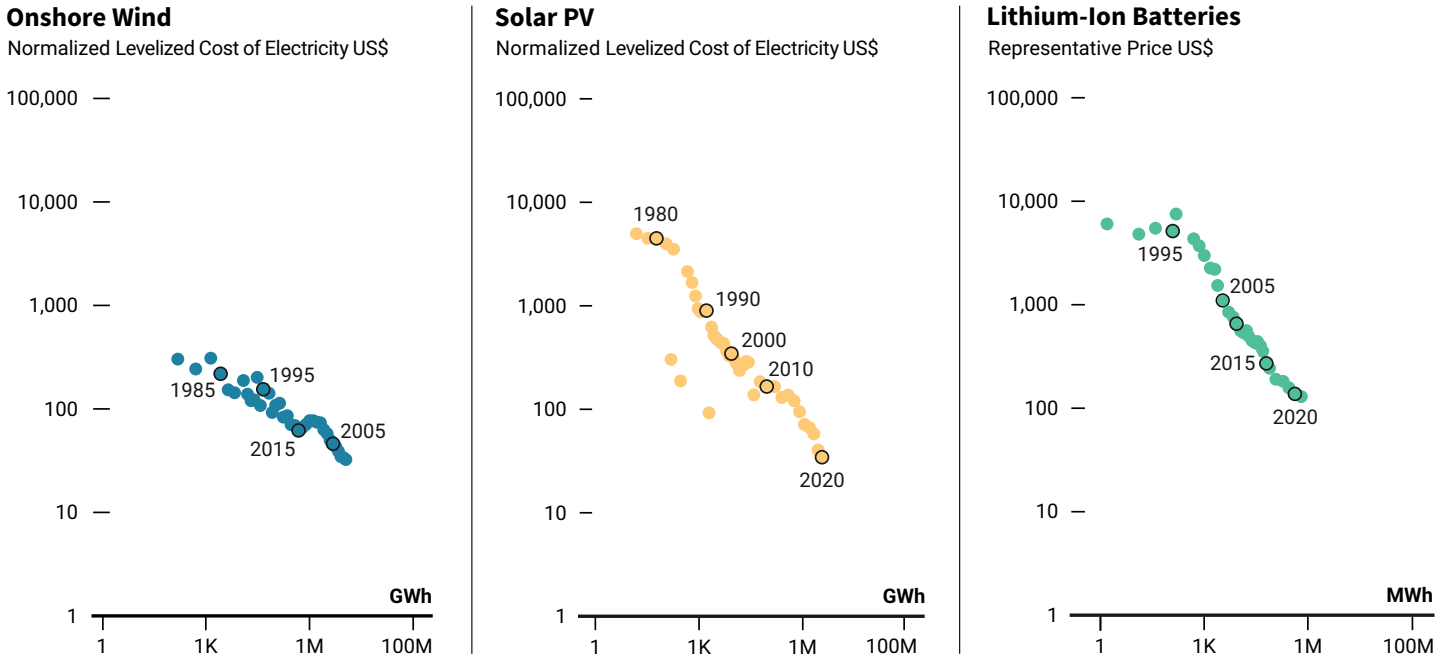
Source: IEA

However, to date, the fastest clean energy technologies have taken 20–30 years to go from early prototype to market diffusion. This process needs to be accelerated by at least 30%.[148] Some of this acceleration will come out of R&D labs and universities, but the bulk will happen through the economies of scale afforded by abundant private investment, incentivized and catalyzed by public policy.

In the short to medium term, the major emissions reductions and economic impacts will come from accelerating investment in technologies that have reached market maturity. These are the products that, over the course of the next decade, will reshape the economy, drive down emissions, and create the jobs and opportunities that will help communities across the country to thrive.

Exhibit 21

Learning Curves for Wind, Solar, and Batteries Show that Costs Will Continue to Fall as Deployment Increases



Source: IRENA, BloombergNEF; Performance Curve Database

The willingness of the private sector to invest in these technologies at the speed of US climate goals will depend on four factors: (1) how fast domestic demand grows, (2) whether stakeholders can address barriers to private investment, (3) how quickly the required public physical and social infrastructure can be built, and (4) whether there are resilient and robust enough supply chains to meet these growing needs. The US national strategy should therefore include the following four strategic pillars:

1. Driving Domestic Demand

The primary barrier to new technology diffusion is higher costs, and the key to driving down costs is scale. It is well established that for every doubling in cumulative production, certain technologies' costs will decrease at a significant and consistent rate (see Exhibit 21). This phenomenon has been studied most comprehensively in solar PV, whose costs have fallen at the rate of 24% for every doubling in cumulative global production.[149] This rate is similar for lithium-ion batteries, whose costs fell an average of 18.9% for every doubling in capacity .[150]

Cost declines take place over two phases: the technology's emergence through publicly funded R&D, and its ongoing diffusion driven by market-stimulating demand-pull policies.[151] Demand-pull measures therefore should vary over the course of a technology's progression through its S-curve, or phases of market maturity.

As a technology diffuses, targeted government procurement, prize competitions, or milestone payments can provide early markets that will help first movers bring down costs through economies of scale, learning by doing, and ongoing experimentation.[152] Advance market commitments can also be a powerful mechanism, as seen from Operation Warp Speed, where guarantees of government procurement provided the demand certainty for companies to invest heavily, and successfully, in new COVID-19 vaccines.[153] These mechanisms need not be limited to government procurement. For example, the payment platform company Stripe has launched an advance procurement initiative that promises to invest nearly $1 billion in DAC technologies, which attempt to remove carbon directly from the atmosphere, over the coming decade.[154]

As technologies come closer to commercial viability, subsidies, feed-in tariffs, and tax credits become more effective tools for improving their marginal economics. Whereas other countries, particularly in Europe, have preferred feed-in tariffs to support renewable electricity and mandates to force EV adoption, the United States has implemented, extended, and expanded a variety of tax credits in its Energy Policy Act to scale clean electricity and electrify transportation. The United States has relied on the tax code since political barriers are lower than new spending or regulatory measures, and changes can be included in sweeping omnibus bills that obscure the significance of new measures.[155]

These instruments include the Investment Tax Credit, which subsidizes investment mostly in solar PV power plants, and the Production Tax Credit, which primarily supports output from wind power, as well as the Plug-in Electric Drive Vehicle Credit to subsidize the purchase price of EVs.[156] These incentives have been effective in promoting additional deployment. A 2015 study found that the national production tax credit alone increased wind energy deployment by an average of 1.4 GW per year between 1990 and 2011.[157] The EV tax credit is estimated to have increased total sales by around 30%.[158] Executive and legislative proposals include a variety of extensions and improvements to these tax credits that, according to one study, would increase the rate of clean energy deployment by as much as 65 GW per year between now and 2031.[159]

This approach is not without drawbacks, however. Policy durability has been a major issue for clean energy tax credits in the United States, which creates uncertainty for investors making decisions on future projects. Studies of the barriers to private sector investment in clean energy show demand uncertainty created by an unstable policy environment is a major inhibitor to investment growth.[160] The variability in clean energy tax credits has also created boom-and-bust investment cycles that have resulted in bottlenecks during periods of high demand and bankruptcies as the cycle goes the other way.[161]

Another major issue with the tax code approach is that these credits often cannot be fully utilized by project developers. This is because tax credits require developers to have a sufficient tax burden against which to offset the tax credit, which means many need to turn to tax equity investors to monetize the credit. Not only is this cumbersome and complex, but since 2008 tax equity has been more than twice as expensive as debt financing.[162] A major change in proposed legislation in Congress would be to avoid this problem through the introduction of a direct-pay option. According to project developers, this direct-pay option would be uniquely helpful in catalyzing investment in the industry.[163]

A strong demand signal is therefore an important step, and in many respects a necessary but insufficient condition for investment growth, but demand-side measures, and particularly tax credits, are no silver bullet. These measures cannot address supply-side challenges, which include technological risks, regulatory red tape, and information asymmetries to name just a few. Barriers to investment are often

sector specific and differ according to the type of capital and financial actor involved. Without addressing these bottlenecks, private investment will remain insufficient to adequately compete in international markets and maximize the opportunity in local communities.

2. Addressing Barriers to Private Investment

The world is currently experiencing heightened policy instability, technological uncertainty, and entrenched incumbency, which means the clean energy transition remains a high-risk proposition for many private investors. A combination of these risks, high up-front capital requirements, a lack of experience in new sectors, and high transaction costs has created a significant green finance gap between the needed investments and those forthcoming from the private sector.[164] Systematically addressing these investment barriers is a critical step in going from the mere invention of clean energy technologies to their mass implementation.[165]

Four broad categories of barriers are preventing investment at scale in clean energy technologies: policy, market, financial, and technological.[166] The primary policy barrier to private investment is the long-term stability of major policies, creating uncertainty in investment decision-making, which disproportionately impacts clean energy given the capital-intensive, long-term nature of many of these projects. The complexity of relevant policies and their interactions, particularly at different levels of government, can also be a significant challenge because of increasing transaction costs in project development.

Market and financial barriers can vary significantly by sector and geography, requiring more of a subnational approach, as described in the following section. Broadly speaking, these barriers can include inadequate or poorly maintained physical infrastructure, insufficient worker development and training, community engagement challenges, lack of financial access or capital availability, and status quo bias in favor of existing companies and technologies.[167] Because these investment decisions are made on a project-by-project basis and these market and financial barriers can be specific to each project, the challenge is to create tailored policy and institutional interventions at different geographic and sectoral levels to mobilize and accelerate investment.

Clean energy technologies also come with novel barriers because of the technological uncertainty and relative lack of expertise and capacity in these fields. Technology risks in particular create what is often called the valley of death between new ideas and commercialized opportunities.[168] In general, there is a lack of available investment between high-risk VC and the lower-risk corporate financing of more mature solutions. This creates a space for the public sector to de-risk capital and draw in larger pools of funds.[169]

The DOE's LPO, for example, explicitly addresses these valley of death issues. Over its 15-year history, the LPO has had considerable success in scaling clean energy technologies by providing loan guarantees and direct loans for nascent technologies. For example, in its first few years of operation, the LPO provided nearly $5 billion in loan guarantees for the first five utility-scale solar PV plants in the United States — that is, plants over 100 MW in capacity — and is now widely credited for helping commercialize the industry across the country.[170]

Loan guarantees are just one of many possible public financing tools. For example, public financing institutions can also take equity stakes that allow the federal government to share in the rewards as well as the risks.[171] Famously, the LPO was an early investor in the EV manufacturer Tesla and the solar

manufacturer Solyndra, which each received around half a billion dollars of public financing support in 2009 and 2010, respectively. The Obama administration was roundly criticized for the failure of the Solyndra guarantee, yet because the LPO was unable to take an equity stake, taxpayers saw no economic returns on the spectacular success of Tesla, whose share price grew by a factor of four during the period of the LPO's investment and would have more than offset the Solyndra loss.

A variety of mechanisms is also available to incentivize clean energy investment through secondary market structures. This includes the aggregation or warehousing of debt instruments as well as new financial products to meet market needs. These tools are important because most of the barriers to greater private-sector investment are not a lack of capital, but more complex mismatches between the risk/return profile of these projects and the capital allocation drivers of different types of private investors.[172] For example, many critical green financing needs lack sufficient scale to be attractive to some of the largest pools of capital, such as institutional investors, meaning that despite trillions of dollars of climate pledges, many asset managers report finding it difficult to deploy all that capital in bankable projects.

Green bonds, for example, have been an important source of green finance at scale and show the innovative role public financing institutions can play in secondary markets.[173] Globally, more than $1.7 trillion of sustainable debt (which includes green bonds) was issued in 2021, more than twice as much as in 2020.[174] The largest single issuer of green bonds globally is Fannie Mae, a US government–sponsored entity that plays a backstop role in the mortgage market, which, despite some legitimate criticism of its current approach, could be leveraged to catalyze further investment in green buildings.[175]

Several countries and a growing list of American states have gone a step further, setting up dedicated green banks to catalyze private investment through innovative public financing solutions. Where the LPO is restricted in its available financial products, green banks can offer blended finance instruments, technical assistance services, and secondary market structures to break down the barriers to rapid clean energy deployment.[176] More than 20 green banks operate in the United States, and government officials and local leaders are considering an additional 11. According to the American Green Bank Consortium, these banks have collectively invested $1.9 billion since 2011, mobilizing a cumulative $7 billion in total investment across the country.[177]

One reason green banks have been so effective is that their double mandate incentivizes them to overcome the incumbency bias of many investors. Financial actors are typically more familiar with the regulations, technologies, networks, and financial instruments of existing technologies than they are of nascent market disruptors. A core goal of public financial institutions, like green banks, and the public sector more broadly is to provide the tools, data, and information necessary for private investors to seize opportunities in unfamiliar terrain. Here the role of public–private coordination will be particularly significant. Public actors with motivations beyond profit maximization can partner with the private sector on first-of-a-kind projects to demonstrate feasibility and provide technical assistance or simply forums for knowledge sharing and best practice recognition, among many other possible forms of collaboration.

3. Expediting New Construction

A key piece in accelerating clean energy technology investment is building new physical capital across the country. In particular, the United States needs to ensure the necessary infrastructure exists to scale emerging clean energy technologies at high speed. Furthermore, local communities need to see material benefits in their lives and livelihoods if they are to support rapid, and in many respects unprecedented, change.

Put simply, new technologies need to be linked to existing systems if they are to function. An electric car cannot be driven without a charger and wind power cannot be harnessed without transmission lines. Because these linkages provide public benefits or externalities that cannot be captured by private providers, they generally need to be built, or at least heavily subsidized, by government. In transitioning to a clean energy system, there is fairly strong agreement about what infrastructure needs to be built, but considerable debate over how and where to build it.[178]

In the energy sector, the United States needs to prioritize building power lines, charging stations, and pipelines for green hydrogen and CO_2 over the next 10 years. To connect all the new solar and wind energy needed to decarbonize the electric grid, the *Net-Zero America* study estimates the United States needs to increase its current transmission capacity by around 60%, which is about 195,000 GW-km of new transmission lines.[179] Electric distribution infrastructure also needs to be improved to allow for greater use of flexible demand and distributed energy resources while also being capable of accommodating significantly higher peak electricity demand. The study also estimates that in a high-electrification scenario, 2.4 million charging ports will need to be built nationwide by 2030. Finally, to allow for meaningful carbon capture and storage, the United States will need roughly 19,000 km of CO_2 pipelines, connecting all regions to geological storage basins.

Put simply, new technologies need to be linked to existing systems if they are to function.

The Biden administration took a large step toward these infrastructure goals with the Infrastructure Investment and Jobs Act, which the president signed into law in 2021. The bill included $2.5 billion to help reach the administration's target of 500,000 EV chargers nationwide. It also contained $10–$12 billion for grid infrastructure, though about half of this goes toward demonstration projects that will help over the medium term but will do little to help site, plan, and construct the hundreds of thousands of miles of new lines needed. Further, to support construction of CO_2 pipelines, the bill established a new $2.1 billion low-interest loan program to help finance large projects and included $3.5 billion for carbon capture hubs, which will demonstrate new technologies and construct large-scale projects, creating demand for pipeline construction.

However, a complex web of procedural rules make it incredibly time-consuming and expensive to build large-scale infrastructure projects in this country.[180] In particular, environmental reviews and zoning regulations have turned many parts of the United States into a vetocracy where bold action requires sign-off from a large number of actors, each with the potential to stymie progress.[181] The Obama, Trump, and now Biden administrations have all recognized the problem but been unable to appropriately reform the National Environmental Policy Act or design policy interventions capable of overcoming the many veto points preventing progress.

These issues are likely to only grow as the demands on land use from the clean energy transition continue to increase. As they do, these questions of development and the institutional capacity to build will come ever more into focus. Counterintuitively, much of the opposition to new solar facilities and other clean energy projects is led by groups who use local conservation and environmental concerns as cover for classic NIMBY motivations, such as preserving views and property values.[182] However, NIMBYism is far from specific to renewable energy projects, but a challenge that plagues US public policy in housing, transportation infrastructure, and every kind of megaproject .[183] Dozens of new laws have been introduced since the 1970s that make it more difficult to build new infrastructure, easier to oppose new projects, and ultimately harder to tackle the existential challenge of the times.

The other major areas of new construction required to take advantage of the opportunities in the clean energy transition are public transit and housing. A recent study found that in public transit, US projects cost 50% more and take 18 months longer to conclude than similar projects overseas, severely reducing the number of new projects built around the country.[184] Meanwhile, in the decade following the Great Recession, housing construction was slower than at any other period since the 1960s, contributing to a housing shortfall estimated at around 1.5 million homes and a broad affordability crisis.[185] In both cases, the major investment barriers are burdensome regulations — environmental reviews in the case of public transit and zoning restrictions in the case of housing — that artificially raise costs, delay decisions, and stymie progress.

Another barrier to expedited construction is supply chain issues. This was seen most dramatically in the high cost of lumber during the COVID-19 crisis, which delayed housing construction at a time when demand was skyrocketing.[186] Addressing these supply chain issues requires long-term investment in new inventions, old capacities, and existing relationships.[187]

4. Building Secure and Resilient Supply Chains

Robust supply chains are critical to deploying clean energy technologies at scale, and to capturing the economic opportunity inherent in the energy transition. It is therefore imperative that the United States develops the data and analysis required to understand end-to-end supply chains, invests in the domestic capacity to produce more at home, and fosters the international alliances that will help diversify strategic supply chains away from its most geopolitically sensitive trading partners.

The first step toward building out future resilient and robust supply chains is to understand their status today.[188] This includes gathering the data and technical capacity on who supplies what, how much it costs, and how new technologies are impacting that supply. This data is currently dispersed behind paywalls, siloed within government agencies, and understood by only a handful of experts. Demand forecasts are also an important piece in understanding supply chains and how they are likely to evolve. Because many clean energy supply chain investments tend to colocate near sources of demand, a high degree of granularity in these forecasts will be important for planning investments across the country.

The DOE has begun this work in earnest, releasing deep-dive reports on more than a dozen clean energy technologies.[189] Government agencies can only do so much, however; market participants and key investors need to support this effort. Ongoing research and collaboration need to be conducted to boost the economic competitiveness of American clean energy industries as they develop emerging technologies and build out resilient, secure supply chains. As these companies work toward their own net-zero targets, it will be important that they are part of forums and organizations that can share best practices and scale novel solutions.

The second element of a US clean energy supply chain strategy is to invest in the capacity to produce many of the necessary pieces domestically. Of course, none of these supply chains will be 100% domestically sourced, nor should they be if the cost competitiveness that drives clean energy deployment is to be maintained. However, some important steps can be taken. These include leveraging existing manufacturing programs, such as the Manufacturing USA network, Manufacturing Extension Partnerships, and DOE's LPO. The Government Accountability Office identified 58 programs across 11 federal agencies that provided support to US manufacturing, and a further nine tax expenditures that provide benefits to the sector.[190]

This fragmentation makes it needlessly complex for manufacturers to access government benefits and compete with foreign producers that operate with more efficient subsidy systems.

In other words, boosting clean energy manufacturing runs into many of the same challenges as boosting domestic manufacturing capacity more broadly. Addressing these challenges requires a suite of solutions, including expanded funding for relevant R&D initiatives, workforce development, technical assistance, and management consulting. New public–private partnerships (PPPs) can also help de-risk new manufacturing innovations and Congress should pass legislation that expands public financing mechanisms, such as loan guarantees and competitive grants. Finally, establishing regional clean energy industrial clusters through coordinated mechanisms between public and private stakeholders can, according to the DOE, "drive innovation, increase competitiveness, and expand domestic manufacturing of clean energy technologies."[191]

Another means of reducing supply chain vulnerabilities is by innovating to get out of problematic inputs or at-risk segments. DOE, for example, aims to eliminate the use of cobalt in lithium-ion batteries by 2030, reducing manufacturers' reliance on imports from the Democratic Republic of Congo, where concerns over the use of child labor in cobalt mining are a major impediment to future growth.[192] Another example is in solar technologies, where DOE has made concentrated solar power (CSP) and thin-film solar technologies, such as cadmium telluride and perovskites, core R&D priorities.[193] The supply chain for CSP, for example, is primarily composed of plentiful commodity materials such as steel, aluminum, and glass, which are produced in relative abundance in the United States.

The final piece of a resilient supply chain strategy is to diversify trading partners in clean energy technologies. As a report from the Center for Strategic and International Studies put it, the United States needs to focus on the "three Rs: reshoring, rerouting and rebalancing."[194] In this report, *reshoring* refers to investing in domestic capacity and *rerouting* means nurturing ties with suppliers from allies and other partners with limited geopolitical concerns. This process will in part require rebalancing trade relationships by investing in foreign capacity as well as domestic, working to bolster the strength of international institutions, and promoting the adoption of global standards. For example, the Pentagon recommended to Congress in May 2022 that it update the National Defense Authorization Act to include Australia and the United Kingdom as eligible sources of funding for critical mineral mining projects.[195]

These core pillars of a national strategy — boost demand, address investment barriers, expedite construction, and invest in secure supply chains — are priorities for accelerating investment. But they are not sufficient. While the Biden administration and the 117th Congress are making great strides in building these pillars and increasing momentum in the clean energy transition, the United States is no monolith and more than one set of actors at more than one level of government is needed to meet this moment.

A core perspective missing in the US energy transition is the regional or multistate vantage point. The United States is made up of at least half a dozen different regional cultures and political economy ecosystems, each requiring tailored strategies that capitalize on their strengths and unique capacities. Such regional investment strategies have distinct advantages because of their scale, specialization, and conditional flexibility.

Regional Investment Strategies – Targeted, Place-Based Strategies to Drive Impact

A national strategy can only go so far. The United States is a complex assortment of cities, states, and regions, with varying histories, economic structures, local cultures, and political persuasions. The clean energy transition can be accelerated by not only recognizing but also embracing this geographic diversity. Further, while geography plays an important role in all investment decisions, the production and deployment of clean energy technologies will be particularly influenced by location and the physical characteristics of place.

The United States needs a series of regionally tailored investment strategies, designed explicitly to accelerate investment in three key areas: (1) the clean energy industrial base and its supply chains; (2) the construction of enabling infrastructure and public works; and (3) the resources, institutions, and capacities to empower communities on an ongoing basis. These strategies should be designed with regionally specific investment barriers in mind, addressing the unique financial, cultural, political, and market constraints on building the projects that will comprise a clean energy future.

Three Key Areas

1. **Clean energy industrial base and its supply chains**
2. **Construction of enabling infrastructure and public works**
3. **Resources, institutions, and capacities to empower communities on an ongoing basis**

As one OECD report puts it, transforming regional economies requires "a focus on interventions that help build systems, create networks, develop institutions, and align strategic priorities."[196] If appropriately targeted and designed, regional investment strategies can achieve these outcomes, fostering new sources of opportunity and dynamism in America's many regions.

In this sense, clean energy policymakers and advocates can learn from the economic literature of place-based policymaking and regional development. In particular, the strategic cluster framework can be readily applied to emerging clean energy industries, which share key characteristics, such as a high R&D intensity, large infrastructure requirements, and knowledge-based entrepreneurship.[197]

As important as cluster development can be to regional growth prospects, it pays not to rely too much on one approach or industry. Regions are exposed to less technological and trade risks if they are home to a wide variety of industries. This three-pronged investment approach addresses these diversification risks by not only promoting investment in more than the industries themselves, but also in the connective tissue and local institutions that help encourage broad growth, encourage new business startups, and attract a wide range of investment activity.

Recipe for Success

Regional investment strategies are a means of setting strategic priorities; helping coordinate investors, financiers, and policymakers; addressing regionally specific barriers to investment; and empowering the communities that form the region's landscape and culture. These goals should be ambitious yet pragmatic and align with existing strengths yet capitalize on latent potential. Perhaps most importantly, they should meet communities where they are, rather than where an advocate halfway across the country thinks they should be.

At a high level, identifying priority investments according to the rubric of the clean energy industrial base, enabling infrastructure, and community institutions can help align policy and regulatory frameworks in pursuit of a common vision.[198] This need not change the policies or incentive structures underlying projects to materially impact investment decisions; , but can accelerate investment simply by providing a degree of stability, clarity, and coherence across levels of government and between geographic regions. Clean energy projects, almost regardless of their stage in the supply chain, tend to be capital-intensive with long time frames, requiring a high degree of certainty about future conditions that well-targeted regional investment strategies can provide.[199]

Multistate regions across the country already have particular specializations and strengths — also referred to as industry clusters — that will inform which sectors and what pieces of the clean energy industrial base and its supply chain to prioritize. Regional investment strategies can mobilize investment by developing sector-specific strategies and goals, helping align diverse government and regional stakeholders. In other words, industry clusters are the nexus between furthering existing economic strengths and capitalizing on future clean energy opportunities.

Regional investment strategies can mobilize investment by developing sector-specific strategies and goals.

In the Gulf Coast region, for example, a strong petrochemical and heavy industrial sector will likely complement investments in green hydrogen and CCUS, where existing skills, infrastructure, and local institutions already have many of the capacities required to be competitive. Already, the DOE's H2Hub Program is incentivizing multistate investment coordination and planning in this region, suggesting such an approach at scale could catalyze private investment and help regions capitalize on emerging opportunities.[200]

Meanwhile, growth in these sectors can only be as fast as the infrastructure and public works in the region can facilitate. These needs will be tied to the demands of a particular sector, such as high-voltage transmission infrastructure in the power sector or hydrogen-ready pipelines in the industrial sector. Furthermore, the tools to accelerate investment are often shared among multiple state and local decision makers, creating a need for an institutionalized structure of planning and coordination, such as a regional investment strategy process. In the electricity sector, for example, grid planners have struggled to plan jointly with neighboring grids, leading to significant bottlenecks and investment delays.[201]

Finally, clean energy investment must be about more than factories and transmission lines if it is to foster inclusive development and regional growth. New investments need to be coordinated with community empowerment strategies, helping attract new industries, spin off new businesses, commission new public works, invest in new capacities, and bolster new institutions.

Barriers to Investment Are Regionally Specific

Every clean energy project is unique, not only because of the specificity of its business model or revenue stream, but also because of its location within the American landscape. Though Americans share many common values, this is a country that celebrates and encourages diversity in cultures, economies, and, of course, politics. This diversity can be a headache for investors, however, because the success or failure of a given project can vary county to county, state to state.

A core feature of a regional investment strategy is identifying the specific barriers to investment in the clean energy industrial base, its enabling infrastructure, and the spillovers to community empowerment. The multistate lens is critical here because many of these barriers are specific to the political economy and regulatory landscape of these regions.

Addressing these barriers is particularly necessary in accelerating the clean energy transition because clean energy technologies are not competing on a level playing field. Instead, they operate in an environment of skewed incentives, uneven policy, and asymmetric information. On the policy front, the United States is a mixed bag of subsidies, tax credits, portfolio standards, and other policy instruments implemented less according to an agreed-upon social cost of carbon than the vagaries of geography, politics, and economic incentives. As ambitious as some states and cities are in their clean energy deployment strategies, none are currently providing a sufficiently strong market signal to invest at the scale or speed required.

Economic development organizations have a catalytic role to play in facilitating investment and implementing regional investment strategies.

More broadly, the US federal structure encourages competition for new investment between the states, each developing distinct policy environments and market frameworks for promoting new businesses and retaining core industries. In accelerating clean energy investment, this general investment environment is just as important as specific climate mitigation policies.[202] This environment can include factors that vary even more than climate policies, such as the overall ease of doing business, regulatory quality, investment facilitation, and competition policy.

Economic development organizations (EDOs) have a catalytic role to play in facilitating investment and implementing regional investment strategies. These entities are uniquely incentivized to create jobs, foster entrepreneurship, and champion business retention, expansion, and attraction. EDOs take a mission-driven approach in their efforts and, based on data, can incorporate clean energy as a priority in locations where it makes the most sense. As McKinsey & Company points out, impact will be greatest when EDOs understand where they can have the most impact, implement strategies codeveloped with local stakeholders, and are resourced for execution.[203]

After policy or technology uncertainty, the most commonly cited barrier to clean energy investment is the perceived high-risk, low-return profile of many of these investments and the high fees and transaction costs that often accompany them. To a certain extent, these issues are resolving themselves over time as

costs fall, demand increases, and investors gain relevant experience and expertise. However, this is not happening fast enough and in as many regions as it could be, and few regions have taken an approach tailored to reducing these important investment barriers.

For the most mature clean energy technologies, such as solar or wind electricity, available capital or offtaker demand is rarely a major barrier to investment.[204] Instead, the bottleneck is the lack of a pipeline of bankable, construction-ready projects often because of regulatory complexity, planning limitations, and permitting delays.[205] This is particularly true in renewable electricity and interregional transmission, but is increasingly a concern for building large projects in a variety of sectors.[206] One key outcome of a regional investment planning process, therefore, would be to create such a project pipeline and identify what it will take to implement at scale.

One notable investment barrier identified in numerous clean energy industries — particularly those related to advanced manufacturing, such as lithium-ion battery manufacturing — is workforce development and technical skills gaps.[207] Developers will often choose locations for new investment based on access to skilled labor. Therefore, one of the most impactful investments regions can make is in the institutions that provide technical skills training for burgeoning industries, such as community colleges. Regional investment strategies can help in this regard by forecasting trends in new labor demand from clean energy industries, identifying skills gaps, and convening relevant corporations and educators to create tailored vocational programs.

An additional barrier to investment is finding appropriate financial instruments and expertise. In an analysis of policy and academic literature as well as industry interviews, one comprehensive study found that some of the top barriers to clean energy investment include “lack of suitable financial vehicles,” “lack of technical advice on green infrastructure investment,” and “lack of liquidity in markets.”[208] Other financial barriers include access to early-stage capital, particularly for startups trying to bring new ideas to the marketplace.[209] This challenge varies considerably by region, with VC funding opportunities much more available in the Bay Area, for example, than the Southeast.

Although many relevant financial regulations are developed at the federal level, regional actors can overcome many of these barriers in a number of ways. These include tools such as PPPs, concessional financing, and investments in the capacity of local financial markets.[210] Regional actors can also play an important intermediation role in connecting large environmental, social, and governance (ESG) or impact investors with local or regional clean energy investment opportunities that often require a third party, such as an EDO. Green investment banks and infrastructure funds have also proven to be effective means of catalyzing private investment in sectors where risks are perceived to be higher, liquidity lower, and capacity lacking.

There is also a growing presence of subnational green banks across the United States, which have shown themselves to be highly capable at overcoming key investment barriers. In 2020, green banks in 15 states mobilized $1.7 billion in total investment for clean energy industries.[211] The sector as a whole leverages an average of $3.70 for every dollar invested, but this varies considerably, with the Connecticut Green Bank boasting a leverage ratio of 6.6:1 and Michigan Saves as high as 30:1.[212] These banks help scale smaller projects, serve low- to moderate-income communities, offer technical capacity in new industry areas, and address debt tenor mismatch issues that constrain private investment. US green banks vary significantly in the sectors they serve as well. These entities could be brought into the regional investment strategy process, serving as key facilitators of investment and community empowerment.

Cluster Framework

Regional investment strategies can help deliver inclusive economic development as part of a strategic cluster framework that reflects the unique competitive advantages of America's varied regions.[213] Clusters are geographically localized concentrations of firms, suppliers, support services, and specialized institutions in related sectors that operate in an active web of collaboration that can lead to higher performance.[214] In clean energy industries, these could be clusters of manufacturing and services firms, combining industries linked in vertical supply chains from critical mineral mining through energy offtakers and everyday consumers.

A core advantage of the cluster framework is as a means for organizing and framing disparate local and regional economic development policies and as a pragmatic way of capitalizing on existing strengths and resources, whether through dedicated cluster initiatives or cluster-oriented economic development plans. Depending on resource capacity and the maturity of existing clusters, it may make more sense to dedicate time and effort to accelerating the growth of a specific cluster or developing strategies that cut across multiple industries. Most importantly, the cluster framework provides a lens through which an ecosystem of public and private actors can concentrate on developing strategic niches in clean energy technologies that account for local dynamics and regional specialization.[215]

The cluster framework provides a lens through which an ecosystem of public and private actors can concentrate on developing strategic niches in clean energy technologies.

Regional investment strategies should therefore build on existing cluster initiatives and regional development strategies across multistate regions. Appropriately targeted multistate regions would be large enough to capture multiple clusters of varying industrial specializations and promote coordination between state and local actors while working at a scale commensurate with the challenge of rapid decarbonization. Each region would develop tailored investment strategies that build on existing strengths to identify opportunities for maximum economic opportunity, export growth, and job creation.

Clusters also can help improve the market economics of many of these technologies. The development of cluster initiatives and clean energy alliances helps accelerate geographic colocation of related clean energy firms, which has been shown to lower costs and facilitate improved access to resources, such as shared infrastructure, pools of skilled labor, entrepreneurship incubators, and financial capital.[216] Cluster initiatives are typically developed by the private sector, reflecting the perceived benefits of collaboration, shared resources, and agglomeration economies.

Major demand centers or suppliers in a region can anchor regional clusters even without dedicated initiatives to foster collaboration. Demand centers will be particularly important in heavy industrial clusters, where colocation can provide opportunities for scale, sharing of risk and infrastructure as well as demand optimization.[217] In industries like wind turbine manufacturing, where transportation costs can be prohibitive, colocation of vertical supply chains is critical to industry success and a major supplier can therefore anchor an entire industry under the right conditions and with the right partners.

Not only can clusters help attract investment to a region, but they also offer economic and social benefits.[218] They create jobs in high-wage industries and boost demand in related goods and services

industries, offering a path out of unemployment for workers in hard-hit areas.[219] Their returns to scale and embedded collaboration networks also make offshoring less attractive to businesses located in industrial clusters, making job creation and investment more sustainable than in industries that are a capital flight risk. Clusters are most impactful when embedded in a vibrant network of diversified industries and therefore able to take advantage of complementary resources and networks.

Clusters also typically evolve around tradable goods whose export revenue can deliver higher value to local communities, injecting more spending into local businesses and creating higher tax revenue for public services. Finally, clusters have been shown to increase local innovative activity and the rate of startup formation and entrepreneurship, two critical factors in sustainable economic growth and development.[220]

Embedding Institutions of Community Empowerment into the Process

Regional development takes leadership. The institution providing that leadership will vary, as will the manner with which it is demonstrated. Historic cases of successful cluster-based development show that local leaders in trusted institutions play an integral role in bringing together the stakeholders that make up a development ecosystem and in coordinating robust action plans.

Furthermore, the market for clean energy industries is global, increasingly competitive, and subject to first-mover advantages and returns to scale that will leave slow movers behind. Seizing the opportunities of this growing market requires investing in the institutions that build local capacity. These institutions include EDOs, research universities, community colleges, startup incubators, business alliances, PPPs, and community nongovernmental organizations. Some of these institutions will be private, others public–private, and still others state or federal government initiatives, of which there are hundreds. These groups already have the networks, local knowledge, and social capital to attract investment and encourage regional growth. However, many lack knowledge of the clean energy transition and a deep understanding of how it can enhance their communities. The best of these organizations reflect the local qualities of their region, creating solutions tailored to the region's policy environment, industrial makeup, entrepreneurial culture, and barriers to investment.[221]

Seizing the opportunities of this growing market requires investing in the institutions that build local capacity.

Cleantech alliances and clean energy innovation cluster initiatives are examples of institutions that help harness specialized resources and can invest in future capacity. Nearly 20 of these institutions are operating around the country in a variety of clean energy industries, helping clusters grow and regions thrive. Empirical studies have also shown that such alliances and initiatives can have significant impacts on job creation, startup formation, and innovative activity. One study of cleantech alliances formed in the United States between 2008 and 2012 found that startups that were part of public–private alliances had as much as a 74% increase in patenting activity and a 155% increase in private financing deals.[222]

In clean energy, which has a disproportionate share of new and uncertain technologies, the country's innovation ecosystem of research universities, national laboratories, and energy innovation hubs plays a particularly important role in connecting stakeholders, transferring technology, and facilitating new investment.[223]

Regional investment strategies should embed these institutions and leaders in an accountable process that represents where people are from and their values. This process should include providing a just transition for communities whose economies rely on fossil fuel extraction and accounting for historical environmental injustices in regions where pollution, strip mining, deforestation, and other environmental impacts have disproportionately affected low- to moderate-income workers, people of color, and other underserved groups. A multistate approach would be broad enough to flexibly accommodate perspectives across different regions of the country while remaining targeted enough to address real-world investment barriers and facilitate tangible investments in local communities.

Community institutions and leaders can also help clean energy investments meet local needs. For instance, in Houston, a landfill that was closed in 1974 because of deadly levels of lead will soon become a 52 MW solar farm, the largest landfill solar installation and second largest brownfield solar installation in the nation.[224] This place-based revitalization project transformed a closed landfill site into a clean energy hub with a paired $750k investment in the EmPowering Solar Jobs program for STEM career opportunities for youth and adults in under-resourced neighborhoods.

An accountable process also means not leaving disaffected workers behind nor papering over the legacies of injustice that remain stark realities in every community. Clean energy investments can create quality growth, which brings long-term value to communities, increases the participation of local populations, and enables people to participate in the wealth creation that accompanies dynamic change. It will be critical that local stakeholders, who represent their communities, are not just included but also heard, valued, and respected.

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