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The Roosevelt Project

Phase 2: Case Studies Overview

November 2022

The Roosevelt Project

A New Deal for Employment, Energy and Environment

About the Roosevelt Project

The Roosevelt Project takes an interdisciplinary approach to the transitional challenges associated with progress toward a deeply decarbonized economy. The project aims to chart a path forward through the transition that minimizes worker and community dislocations and enables at-risk communities to sustain employment levels by taking advantage of the economic opportunities present for regional economic development. The first phase of the project involved an analytical assessment of cross-cutting topics related to the transition. The second phase of the project assesses the transition through the lens of four regional Case Studies, working with local partners on the ground in the Industrial Heartland, Southwest Pennsylvania, the Gulf Coast, and New Mexico. The project was initiated by former Secretary of Energy, Ernest J. Moniz, and engages a breadth of MIT and Harvard faculty and researchers across academic domains including Economics, Engineering, Sociology, Urban Studies and Planning, and Political Science.

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The Roosevelt Project would like to thank the Emerson Collective for sponsoring this report, and for their continued leadership on issues at the intersection of social justice and environmental stewardship.

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1. Introduction

The latest publication of the Intergovernmental Panel on Climate Change (IPCC) is unequivocal: climate change is widespread, rapid, and intensifying, and drastic action must be taken immediately to mitigate additional—and dangerous— atmospheric warming. Climate impacts are already affecting communities across the United States, from intense heat in the Pacific Northwest to historic flooding in the Midwest, and a growing majority of Americans today recognize the urgency to act on climate. Accordingly, shifts in public sentiment, the financial industry, and the corporate world are driving climate action across the economy. Managing one of the most complex industrial transitions in history is now a paramount issue. As the United States transitions and transforms its energy system, a multitude of industries, from electric power to transportation to manufacturing, will be directly affected, and a diverse array of communities will be forced to deal with the potentially uneven distribution of the costs and impacts.

The goal of the Roosevelt Project is to chart a course through the transition that protects those communities and people who may otherwise be adversely affected. The Roosevelt Project derives its name from three prominent figures in American history: Theodore Roosevelt, for his stewardship of the environment during his presidency, protecting over 230 million acres of public land; Franklin Roosevelt, for embodying a commitment to expanding the middle class in response to the Great Depression and developing America's infrastructure in the New Deal through a variety of programs, including the Tennessee Valley Authority, Works Progress Administration, and the Bonneville Power Administration, among others; and Eleanor Roosevelt, for her staunch support of social justice issues. This includes, among other activities, chairing the UN Commission on Human Rights and overseeing the development of the Universal Declaration of Human Rights. This project looks to combine the legacies of these three titans of American history to develop policy priorities and an action plan that will enable us to move beyond the false choice of economic growth or environmental security.

In our initial white papers, the Roosevelt Project demonstrated that through coordinated and comprehensive planning and policy across local, state, and federal governments, working alongside labor unions, businesses, community organizations, innovators, and the investment community, the United States can progress toward an equitable, sustainable, and prosperous future for all Americans.

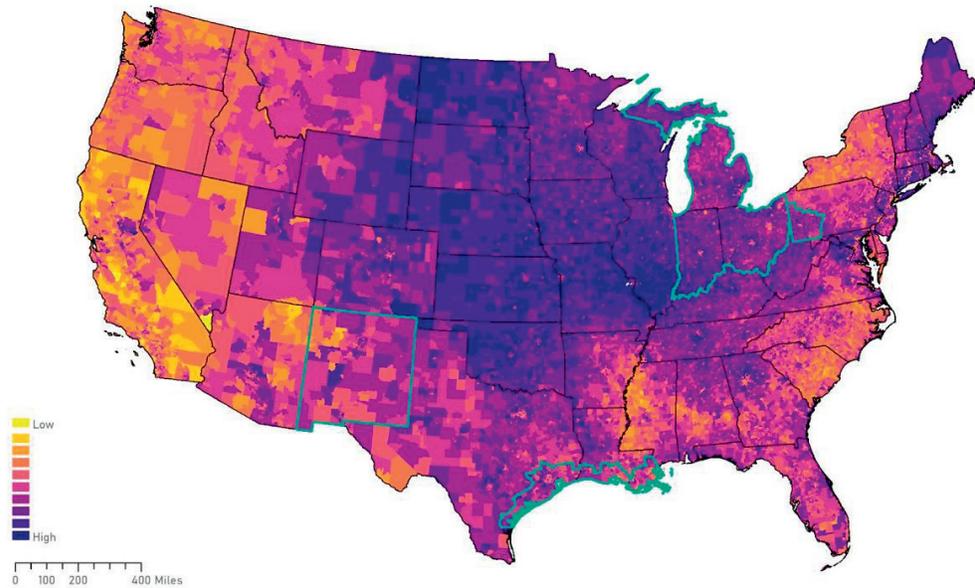
In particular, we highlighted the importance of a comprehensive, regional approach to transition planning, given the extraordinary variance in economic, social, and geographic conditions across the United States and its federalist political structure. In addition to structural realities, jurisdictions and communities also vary in their ability to adapt to industrial transition—our research highlights factors such as local social fabric, the availability of human capital, and business and policy environments as key enablers of successful transition.

Phase 2, a series of regional case studies, builds on this work through comprehensive analyses of the energy transition in four regions of the United States. These case studies were chosen to capture variance across the spatial unit of analysis (county, state, region); techno-economic, resource and political drivers of the transition; local social, economic, and demographic realities; and, importantly, opportunities for deep collaborations with local partners. This variance is captured in Figure 1 below and motivates the cases explored here:

Figure 1: Roosevelt Project case study regions.



Figure 2: Total household carbon footprints for continental United States.



Source: Green and Knittel, 2020.

Southwestern Pennsylvania faces ongoing dislocation from the decline of coal, as well as disruption from the potential decline of natural gas. The region will also face a moderate risk of heat stress and high risk of extreme rainfall in the years to come, driven by climate change. Across Appalachia, coal production has declined by over 45 percent since 2005, driven by a lack of economic competitiveness and emissions regulation, and is expected to drop further in the coming years. The region has lost over 33,500 coal jobs since 2011, representing 82 percent of total

U.S. coal job losses. The bulk of those losses are concentrated in just 16 Appalachian counties. Pennsylvania as a whole is home to 9 percent of the nation's coal jobs today. The economic impacts of the ongoing decline of coal in Southwestern Pennsylvania have been buffered in part by a boom in natural gas. Pennsylvania has gone from having negligible gas production, as recently as 2008, to producing 19 percent of the nation's natural gas today. This boom shows little sign of slowing: Greene County experienced a 33 percent year-over-year growth in natural gas production in 2019. Without intervention, Southwestern Pennsylvania faces continued, accelerating job losses due to the decline of coal and the impending decline and uncertain role of natural gas in the future.

The **Industrial Heartland** case study encompasses the states of Michigan, Ohio, and Indiana and focuses specifically on the Midwestern motor vehicles manufacturing sector. Manufacturing generally is the largest employment sector in all three states, with motor vehicles contributing over 350,000 jobs. Communities in Ohio and Indiana are highly susceptible to future climate damages, particularly with respect to high heat, extreme rainfall, and water stress. Michigan's environmental future is relatively less fraught, but the state could eventually shoulder the burdens of its southern neighbors as they face increasing climate damages. The region's economic future is integrally tied to its motor vehicles manufacturing industry—any future planning should confront rapid changes in that sector accompanied by the electrification of transportation. All three states are densely populated, stand to retire substantial fossil infrastructure, and must consider a transition away from traditional energy sources across all sectors (electricity, transportation, and buildings).

The **Gulf Coast** case study includes counties surrounding the Texas and Louisiana border, a region that contributes substantially to American oil and gas production and its related petrochemical and chemicals industries. Texas alone is home to 37 percent of total U.S. crude oil production and 24 percent of total U.S. natural gas production, in addition to the most installed wind energy. This region will experience adverse effects due to climate change and economic headwinds if decarbonization plans are not designed with resilience in mind. In certain areas, climate change will pose significant water stress that will affect agriculture, impact oil and gas operations, and threaten public health. Rising global temperatures will also increase coastal storms and sea level rise risk for much of the region. Among the four cases, the Gulf faces the most serious threats from simultaneous climate impacts and economic dislocation.

The **New Mexico** case study focuses on the fossil fuel industry and economic and social welfare challenges that frontline and underrepresented communities face in a state that is heavily dependent on oil and gas revenues. New Mexico is a minority-majority state: 48.5 percent of the state population identifies as Hispanic or Latino and 8.6 percent as Native American. The state has roughly 21 percent of its population living below the poverty line, 5.8 percentage points higher than the national average and unevenly distributed across regions. In the coming years, New Mexico will primarily experience drought and water stress that could have far-reaching consequences, from agriculture to mining to electric power. The state is also home to leading national energy research institutions that could further develop technologies that will aid in the future decarbonization efforts, and it has recently adopted a new set of future-oriented climate and social goals that may be in tension with its legacy fossil fuel industry. New Mexico also has considerable solar generation resources but faces transmission isolation from major population centers.

A key challenge in efforts to manage an industrial transition, perhaps even more acute in the context of the energy transition, is the need to define the goals of the transition upfront. What does success look like? In the energy transition, the moral imperative of protecting the environment and its value for future generations meets an economic imperative to provide the dignity of good-paying jobs to a broad swath of the citizenry, all of which intersects with a cross-cutting ethical imperative to fix longstanding issues of equity and inclusion in our economy writ large, which are certainly salient in the energy industry. Moreover, all of these issues occur across decadal timescales replete with embedded uncertainties—perhaps the only certainty is the fact that if the transition is managed poorly, improvements in economic realities today will likely erode physical and/or capital resources in 2050, while simultaneously, investments in future well-being will come at the economic expense of people and communities in the present.

In fact, many stakeholders engaged by the Roosevelt Project noted this challenge and cautioned that the perceptions of a failed transition have become a mobilizing force behind efforts to slow the transition itself. This finding underscores the basic premise of the Roosevelt Project—that only through adequate planning and management of the transition can we create the political space where progress toward mitigating climate change will move forward as urgently and effectively as is possible. Building on that premise, the core contributions of this work are a set of policy recommendations for local, state, and federal governments and key regional activities that can take place in parallel to ensure successful transitions.

The four Roosevelt case studies also validated that the current coalitions of people and organizations attempting to manage energy and economic decisions have often either undermined or explicitly excluded communities of color and frontline groups. Across the four case studies, environmental justice issues manifest in a variety of ways, from the Industrial Heartland, where Black communities in Flint that have played pivotal roles in automobile manufacturing for decades are now at risk of losing jobs as the transportation system electrifies; to New Mexico, where Indigenous peoples remain systematically excluded from the state's oil and gas industry; to the Gulf, where petrochemical plants and corresponding environmental hazards are concentrated in communities of color. This work contributes to the emerging literature and social movements centered on environmental justice, with specific foci on measures that community leaders can implement to ensure that historically underrepresented voices are heard and that their opinions carry weight in local decision-making processes.

The report continues as follows. Chapter 2 provides baseline macroeconomic projections in the case study regions and the United States as a whole, as decarbonization occurs from 2020 to 2050, based on a combined power sector and regional economic modeling exercise. Chapter 3 provides executive summaries of the four case studies, highlighting the key themes and analytical findings from each region. Chapter 4 provides an overarching and multidimensional framework for thinking about the energy transition in these regions, along with a summary of findings and recommendations, and explores key environmental justice themes in the case study areas.

2. Modeling the Economic Impacts of Deep Decarbonization (2020–2050)

This chapter provides high-level findings from a modeling exercise that evaluates the economic impact of deep decarbonization for the United States as a whole and for the four Roosevelt case study regions by 2050.¹ There is a growing literature studying the economic effects of national decarbonization in the United States. The Roosevelt Project does not seek to replicate the results of other studies but rather to provide new analysis that shifts the focus of that research from broad national assessments of decarbonization itself toward an understanding of the ability of major policy to mitigate negative impacts at a regional level. Nevertheless, the Roosevelt Project modeling makes fundamental assumptions on reasonable technology pathways that require significant government and private sector involvement, from research and development to appropriate regulatory frameworks and partnership models (a topic discussed further in the “Designing Industrial Policy for the Energy Transition” section in Chapter 4). Since much of the extant literature on the energy transition assesses technological and energy policy pathways for decarbonization, we have chosen primarily to examine how specific distributive tax, trade, workforce retraining, and other social policies can ameliorate the negative regional impacts of those decarbonization pathways.

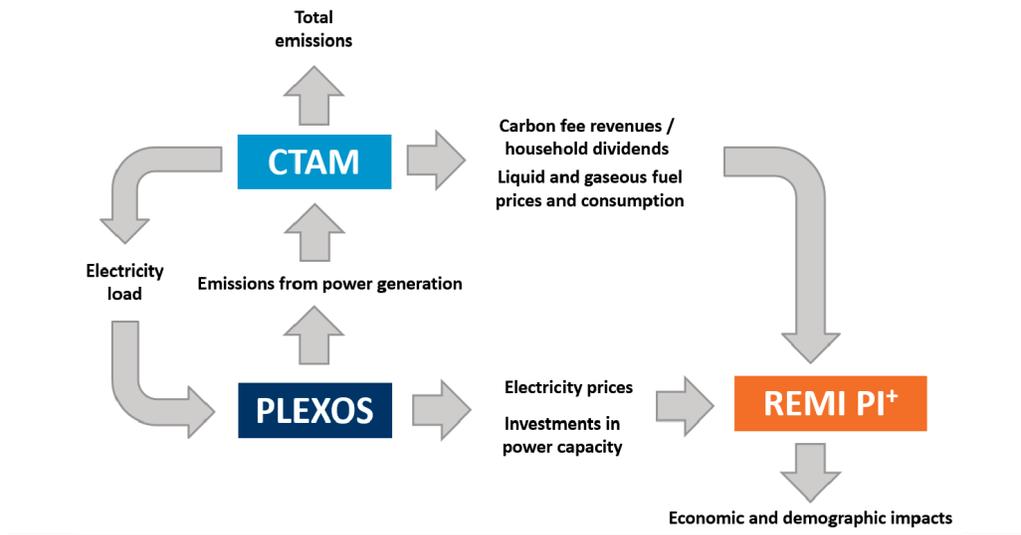
To that end, the Roosevelt Project conducted an economic impact study to assess three possible energy and economic futures for the U.S. economy and the project’s four case regions. That effort and the high-level results are included below, as is a detailed modeling methodology appendix.

Methodology

The analysis utilizes three complementary models to represent the U.S. economy, its embedded energy systems, and resulting emissions: (1) PLEXOS, (2) CTAM, and (3) REMI. PLEXOS is an industry-standard electricity systems model, which is used to forecast generation and capacity changes in the electricity sector. PLEXOS computes both the cost of meeting day-to-day needs on the electricity grid and the cost of retiring legacy power units and building replacement generators. CTAM generates emissions by region and for the United States as a whole and calculates revenues generated by a carbon tax. Finally, REMI is a dynamic, multiregional, computable general equilibrium (CGE) model of the U.S. economy. REMI aggregates a comprehensive set of economic and demographic data and produces macroeconomic forecasts, including job creation, gross domestic product, real personal income, and industry-by-industry production.

The three models operate iteratively to ensure internal consistency. Figure 3 illustrates an example set of the data flowing between the three models for a carbon fee. Of course, the full analysis required many more linkages to model more nuanced scenarios. Detailed modeling methodology can be found in the attached appendix.

Figure 3: Integration and example dataflows between PLEXOS, CTAM, and REMI.



Scenarios

This analysis considers three different scenarios. The first scenario (Base Case) uses Annual Energy Outlook 2020 assumptions. It models the economic outcomes that would arise from a transition scenario where emissions continue declining in the United States at their current, relatively slow pace (i.e., less than one percent decline per year through 2050). This baseline scenario would not achieve Paris Climate Agreement goals of 80 percent emissions reductions until 2098.

The second scenario (Decarbonized) includes a set of updated technology assumptions—for example, renewable capital cost reductions—and new energy policy programs, including a nationwide renewable portfolio standard and escalating carbon price that together achieve a net zero economy by 2050. Notable changes from the baseline scenario to the net zero scenario include: carbon pricing starting at \$40/ton in 2025 and escalating 8 percent per year, revenue recycling through per-capita dividends, accelerated deployment of energy efficiency, and electrification of end uses, including transportation, industrial processes, and heating. The Decarbonized scenario also requires substantial use of offsets for hard-to-decarbonize sectors.

The final scenario (Roosevelt) maintains all of the net zero assumptions under the Decarbonized scenario but layers on a set of federal policies that we have identified as critical to enabling effective transitions in the regions under consideration. Those recommendations, noted here through the lens of modeled assumptions, include:

- Recycling carbon price revenues according to regional carbon intensity rather than on a per-capita basis;
- Implementation of a border adjustment for energy-intensive, trade-exposed industries;
- \$1.5 trillion in infrastructure investments over a 10-year period beginning in 2025, distributed based on regional emissions and projected population growth;

- 1 percent of annual carbon tax revenues set aside for regionally targeted impacted worker retraining;
- Exogenous bump in domestic battery production from, for example, Buy America or increased incentives for domestic manufacturing of a strategic industry;
- 50 percent decrease in the cost of direct air capture, resulting from substantial federal and private R&D support; and
- 25 percent reduced carbon intensity of liquid fuels by 2050, to simulate the potential emergence of a hydrogen economy.

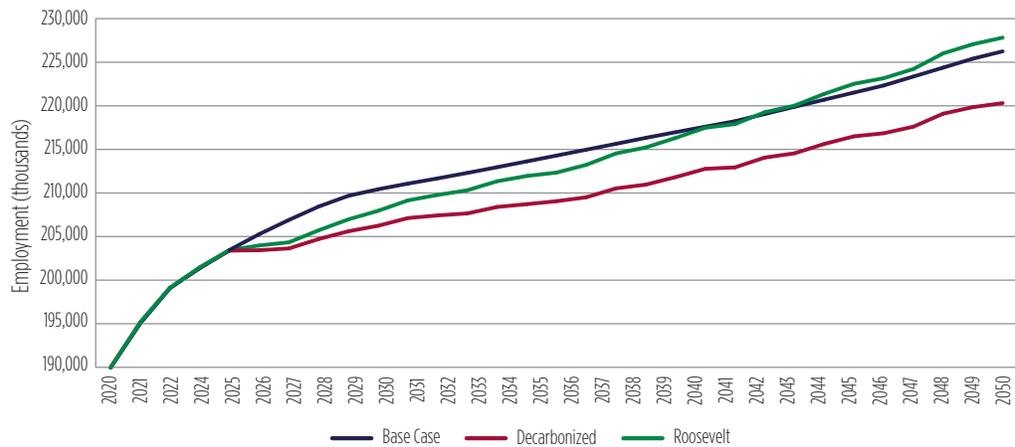
It is worth noting that the technology pathways in both the Decarbonized and Roosevelt scenarios underscore the importance of expanded public R&D, strategic investments and incentives to build domestic capabilities in key sectors, and a suite of policy interventions that target the broader energy innovation ecosystem. The Roosevelt Project does not adhere to a specific technology pathway for U.S. decarbonization but recognizes that an appropriate policy portfolio is crucial for the cost reductions, cross-sector efficiency targets, and technology adoptions and solutions that are required for achieving 2050 objectives. The literature provides ample evidence that government involvement is necessary to accelerate the deployment of renewable and low-carbon technologies, from electric vehicles to offshore wind, and can be channeled through various instruments, such as funding for demonstration projects, tax credits and grants for commercialization, and technical standard setting. The regional basis of the modeling is also useful in evaluating the innovative potential in transition areas, where these policy interventions may help address critical gaps in regional entrepreneurial capacity and generate buy-in from key stakeholders (Karplus, Kearney, and Pawar 2020).

For a more detailed description of the modeling effort, see Appendix A, “Modeling Memorandum.”

Results

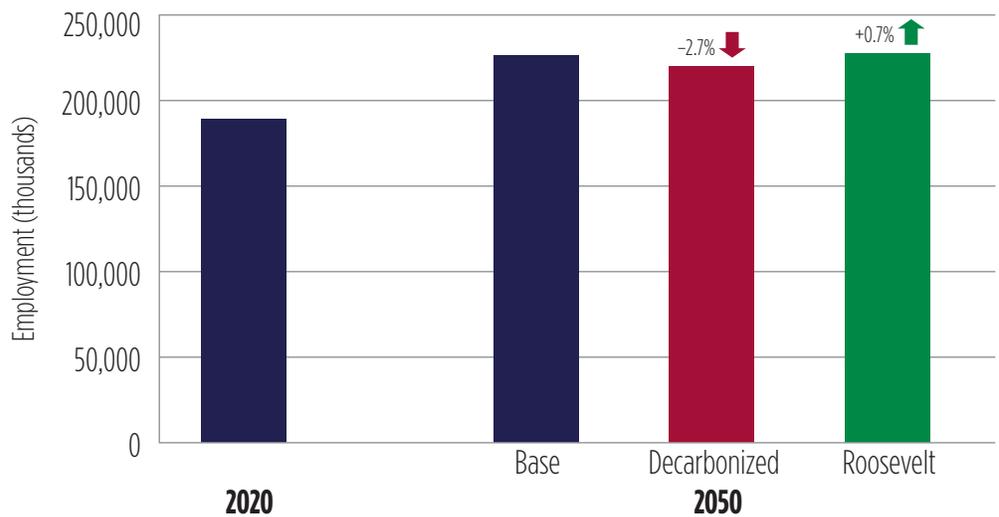
Ultimately, the analysis finds that the Roosevelt scenario, which incorporates a comprehensive set of federal policies, reverses a slower growth rate associated with the Decarbonized pathway and overtakes the Base Case in 2040, adding an additional 1,604,000 jobs (Figure 4) by 2050. As noted in the Roosevelt Project’s *Energy Workforce in the 21st Century*, most climate policy economic models show employment loss and/or slower growth following implementation of a carbon tax, absent ameliorating policies (Foster, Nabahe, and Ng 2020). This is the case both nationally and in the four regional case studies, starting in 2025 with the \$40-per-ton escalating carbon tax.

Figure 4: U.S. employment case study scenarios, 2020–2050.



Nationally, the Decarbonized scenario results in 2.7 percent less employment in 2050 than the Base Case, while the Roosevelt scenario results in a 0.7 percent increase in employment (Figure 5).

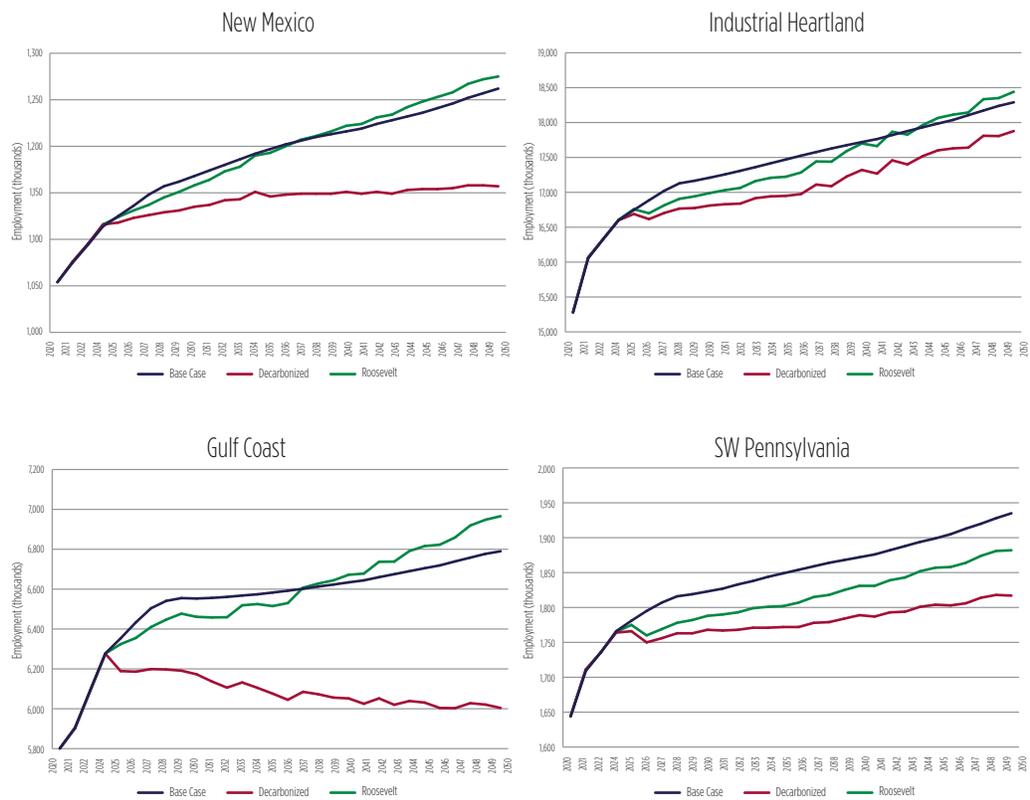
Figure 5: U.S. employment in the Base Case, Decarbonized, and Roosevelt scenarios, 2020 and 2050.



In addition, in the Decarbonized scenario without policy supports, employment losses are particularly stark in three of the Roosevelt Project case study areas: the Gulf Coast, Southwest Pennsylvania, and New Mexico (11.6 percent, 6.1 percent, and 8.3 percent declines in regional employment growth, respectively, from the Base Case), demonstrating the importance of fossil fuel-related industries in these regions and the challenge that poses to an equitable energy transition. The Gulf Coast faces a particularly challenging future under this scenario, experiencing an actual decline in employment for three decades.

However, by 2050 under the Roosevelt scenario, employment growth in the Gulf Coast, New Mexico, and Industrial Heartland regions ultimately outpaces the national average. Although 2050 employment growth in Southwest Pennsylvania is positive, it still lags behind the Base Case in the Roosevelt scenario (see Figures 6-9). This suggests additional policy support and intervention will be necessary to protect Appalachian counties from the economic restructuring of deep decarbonization. For example, the case study work specifically points to the development of a local hydrogen hub or carbon capture industry.

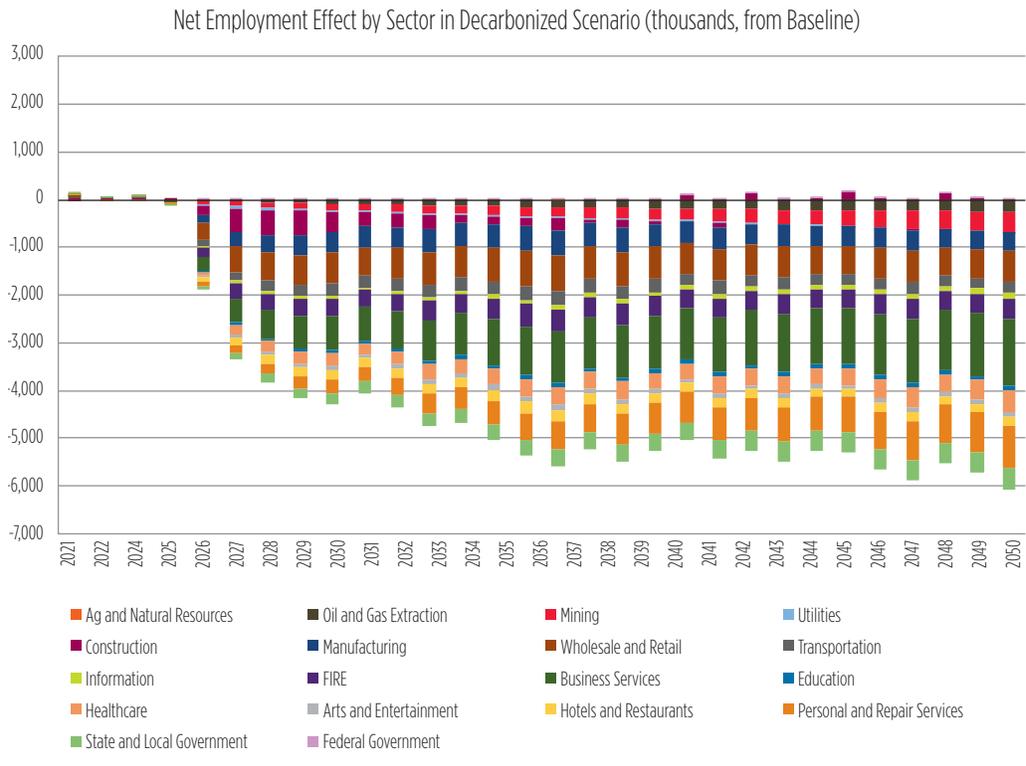
Figures 6-9: Employment in the Base Case, Decarbonized and Roosevelt scenarios by Roosevelt Project case study region, 2020-2050.



In the first decade of analysis, all regions see an initial decline in employment, coincident with the introduction of the carbon tax. That decline results in slower growth rates in all Decarbonized case study scenarios, with a long-term decline in employment in the Gulf Coast. By contrast, the Roosevelt policy interventions result in accelerated job growth rates that lead to greater job growth than the Base Case in all case studies except for Southwestern Pennsylvania.

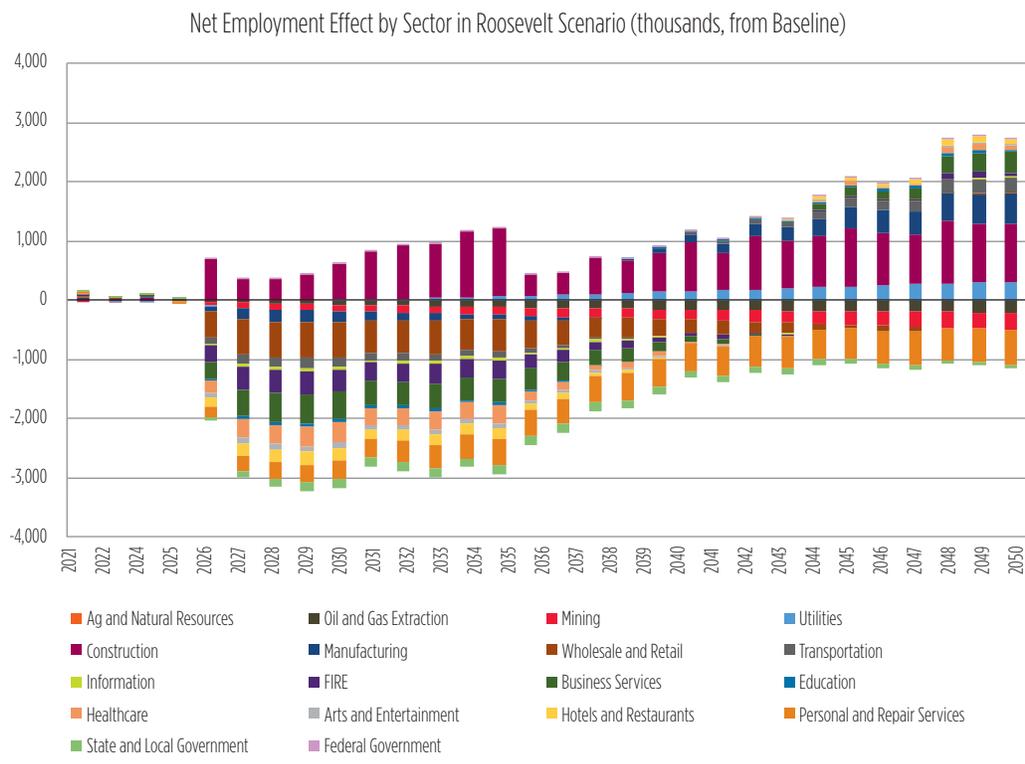
In the Decarbonized scenario, initial job losses, followed by slower growth rates, occur nationally in virtually all sectors, including construction, manufacturing, wholesale and retail, finance and insurance, and business services (Figure 10).

Figure 10: Net Employment Effect by Sector in Decarbonized Scenario, 2020–2050.



The Roosevelt scenario also sees early losses in many of the same sectors, but these are partially offset by immediate growth in the construction sector as a result of the \$1.5 trillion, 10-year infrastructure investment. By 2050, the only sectors in the Roosevelt scenario that see major declines are personal and repair services, oil and gas extraction, and mining (Figure 11). By contrast, manufacturing, utilities, transportation, and business services register notable job gains by 2050 under the Roosevelt scenario, far exceeding the declines in the other sectors.

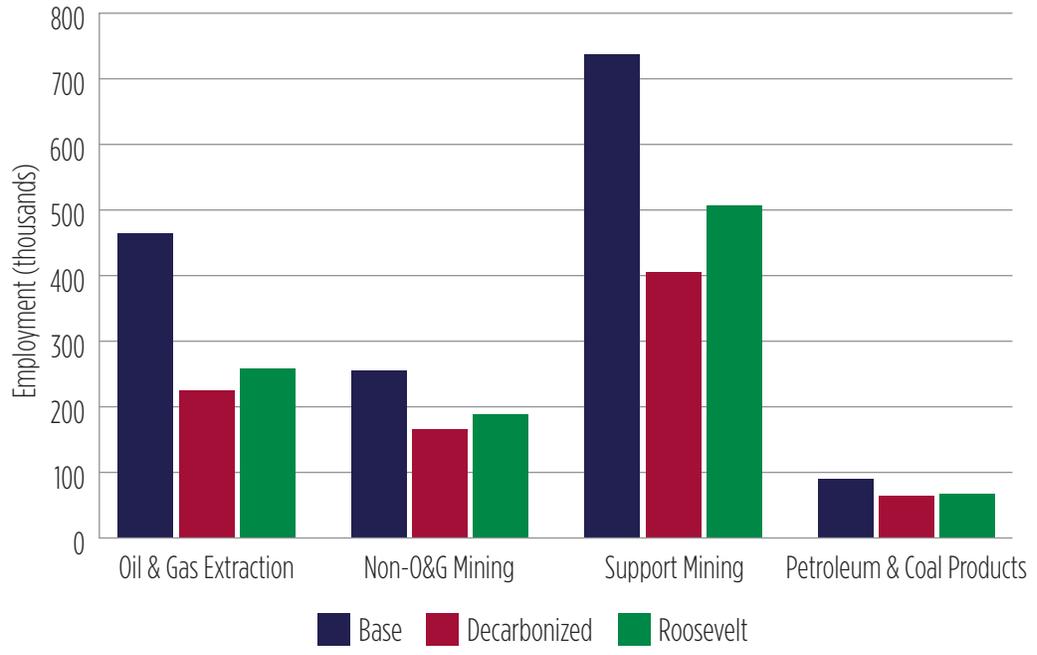
Figure 11: Net Employment Effect by Sector in Roosevelt Scenario, 2020–2050.



The Roosevelt scenario policy interventions had specific benefits to employment in the utility, construction, and manufacturing sectors. Collectively, these three sectors account for 70 percent of the increased employment over the Base Case. Utility employment is projected to increase by 320,000 as a result of the investments expanding carbon capture, hydrogen fuels, and workforce retraining. Manufacturing is expected to expand from border adjustments for energy-intensive, trade-exposed industries, the domestic procurement requirements for battery manufacture supporting vehicle electrification, worker retraining, and infrastructure investments. Construction is projected to grow primarily from infrastructure investments and the expansion of carbon capture and hydrogen fuels.

Similarly, these same policy interventions drove the resulting employment growth in specific geographic regions, most notably in the Gulf Coast. It is also noteworthy that while employment in oil and gas extraction, mining, mining services, and repair and maintenance all declined in both net zero scenarios, the dislocation was significantly less in the Roosevelt scenario as a result of the redistribution of infrastructure investments and carbon tax dividends to carbon-intensive counties, along with the growth of the direct air capture and hydrogen sectors (Figure 12). Further, additional employment opportunities can be created through more focused local efforts to develop a hydrogen economy or broaden deployment of carbon removal. Such efforts are described in the case studies but reside outside of the modeling purview covered here.

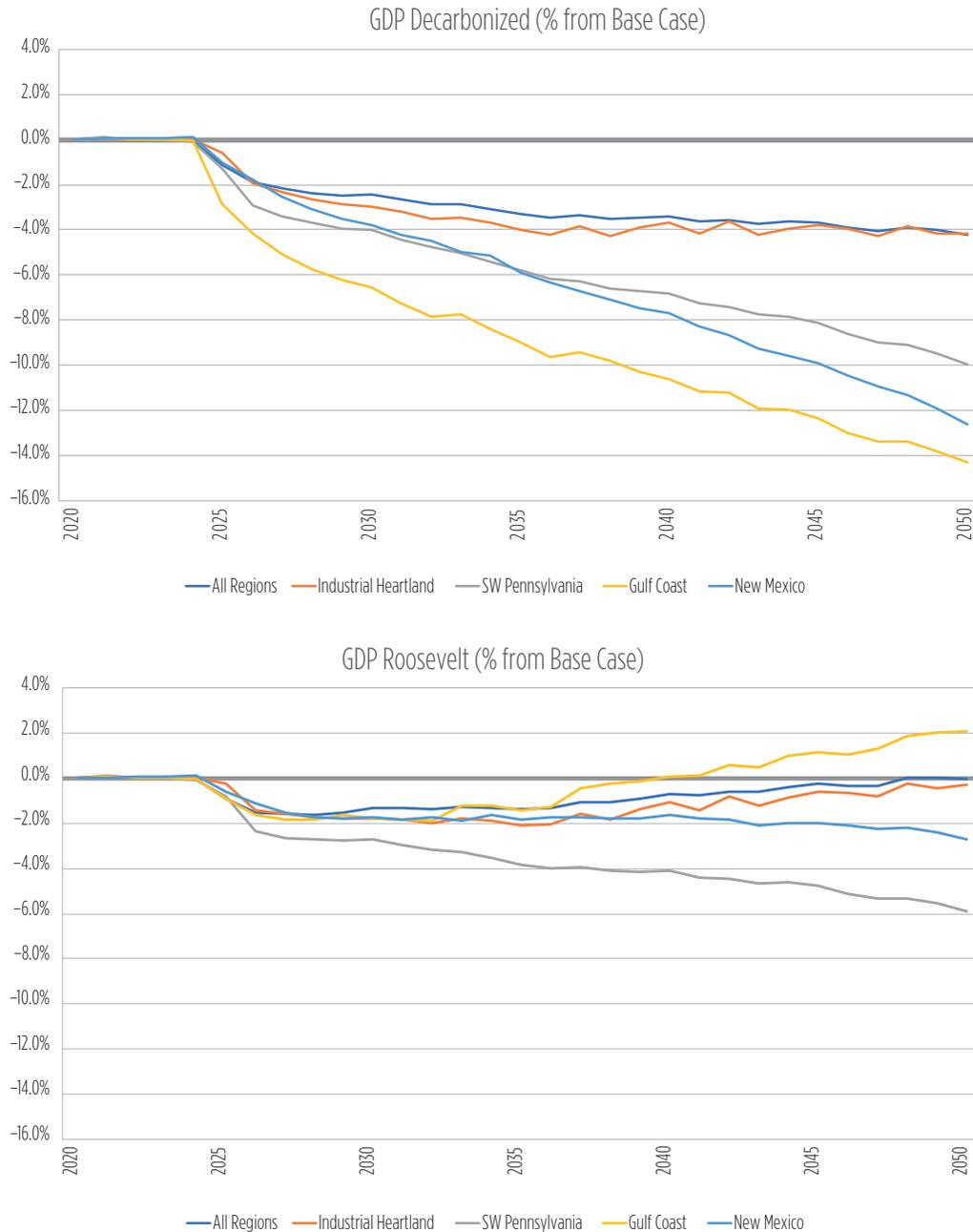
Figure 12: Fossil industry employment declines by scenario in 2050.



Of course, this employment analysis covers broad trends across the United States and embeds many complex assumptions. As such, we can use these findings as federal policy guideposts for the process of creating an integrated energy transition and economic development strategy while addressing specific regional variances.

Interestingly, our analysis showed different results in GDP impacts, which did not uniformly correspond with employment growth outcomes. GDP growth slowed in both the Decarbonized and Roosevelt scenarios, following the introduction of the carbon tax in 2025. By 2050, GDP was 4.2 percent less in the Decarbonized scenario than in the Base Case. Roosevelt did recover significantly but was still 0.1 percent less than the Base Case in 2050. However, the regional variation was more extreme, as shown in Figure 13.

Figure 13: Percent difference in U.S. gross domestic product in the Base Case vs. the Decarbonized and Roosevelt scenarios in the Roosevelt Project case study regions, 2020–2050.



The Roosevelt Project is foundationally interested in how to design and implement policies that encourage thriving communities. We are also focused on how to preserve and create quality jobs in the specific regions that are being impacted by electrification and decarbonization transformations, regardless of the relative proportion of resource types present on the grid. The Roosevelt case study scenarios, modeled in REMI, demonstrate that, under one specific decarbonization set of technology assumptions, targeted social policies can have a consequential impact on economic outcomes for regions most at risk. As we go forward in the energy transition, this focus on social policy designed for regional outcomes will determine the success of the transition to come.

3. The Roosevelt Project Case Studies

Across the United States, the energy transition will manifest differently, as a function of social, demographic, environmental, political, and economic realities on the ground. A comprehensive assessment of the U.S. energy transition requires considering these key sources of variance and taking regional approaches to the transition itself. Accordingly, the Roosevelt Project's four cases were selected to capture this variability. The cases include the Industrial Heartland, Southwestern Pennsylvania, the Gulf Coast, and New Mexico.

In these four regions, the Roosevelt Project assembled case study teams that included MIT and Harvard researchers working hand in hand with local research partners on the ground. Each case required regional collaborators and advisors drawn from state and local government, NGOs, educational and research institutions, the business community, and others, as appropriate. Interestingly, travel limitations imposed because of the COVID-19 pandemic served to increase the depth of these partnerships, ensuring that communities in the four case study regions play an elemental role in the findings presented in this report.

The case study outcomes are therefore a reflection of the combined efforts of researchers across a variety of backgrounds and disciplines, with the sole focus being consideration of the transition from the perspective of a given case region. Given the scope of analysis, however, and the reality that what might work in one setting may not in another, the findings and recommendations are consensus driven within specific cases and among individual case study authors and not endorsed by the broader Roosevelt Project team or External Advisory Board members.

3.1 Industrial Heartland Case Study

David Foster, Nina Peluso, Christopher Knittel, Darryle Ulama, Kristin Dziczek, Bernard Swiecki, Brett Smith, Edgar Faler, Michael Schultz, Yen Chen, Terni Fiorelli, Christina Hajj, Grace Lutfy, Jalonne White-Newsome, Keith Cooley, Colleen Lin, Kira Rib, Sanya Carley, David Konisky, Jennifer Silva, Shaun Khurana, Naomi Freel, Amanda Woodrum



Introduction

The Industrial Heartland case study evaluates barriers to the electrification of the motor vehicle manufacturing sector in the tristate region of Michigan, Indiana, and Ohio. Our goal is to recommend best practices and public policies that promote equitable solutions to the anticipated disruptions caused by vehicle electrification and other related clean energy transitions in the region.

We undertook this project with a community-first frame, understanding that while economic and industry trends ultimately drive many of those disruptions, solutions arise from the perceptions at the community level. We center principles of equity and justice and strive to provide policy recommendations that are feasible and adaptable.

Listening to Communities and Workers First

Our investigation started in six heartland communities—Detroit and Flint, Michigan; Kokomo, Indiana; and Lima, Lordstown, and Toledo, Ohio. There, our Indiana University researchers recruited current and former autoworkers, managers, and community leaders to share their concerns and aspirations about electrification. The 150 participants in those 67 focus groups understood the momentousness of decarbonization, with some characterizing the impending transition to electric vehicles as the next industrial revolution. At the same time, participants expressed a fear of the unknown, raising questions about whether there will be a market for electric cars, about whether car companies and the government will overpromise and under-deliver, and about equity and access, whether in terms of public infrastructure, workforce development, or affordability.

We also heard stark differences in responses based on the type of participants. For community members, leaders, and managers, a sense of tentative hope emerged about the possibility of agile development, new technological innovations, and community revival. For autoworkers, however, the transition felt much more precarious. While workers believed that the car companies “owe” them a job in return for their years of hard work, they nonetheless seemed resigned to the notion that their loyalty would go unrecognized. They grudgingly accepted that electric vehicle production would be better than nothing at all, yet also feared they would be easily replaced and ultimately left behind.

Dr. Jalonne White-Newsome also interviewed over 30 public health and environmental justice experts in our six targeted communities to inform how the transition to electric vehicles (EVs) will affect the health of the natural environment, the community, and our local economies. While the primary focus of an industrial transition is typically on jobs and workforce, we found that without a conscious effort to identify and accelerate the public health benefits and address racial and environmental justice issues in the impacted community, an important opportunity will be lost.

State of the Automotive Industry

Driven by a fundamental change in vehicle propulsion technology, the U.S. automotive industry is on the verge of a structural transformation. In 2019, the tristate region built 40.9 percent of U.S.-produced vehicles (Wards Intelligence 2021). Only 7.3 percent of those were battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) (LMC Automotive 2021). By 2028, the region is forecast to produce 42 percent of U.S.-built BEVs and 30.9 percent of U.S.-built PHEVs (LMC Automotive 2021).

The shift to BEVs also has critical implications for the region's labor force. The region is home to 34 percent of North American engine manufacturing output, 62 percent of North American transmission production (LMC Automotive 2021), and the country's largest automotive engineering and product development employment cluster (U.S. Department of Labor, Bureau of Labor Statistics 2019). As propulsion technologies shift, both production and engineering jobs are at risk.

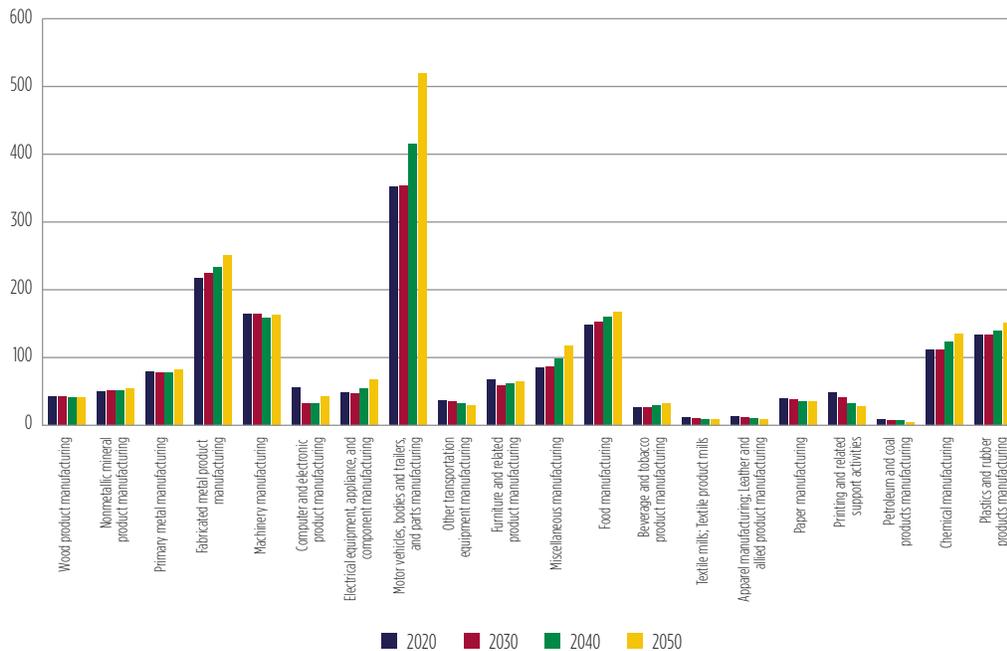
The electrification trend also has potentially significant consequences for suppliers. Smaller suppliers may not have sufficient scale, and in some cases the requisite access to capital, to support newly designed, dedicated EV architectures, otherwise known as vehicle "platforms," designed by automakers to achieve targeted cost reductions via new economies of scale.

Globally, regulatory mandates are the primary driving force behind vehicle electrification, and, as a result, the United States is a laggard compared to international competitors. Typically, development of new technologies occurs in the national markets expected to provide the most significant sales opportunities for those technologies, which, in this case, means China and Europe. Thus, initiating R&D incentives for U.S. auto companies while providing domestic manufacture preferences will be vital to developing the competitive position of U.S. assembly, battery, and drivetrain production.

Modeling Results

Our economic modeling in the Roosevelt case verified that, with the ameliorating federal policies advocated in our work, over 560,000 more jobs would be created in the tristate area, while reaching net zero emissions by 2050 (Roosevelt vs. Decarbonized scenario). 50,000 of those jobs would be in motor vehicle manufacturing. With the Roosevelt policies, job growth would also exceed the Base Case scenario by 150,000. Overall, in the Roosevelt case, 3,150,000 new jobs would be created in Michigan, Indiana, and Ohio, including 265,000 new manufacturing jobs.

Table 1: Manufacturing job growth in tristate region (Roosevelt scenario), thousands of jobs.



Key Findings

The Industrial Heartland case study finds the transition to motor vehicle electrification in Michigan, Indiana, and Ohio could result in significant job loss without the right supportive policies. Between 75,000 and 100,000 jobs and over 1,000 businesses are linked to the production of internal combustion engine (ICE) components and powertrains in the tristate region. Further, our community research surfaced the deep skepticism among current autoworkers as well as low-income and fence line communities that this transition will benefit them. The legacy pollution in the tristate region from over 180 motor vehicle plant closures since 1980 continues to underscore the challenge. To deal with that skepticism, the federal government must urgently mobilize and coordinate the delivery of its resources with transparency, community input, and accountability. With these stakes in mind, we make the following policy recommendations.

Key Recommendation

We recommend the immediate formation of a national Transportation Electrification Commission (TEC), cochaired by the Council of Economic Advisors and an industry representative to oversee federal resource deployment. This commission should include the secretaries of energy, commerce, transportation, and labor, with deep participation by the motor vehicle industry and its supply chain, labor unions, and impacted communities.

The Transportation Electrification Commission’s mandate should be to:

1. Promote strategies and collaborations at the state level for domestic manufacturing development that prioritize current and former motor vehicle communities,
2. Decarbonize manufacturing through innovation, research, and development while ensuring economic competitiveness,

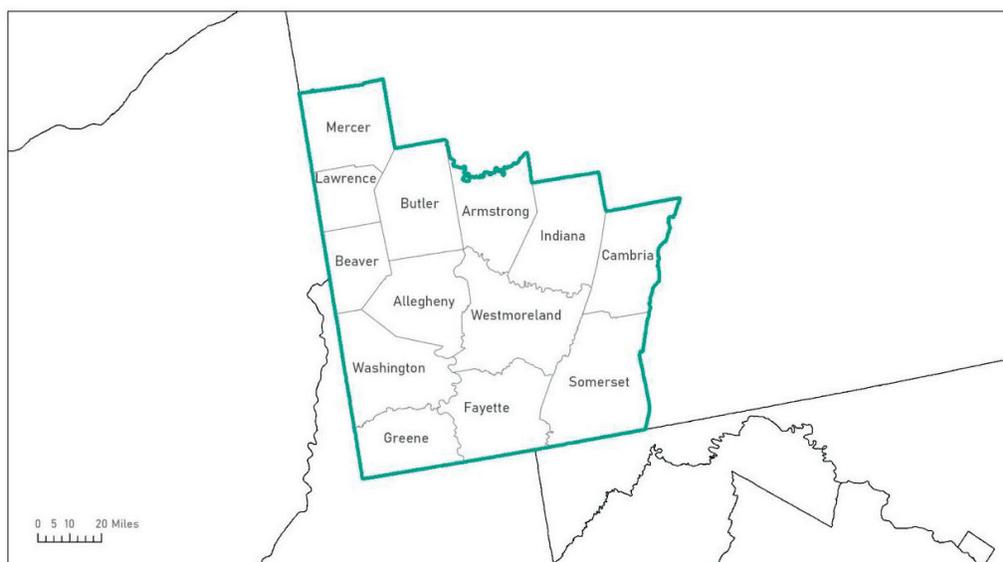
3. Create quality American jobs, accessible to all Americans, while promoting labor/management cooperation,
4. Review the wage, benefit, and other working condition disparities within the motor vehicle industry and make recommendations on how to reduce them, including consideration of labor law reform, sectoral bargaining, and stakeholder representation on corporate boards,
5. Monitor and remediate environmental impacts while accelerating the public health benefits of electrification,
6. Mandate Community Benefit Agreements (CBAs) wherever federal funds are expended for electrification and establish a standard CBA process to provide adequate resources, transparency, accountability, and technical assistance to communities impacted by the transition, and
7. Deploy accessible, low carbon, mass transportation alternatives.

Additional Policy Recommendations

1. **Repurpose manufacturing programs.** Repurpose the current Advanced Technologies Vehicle Manufacturing (ATVM) loan program, Manufacturing Extension Partnerships, Industrial Assessment Centers, a new 48C Advanced Energy Manufacturing tax credit, an industry R&D tax credit, and consumer rebates and tax credits to ensure the transition of current and former motor vehicle communities.
2. **Tighten EV trade policy and domestic content rules.** Strengthen existing trade agreements, such as the USMCA, and procurement policies to guarantee greater U.S. domestic content in EVs, battery assembly, and supply chains. Institute border adjustments for energy-intensive industries, such as steel, in the supply chain.
3. **Strengthen EV purchaser tax credits.** Ensure that EV tax credits provide added incentives for domestic content, quality jobs, and access to used vehicles in low-income communities.
4. **Advance equity access and opportunity issues.** Enable inclusive planning processes for new plants, expansions, and closures; access to EV infrastructure in all communities; availability of electrified public transportation; and equity reporting and standards across all impact areas.
5. **Job quality assurance and access.** Utilize project labor and community benefits agreements wherever federal investments are provided for electrification.
6. **Job training.** Enact a comprehensive energy transition adjustment assistance program, designed at the community level, covering all motor vehicle employees, employers, and related energy employment. Provide incumbent employer tax credits for retraining and retaining existing employees. Prioritize displaced auto and energy sector workers along with low-income communities for new opportunities created by federal investments.

3.2 Southwest Pennsylvania Case Study

Steve Ansolabehere, Kathleen Araújo, Yiran He, Alison Hu, Valerie Karplus, Heidi Li, Elizabeth Thom, Dustin Tingley



Southwest Pennsylvania has long fueled the U.S. energy and manufacturing industries. For over a century it has powered the nation with coal and steel, and today it is one of the nation's top natural gas producers, thanks to the development of the Marcellus and Utica shales. Yet, as the nation and the world seek new, more efficient ways to use energy without emitting carbon dioxide (CO₂) and other greenhouse gases (GHGs), Southwest Pennsylvania faces an important transition. How can the region continue its economic development without leaving workers and communities behind?

This case study shows the importance of taking an “all of the above” approach. The Commonwealth of Pennsylvania has enormous fossil fuel resources and related manufacturing and industrial sectors that are expected to grow under business-as-usual policies. Fossil fuel extraction, power generation, and manufacturing provide considerable income and relatively well-paying employment throughout the region, especially in rural areas. It is possible to lower carbon emissions in these industries while meeting growing global demand for energy and manufacturing. The commonwealth also has considerable capacity to contribute to other energy sectors, including wind, solar, and nuclear power, and to capitalize on emerging manufacturing opportunities, such as additive manufacturing and clean steel.

Many of these opportunities will take time to cultivate, as they require substantial investment and infrastructure development. Meanwhile, the region's energy and manufacturing sectors are already under pressure, and some changes in the energy sector will be felt by workers and communities in the near term. For example, several coal mines and steel mills have been idled in recent years. A smooth transition of the energy and manufacturing sectors in this region will require investments and policies that address the needs of communities and workers. Making such investments and crafting such policies now will set the region on a course for future economic development.

1. In the near term, the Commonwealth of Pennsylvania should undertake a large-scale effort at remediation of methane leakage from wells and pipelines, of water contamination, and of brownfield sites. Plugging and capping the over 400,000 legacy wells in the area will provide immediate employment for workers, reduce greenhouse gas emissions, and improve public health.
2. In the medium and long term, development of carbon capture, utilization, and storage (CCUS) and hydrogen will allow the region to continue the use of existing fossil fuels in ways consistent with the rising demand for low greenhouse gas production. CCUS and hydrogen will require construction of pipelines and storage infrastructure and retrofitting of existing facilities. The Commonwealth of Pennsylvania will need to develop CCUS and hydrogen plans now to take advantage of these opportunities.
3. For the short to longer term, other areas of energy production and manufacturing represent substantial employment and growth opportunities for the region. Energy efficiency and the grid are and will continue to be a large source of employment in the energy sector. Additional training programs are needed to meet the growing demand for these industries. Wind, solar, and nuclear energy have substantial potential and could advance with new momentum from the Infrastructure Investment and Jobs Act and provisions of the clean energy and climate package. Shifts in state laws, such as loosening restrictions on community solar and the expansion of carve-outs for renewables in the Alternative Energy Portfolio Standard, will support the attainment of some of this potential. Clean technologies for advanced manufacturing also hold considerable promise for the development of modern manufacturing industries in this region.
4. Under all scenarios for the future, the region will need an effective workforce development strategy. State public agencies should more strategically align their efforts toward economic development and job planning. Innovations in the energy sector will displace workers in traditional energy jobs, and emerging energy industries will require an appropriately trained workforce. Programs that engage local industry with area community colleges and local universities have proven very effective for helping workers adapt to the evolving job markets.

It must also be kept in mind that energy is just one of several key industries in the region today. Southwest Pennsylvania emerged from the decline of the steel industry in the 1990s with a much more diversified economy than it had in the past. In the 1990s, the region's political, civic, and economic leaders identified health care as an opportunity for the future direction of the economy. Health care is now the largest industry in the region. In fact, health care is the largest employer and largest source of income in all but one of the 13 counties in Southwest Pennsylvania. But health care is not alone: the region has substantial finance, higher education, tech, and manufacturing industries as well. The diversification of Southwest Pennsylvania's economy means that changes in the energy sector may not have as profound an effect on the region as they did in the past. The focus of this report is on energy, but the other sectors of the economy will also be important sources of employment for displaced fossil fuel energy workers and the creation of new economic opportunities.

The coming changes in the energy sector will require the Commonwealth of Pennsylvania and local political and economic leaders to identify successful models for adapting economic development and effectively deploying resources to impacted communities. Areas that have the highest dependence on fossil fuel

extraction and power generation tend to be rural counties in this region. Economic development can be stimulated through regional infrastructure, especially transportation networks and broadband internet. There is a need to align the commonwealth's policies with public and industry demands. The commonwealth and the Southwestern Pennsylvania Commission should convene public-industry task forces and working groups that meet regularly to examine regional development in line with the needs of communities. It should be noted that the case analysis primarily reflects developments in the region as of mid-2021. As of this writing, developments in the region and at the national level were evolving rapidly.

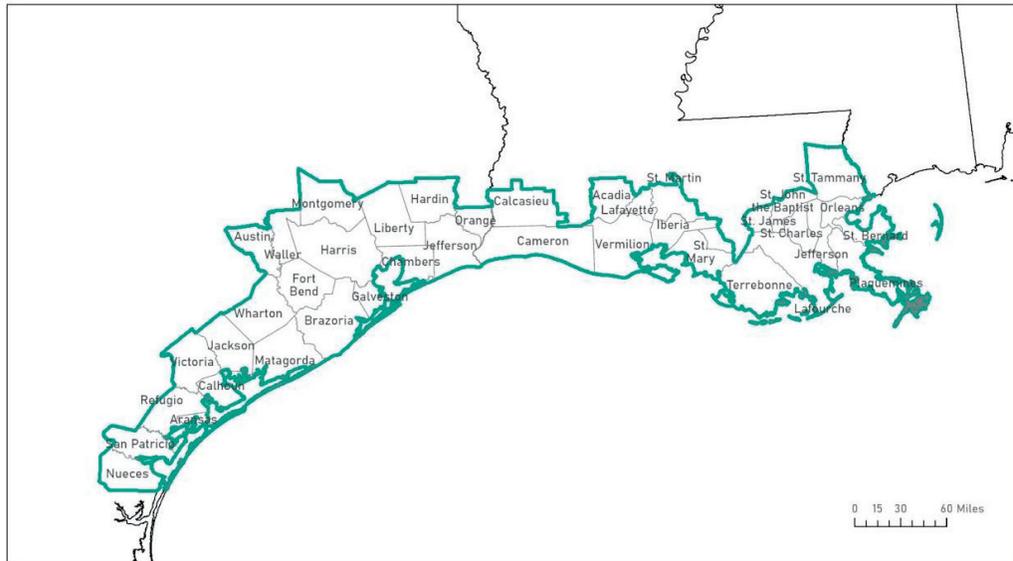
The coming transition in global energy production presents Southwest Pennsylvania with a unique opportunity to cultivate entirely new industries out of existing resources, such as CCUS, hydrogen, and advanced manufacturing. Doing so will take time and investment. Fortunately, the region has a combination of assets that few other places in the world enjoy. It has the natural resources, the history, the know-how, and the people to help the world create a cleaner energy future.

Key Findings and Recommendations

1. In the near term, the Commonwealth of Pennsylvania should **undertake a large-scale effort at remediation of methane leakage from wells and pipelines, of water contamination, and of brownfield sites**. Plugging and capping the over 400,000 legacy wells in the area will provide immediate employment for workers, reduce greenhouse gas emissions, and improve public health.
2. In the medium and long term, **development of carbon capture, utilization, and storage (CCUS) and hydrogen will allow the region to continue the use of existing fossil fuels in ways consistent with the rising demand for low greenhouse gas production**. CCUS and hydrogen will require construction of pipelines and storage infrastructure and retrofitting of existing facilities. The Commonwealth of Pennsylvania will need to develop CCUS and hydrogen plans now to take advantage of these opportunities.
3. Other aspects of energy production are under-developed and present substantial employment and growth opportunities for the region. Energy efficiency and electricity infrastructure are and will continue to be the largest source of employment in the energy sector. Additional training programs are needed to meet the growing demand for these industries. Wind, solar, and nuclear energy have substantial potential, but they are not predicted to develop substantially under business-as-usual policies. Changes in state laws, such as loosening restrictions on community solar, are needed to realize some of this potential. Additionally, **clean technologies for advanced manufacturing hold the promise for development of modern manufacturing industries in this region**.
4. Under all scenarios for the future, **the region will need an effective workforce development strategy**. Innovations in the energy sector will displace workers in traditional energy jobs, and emerging energy industries will require an appropriately trained workforce. Programs that engage local industry with area community colleges and local universities have proven very effective for helping workers adapt to the evolving job markets.
5. **Convene regional and statewide private-public commissions** to study pathways for regional economic development focused on Appalachia.

3.3 Gulf Coast Case Study

Jason Beckfield, Devin Booker, Kerry Bowie, Brianna Castro, Christine DeMyers, Daniel Alain Evrard, Ayodele Theard-Lewis, Darryle Ulama



Oil, gas, and petrochemicals enable modern life, from the energy consumed by the neonatal intensive care units that save thousands of infants every year, to the plastics in our clothes and computers, to the global transportation network connecting communities. How can these human needs be met while also meeting the human need to reduce greenhouse gas emissions?

This is the essential question raised in energy transitions. Indeed, the next two years are pivotal for policies aiming at answers on the U.S. Gulf Coast, home to 10 million people. Louisiana governor John Bel Edwards has appointed a high-profile Climate Change Task Force, which is now fully formed, holding hearings, and seeking solutions. After the deadly failures of the Texas electrical grid last winter, many Texans are calling for improving the electrical system. These state-level moves, combined with pressure from United States and international investors, renewable energy investments by traditional energy companies, the political priorities of the current federal executive administration, and the urgent need to reduce greenhouse gas emissions, all indicate that now is the time to accelerate energy transitions.

In summary, Louisianans and Texans currently confront challenges to the energy system:

- Shifting global energy demands,
- Increasing risks of land loss from erosion, subsidence, and stronger storms,
- Rising investor calls for community accountability,
- New public commitments to reduce greenhouse gas emissions,
- Risks from extreme cold, extreme heat, and more frequent flooding,
- Changing technological developments that transform markets, and
- Disproportionate burdens of environmental risks.

The Gulf Coast—especially its most energy-intensive part, from Corpus Christi to New Orleans—is rich in cultural and ecological diversity and can lead the United States in community-based adaptation strategies. As communities adapt, large-scale low-carbon or decarbonized energy transitions are underway. Yet,

communities along the Gulf Coast face many challenges to system-wide energy transitions that support vibrant economies and community life.

1. BIPOC people, the poor, and petrochemical workers face transition risks.
2. The production and consumption of oil and gas contribute massively to the region's public budgets, private employment, and overall economy.
3. The region hosts large investments in existing energy infrastructure, including large ports in Houston and New Orleans, which can create incentives to maintain the status quo, unless new opportunities are well planned and coordinated.
4. Many people in the region feel excluded from decision-making, distrustful of powerful institutions, and disrespected in the national debate over energy and climate.

How can the region acknowledge and also overcome barriers to leading energy transitions? What can Gulf Coast communities, employers, policymakers, and leaders do in the next 12–24 months to build the foundation for successful energy transitions that:

- Sustainably provide reliable and cost-effective energy,
- Offer equitable employment opportunities,
- Build on the region's many comparative advantages,
- Recognize and respond to legacies of environmental injustice, and
- Manage and reduce carbon to mitigate the risks of extreme weather?

Our study of the U.S. Gulf Coast identifies short- and medium-term actions that can transform these challenges into opportunities for an equitable and therefore successful energy transition. We approach the question of what energy transition pathways might be most promising for the region with a sense of gratitude toward the people whose work in oil, gas, and petrochemicals makes our modern lives possible and a sense of optimism about the leadership roles the region can play in the energy system of the future, given its immense comparative advantages.

This study offers practical pathways to success. Guided by our local Expert Advisory Group, we have completed a yearlong study drawing on:

- In-depth interviews with more than 70 stakeholders interested in the energy system,
- Participant observation at industry and environmental justice events,
- Social network analysis of businesses operating in the region,
- Demographic analysis of data from the U.S. Census Bureau,
- Economic modeling of the effects of different pathway scenarios, and
- Local fieldwork with marginalized Indigenous coastal communities.

Our analysis shows that today's transitional steps powerfully impact tomorrow's community wellbeing, especially employment. Focusing only on the outcome of employment, the clear takeaway is that policy choices can make energy transitions net positive for jobs, even in this energy-intensive region, which features difficult-to-decarbonize industrial production and a large and needed oil-and-gas-producing sector.

How? What are the pathways to successful energy transitions on the U.S. Gulf Coast? The complexity and centrality of energy transitions to life on the Gulf Coast calls for leadership from the private sector, coordination and predictability from all levels of government, and engagement with communities who bear the risks of the energy system. We recommend action in nine areas:

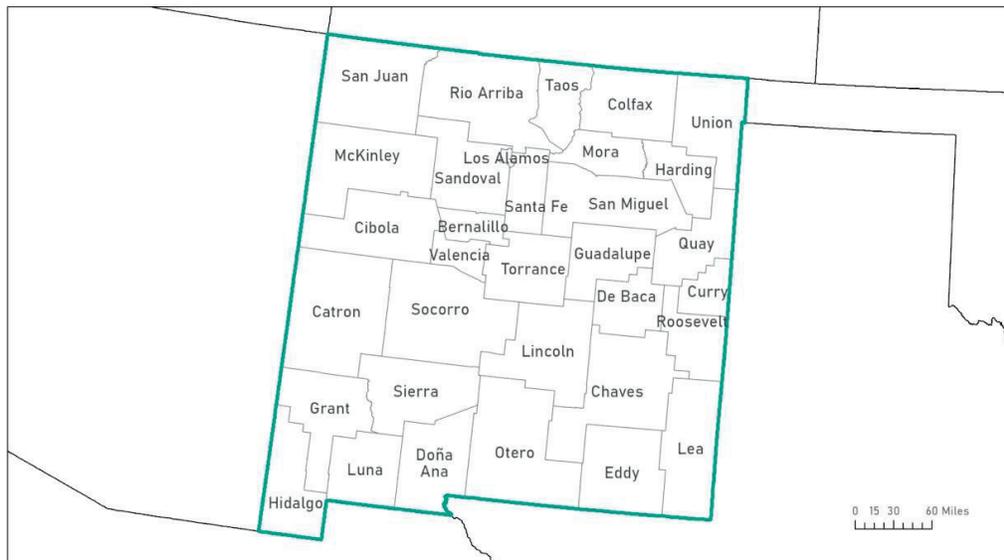
1. Initiating a regional Gulf Energy Transitions Council—community, industry, and policy leaders—that would be charged with setting energy transition goals, monitoring progress, building trust among polarized communities, and facilitating accountability.
2. Establishing a regional training consortium of employers, colleges, and policymakers to build new training programs to meet rapidly changing needs of energy employers.
3. Pursuing nature-based carbon management for carbon storage, environmental justice, and storm resilience—a true win-win-win.
4. Supporting social equity, entrepreneurship, and workforce development via an inexpensive Clean Energy Internship Program for Environmental Justice, which could be supported by federal dollars under the Justice40 guidelines.
5. Implementing low-level but predictably increasing renewable portfolio standards to incentivize investment in renewable energy for complementary transitional power.
6. Enabling the region to use all of its natural resources in energy transitions, including wind, solar, geothermal, tidal, and hydrogen energy, in addition to traditional sources.
7. Using onshore and offshore carbon sinks to profit from the current federal 45(Q) carbon incentive, verifiably reduce greenhouse gas emissions, and support land stewardship.
8. Demonstrating new technologies with local incubators and presentations by the National Renewable Energy Laboratory to local stakeholders, including industry associations, as well as environmental justice communities.
9. Supporting action to raise predictability and reduce risks for markets. Our current political polarization is imposing high costs and delaying action.

We conclude our report by showing examples of initiatives that are already underway in the region, which already has a long and proud tradition of adapting to changing energy sources:

- Louisiana's and Houston's announcements of 2050 net zero goals.
- The Gulf Region's GNO Wind Alliance, with well over 100 members and counting.
- The Lowlander Center's sustainable energy construction-training demonstration.
- ExxonMobil's 2021 announcement of a \$100 billion investment plan for carbon capture.
- G2 Net-Zero LNG (liquefied natural gas) project using existing infrastructural endowments.
- Greentown Labs, the largest climate-tech incubator in North America, opening its second location in Houston in 2021.
- The Lake Charles area's promotion of LNG with CCS, including training programs.
- The Greater Houston Partnership's release of its energy transition strategy.
- The Louisiana Climate Task Force's release of its draft strategy and action reports.
- The Center for Houston's Future roadmap of a hydrogen hub strategy.

3.4 New Mexico Case Study

Sabrina Curtis, Daniel Gallagher, Yiran He, Valerie Karplus, Melanie Kenderdine, Sade Nabahe, Darryle Ulama, Orland Whitney



New Mexico’s low-carbon energy transition is already well underway. Home to conventional and renewable energy production and resources, a robust innovation infrastructure, a large rural population, and a diverse ethnic heritage, New Mexico is tackling the transition from a position of strength. As an early mover in the national energy transition, New Mexico has some of the most aggressive climate policies of any U.S. state, a multifaceted homegrown entrepreneurial ecosystem, and a range of activities to deploy advanced energy infrastructures that support renewables, hydrogen, and carbon capture and storage.

This case study focuses on taking New Mexico’s energy transition to the next level: building long-term momentum so that the state can thrive in a future with net zero greenhouse gas (GHG) emissions. The analysis evaluates opportunities for transition on multiple dimensions: cost effectiveness, workforce opportunities, ability to build on the state’s capabilities and resources, and concerns of distributive justice. It incorporates the voices and experiences of local stakeholders. It asks how New Mexico’s diverse communities see themselves in this clean energy future.

The clean energy transition, while critical for the future of New Mexico, the U.S., and the world, will encounter obstacles along the way. The state budget relies heavily on revenues from fossil fuel development. Without thoughtful, informed, and targeted investments in transition technologies and policies, the clean energy transition could have a detrimental impact on state revenues. Absent new sources of state revenues, this could make it easier to spark resistance to the clean energy transition. Also, in the long term, as the transition proceeds and the pressure to reach net zero emissions increases, reductions will require deploying technologies that are currently relatively expensive, replacing current jobs and requiring new supporting infrastructures; planning now will be critical to ease disruption later. Finally, without clear-eyed attention and efforts to address its distributional impacts, the clean energy transition could exacerbate ethnic and income inequities and increase the urban/rural divide in the state.

The analysis is structured to place these issues in context, analyze need and impacts, and make recommendations for the energy transition. Chapter 1 sets the stage by describing the context for the case study, the state's energy system today, and major sources of GHG emissions. Chapter 2 evaluates major opportunities for the state's energy sector and economy in a transition. Chapter 3 discusses the implications of transition pathways for jobs, salaries, communities, and workforce development. Chapter 4 considers what changes to the state's institutions and policies would support transition and what processes for achieving these changes would be viewed as legitimate by the state's diverse population, raising the prospects for a sustainable transition. Chapter 5 concludes with recommendations.

Recommendations from the case study focus on how technology opportunities, economic and workforce development initiatives, and public policies, working in tandem, could advance a clean energy future in New Mexico. The recommendations are designed to connect with and mutually reinforce each other.

Among the recommendations on energy technology opportunities, **this case study identifies options for the state to address distributional inequities and public revenue gaps** that could prevent the transition from gaining momentum. The recommendations recognize that jettisoning existing traditional energy infrastructures would undermine an important source of jobs, public revenues, and affordable energy services for the state's citizens.

In electricity, the case study recommends that the state's leaders develop a vision and targets for power sector decarbonization that recognize the value of existing and future flexible generation options, as renewable energy expands to meet the state's goals of 50% renewable energy by 2030, 80% renewable energy by 2040, and 100% carbon-free energy by 2045. In the electricity sector, opportunities to develop natural gas and other energy sources with carbon capture and storage (CCS) should be evaluated for their potential to enable an increase in wind and solar generation given a fixed level of installed capacity and improve overall reliability of the electricity supply.

This evaluation should also consider the extent to which repurposing fossil fuel infrastructures would preserve jobs and public revenue and keep the costs of transition manageable. In transportation, the state should consider approaches to limit the burden on rural households, which tend to have lower incomes and higher driving requirements. Approaches will need to go beyond current strategies of electrification and vehicle mileage reduction to consider how to make clean options affordable to rural households. Subsidies for efficient vehicle purchases, early vehicle retirement, and refueling infrastructure for alternative fuel vehicles are options here. Distributional impacts should also be a central consideration in the design of a low-carbon fuel standard, which is under discussion. Finally, our case study identified long-term opportunities for the state. It recommends evaluating prospects for hydrogen-CCS hubs in its northwest and southeast corners, in partnership with oil and gas companies, their workforces, and infrastructure operators. It also recommends studying the feasibility of using deadwood in forests, which poses a fire hazard, as a feedstock for the net-negative emissions technology bioenergy with CCS (BECCS), which could offset residual GHG emissions and help support climate neutrality by mid-century.

Beyond energy, a second category of recommendations focuses on **harnessing opportunities created by a clean energy transition**. First, case research found

that New Mexico, as the nation's second-largest copper-producing state and a potential source of other clean energy materials inputs, could potentially position itself as a competitive player in environmentally responsible mining. The case study recommends a feasibility study to assess the potential for such an activity to supply U.S.-based clean energy manufacturing and to generate high-quality jobs and public revenues. Second, the case study recommends pursuing with greater urgency and public resources a set of opportunities to increase and monetize recovered methane that would otherwise be emitted from agriculture and from oil and gas production and distribution, building on the state's new regulation requiring operators to capture 98% of methane by 2026. Third, the case study highlights the ways that the state's innovation assets—including community colleges, universities, national labs, and entrepreneurship hubs—could be engaged to support the realization of transition-related opportunities in energy and the knowledge economy. The state's national labs have an opportunity to play a major role in many proposed research pathways, from the design of CCS and hydrogen hubs, to energy materials research, to setting standards for processes such as responsible mining.

A third category of recommendations focuses on public policy, including policy related to workforce retraining and development and public revenues. These recommendations are complementary and work synergistically with the recommendations above. First, policymakers should clarify that the Energy Transition Act (ETA) targets a goal of net zero grid emissions by 2050. This would allow near-zero carbon sources of electricity, in particular natural gas with carbon capture and storage, to contribute to reducing the carbon footprint of the electricity mix. Residual emissions could be offset through the use of carbon dioxide removal (CDR) technology or offsets.

Second, GHG emissions from sectors other than electricity will need to be addressed through policy. Here, the case study recommends developing new legislation and executive actions that address emissions from transportation, oil and gas, and agriculture. In transportation, particular attention should be given to impacts on low-income and rural households. If the low-carbon fuel standard is pursued by the state legislature as planned, provisions for encouraging broad availability and affordability of a diverse portfolio of low-carbon fuels suited for heavy-duty commercial and freight, such as hydrogen, as well as for passenger vehicles, could help to increase support among those concerned about distributional impacts.

Three recommendations focus on workforce development. The first involves supporting strategic partnerships for relevant government departments, employers in clean energy production and supply chains, higher education institutions, and certified apprenticeship programs to establish pathways for “newskilling, reskilling, and upskilling” workers, to ensure that they possess adaptable core skill sets that are sufficiently robust to meet projected needs in a range of transition trajectories. Examples include the construction trades and building energy efficiency. The types of training required will be highly diverse, ranging from certificate programs to expanded apprenticeship programs to four-year STEM degrees. Counseling to disseminate information about opportunities and facilitate job matches, especially for underrepresented groups, will be needed.

To support this effort, a second recommendation calls for a comprehensive ongoing study of prospective workforce impacts of energy transition through

2050 by industry and by sociodemographic group. This study should clearly differentiate near-term construction jobs from other job categories within clean energy sectors, as construction jobs are expected to be a large component of the jobs initially created and existing workforce skills and apprenticeship programs can be readily leveraged, while jobs associated with longer-term opportunities such as carbon capture and storage are more likely to require tailored technical training. A goal through 2030 should be to establish a standing capability to guide new or unemployed workers to opportunities in the state's clean energy economy. The strategic partnership mentioned above could leverage federal or state support to catalyze activities, adapt approaches from other contexts across the U.S. and worldwide, and engage with the state's executive branch and legislature on the design of transition assistance programs. A third recommendation focuses on ensuring a commitment to high-quality job creation, including by expanding and strengthening existing wages and benefit structures, apprenticeship opportunities, building standards, and worker safety requirements.

Focusing on the equity dimensions of the recommendations in this analysis on renewable energy expansion, this case study shows that financing provisions, workforce engagement, and educational outreach are needed to ensure full participation of Indigenous communities in renewable and clean energy expansion on native lands. Another recommendation calls for expanding current efforts to reduce or replace fossil-dependent revenue sources in public budgets, in the state as well as tribal governments.

A final category includes **one recommendation intended to strengthen the participation of key stakeholders and the broader public in decisions** on technology pathways and policy related to the transition. The goal would be a model for hearing concerns and soliciting ideas on initiatives related to transition, with representation by tribal, ethnic, state, labor, industry, and other leaders. Examples of models are discussed, but ultimately the case study recommends that the Interagency Task Force on Climate Change determine a suitable model via a consultative process.

4. An Energy Transition Framework

The complexity of the energy transition demands a multidimensional framework with which to analyze the key opportunities and constraints that transition regions will face over the next several decades. For example, the four Roosevelt Project case studies emphasize the uneven, distributional dimensions of the energy transition across geographies, economic sectors, labor market segments, and demographic groups and demonstrate the importance of targeted and place-based policies. The transition to low-carbon energy is poised to displace jobs in communities that rely extensively on fossil fuels and fossil-driven industries, many of which still underpin regional economic viability today. Yet the transformation of the domestic energy system is replete with new opportunities to revitalize deindustrialized regions, embed next-generation industries, combat climate impacts, and marshal resources in a manner consistent with social equity principles. In this context of transition, it is important to examine the internal ability of these regional economies to adjust to and harness new sources of local economic activity, particularly as it relates to opportunities made possible by the transition itself. Simply stated, how and under what conditions can a region that is dependent on a fossil fuel economy transition to a low-carbon economy?

The Roosevelt Project approaches this question through an interdisciplinary lens. Any solution set must simultaneously address the economic realities of industrial transition and the social-demographic implications of these economic shifts, with a focus on distributed outcomes across social groups, particularly those that have historically been excluded and/or impacted by the energy economy. Accordingly, an industrial policy framework that comprehensively approaches these interrelated challenges is critical to ensuring a successful and just transition.

The Economics of the Energy Transition

Existing literature on regional economic development focuses on two competing forces: convergence and agglomeration. Barro and Sala-i-Martin (1995) define convergence as growth of a focal industry declining in the level of economic activity due to diminishing returns. Glaeser et al. (1992) describe agglomeration as a countervailing force in which growth accelerates in the level of a focal industry's economic activity, arising from proximity-based productivity gains and knowledge spillovers. Delgado, Porter, and Stern (2012) find that agglomeration dominates in a colocated set of similar industries, or cluster, in which businesses supply complementary functions.

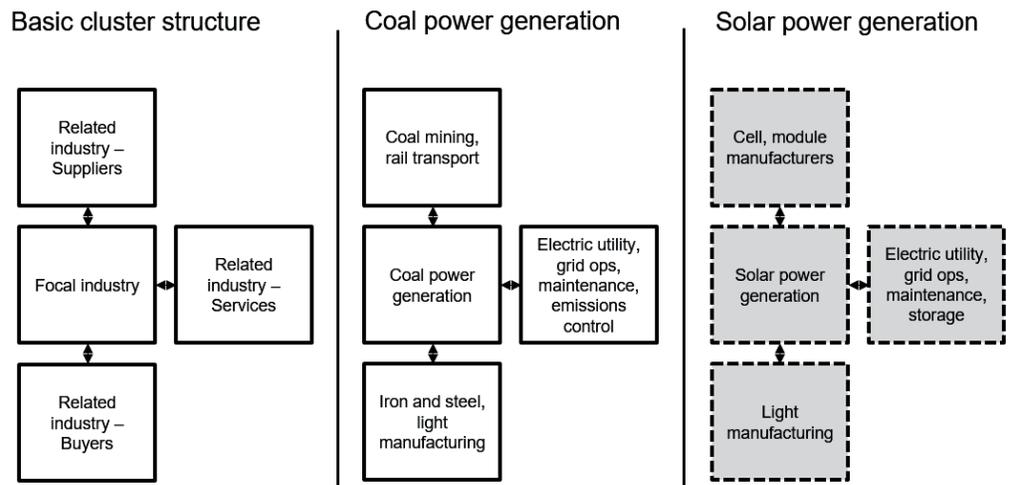
The context of deep decarbonization could be particularly painful for transition regions because it unravels the benefits of agglomeration. Consider, for example, economic activity in Southwest Pennsylvania: agglomeration occurred across closely related industries including mining (primarily coal), associated combustion processes for electric power and high-quality heat, and then downstream consumption of inexpensive electricity and heat, especially but not exclusively in steel production. In a transition, particularly one that removes access to low prices for energy and high-quality process heat, the economic unraveling could be devastating across the entire supply chain.

However, unlike recent industrial transitions, where communities have been affected by the wholesale decline of certain industries, often as a result of international competition (e.g., steel manufacturing in Appalachia), the energy transition is two-sided: electricity generated from coal and natural gas will decline

and be replaced by new low-carbon generating technologies. While this transition will involve a shift away from carbon-intensive processes, there is plausible optimism that new technology and new firms could take their place locally and offer new economic opportunities.

For regions in transition, there are two challenges to capturing the value of these opportunities. First, the new industries could form in orthogonal technological spaces relative to existing industries. For example, on the one hand, the technological basis, workforces, and supply chain for solar photovoltaic (PV) technology has little overlap with those of coal mining and coal-fired power production. As a result, regions facing transition may be at a disadvantage with respect to existing assets and competencies to be able to take advantage of new technological opportunities. Moreover, solar PV is an imperfect substitute for a coal plant, as it is less amenable to producing high-quality process heat. Figure 14 shows how a clean energy transition could undermine the agglomeration advantages enjoyed by fossil-fueled local economies.

Figure 14: How the transition to clean energy (in this case, from coal power to solar power) undermines agglomeration economics in a region. *Left panel:* Basic structure of an industry cluster; *Middle panel:* Agglomeration economies enabled by low-cost electricity and heat; *Right panel:* Implications of shifting from coal to solar PV electricity in a cluster during low-carbon transition. Changes indicated by dash lines and grey background.



On the other hand, the industrial structure for technology pathways that include carbon capture, utilization storage and/or removal, renewable natural gas, or hydrogen, could leverage existing complementary elements of the current industrial structure in economies currently based on fossil fuels. It seems fairly obvious that the ability to capture carbon cost-effectively, either through point source capture or direct air capture, would enable extractive industries to sustain in a zero-carbon future. But, even in the case where those cost curves do not decline precipitously (resulting in some deployment of capture assets but not enough to prevent associated regional economic losses), the use of hydrogen, even if produced through electrolysis derived from renewable electric power, would still leverage the existing industry structure for gas transport, related industry suppliers, and business models.

The Transition Paradox

This framework highlights the importance for a given region in the energy transition to leverage pathways to decarbonization that amplify existing industry structures within that setting. In the context of the Industrial Heartland, where there is already an existing and robust electric power industry, horizontally integrated across older resources (thermal plants) and new resources (e.g., large-scale battery production), the transition to electrify the automotive fleet can, with relative ease, leverage existing internal competencies. In the Gulf Coast and Southwest Pennsylvania, a path to decarbonization that rules out the use of fossil fuels—even under zero-emissions scenarios using carbon capture, utilization, and storage capabilities or hydrogen pathways—is expected to have a much more destabilizing effect on regional economies.

Economics and innovation literature is full of theory and empirical evidence that documents how technological evolution is endogenous to broader economic and policy conditions. The energy transition is no exception. The types of solutions that arise and enable pathways to decarbonization will themselves be a function of the policies put in place to drive decarbonization. On the one hand, a basic regulatory approach, such as a national renewable power standard, will incentivize technology pathways related to renewable power—wind, solar, batteries, etc.—but does not necessarily provide the market signal to incentivize development of carbon-free fossil-based alternatives. On the other hand, putting a price on carbon is more agnostic to the technological trajectories that eventually lead to decarbonization.

Simultaneously, as shown in Green and Knittel (2020), there is significant variance in the costs of carbon policy to the regions considered here, with clean energy standards generally disproportionately affecting fossil-producing regions. Moreover, only carbon pricing creates revenues that can be redistributed to communities that endure these higher costs.

The paradox, then, is a reinforcing negative feedback loop: the general lack of political will in these communities to take action against climate change induces sets of climate policies that do not adequately incentivize decarbonization energy opportunities that these communities are well-positioned to leverage or create the revenue streams that could support the transition in these communities. The lack of these opportunities then reinforces entrenched political dissent, and the cycle continues.

Through consideration of the Roosevelt Project case regions, it is very clear that the surest way to ensure a successful energy transition at the community level is to

1. Create adequate incentives for the continued utilization of carbon-free fossil derivatives or clean fuels that leverage existing fossil infrastructure and industrial competencies; and
2. Repurpose revenue to communities adversely affected by the transition itself to support worker training, infrastructure conversion, and other transition adjustment assistance and programming.

The goal of the Roosevelt Project phase 2 case studies is to identify the coalitions, assess the opportunities, and inform the policy pathways that enable communities to break the transition paradox cycle. Each of the four case studies explores these dynamics in depth through rich, multidisciplinary approaches. Though the findings of each case are grounded to their particular contexts, they share many features and complexities with communities across the country and offer crucial lessons to jurisdictions facing the challenges and promises of the energy transition.

Environmental, Energy, and Climate Justice in the Energy Transition

It is critical that efforts to develop a more inclusive and representative energy economy grapple with the unique ways that the energy industry affects low-income, frontline, and minority communities and prioritize their engagement in the process. Ensuring a just energy transition that addresses harmful impacts and prioritizes underserved communities in sharing in its benefits is a major through line of the Roosevelt Project. All four Roosevelt Project cases highlight the importance of engaging underrepresented communities in planning and executing the energy transition and articulate the downsides of failing to engage these communities.

The United States environmental justice (EJ) movement grew out of a patchwork array of efforts. As it exists today, EJ owes its comprehensive and people-centered viewpoint to decades of iteration between stakeholders, grassroots organizations, civil rights groups, and labor unions at the state and local level and, at other times, academic institutions or federal government agencies and departments (Mohai, Pellow, and Roberts 2009; U.S. Department of Energy Office of Legacy Management, n.d.).

In recent years, growing public and scholarly discourse have led to the emergence of climate justice and energy justice, new modes of thinking built on EJ principles that recognize the distributional dimensions of a rapidly changing planet. Climate justice emphasizes issues of allocation, mitigation, adaptation, resilience, and intergenerational rights as core to addressing the climate crisis. In particular, climate justice is interested in how different societal structures spurred by climate change can have adverse impacts on underprivileged populations (Simmons 2020). Similarly, energy justice emerged as a tool to evaluate the uneven technological, economic, and policy processes of the broader transition to low-carbon and renewable resources (Carley and Konisky 2020; McCauley et al. 2019). The fundamental link that connects environmental, climate, and energy justice is the recognition that existing structural inequities create winners and losers. Of course, recognition of the disparities rife within the system alone will not suffice. Rather, environmental, climate, and energy justice should be a central focus of policymakers and other decisionmakers, built into the processes already in use (Sovacool et al. 2014).

The simultaneous crises that unfolded in 2020—from a once-in-a-generation global pandemic to a national reckoning with anti-Black racial violence and police brutality—have brought issues of structural and systemic inequity front and center in the United States. Accordingly, the literature on the topic, already vast, has expanded with some important new contributions.

The consensus across energy justice literature is that there are three or four central modes of justice:

1. **Distributive justice**, which considers how impacts of and externalities from the energy system are distributed across society;
2. **Procedural justice**, which is concerned with the participation in, access to, and knowledge of major decision-making processes;
3. **Recognitional justice**, which acknowledges differing needs within the energy system across different populations; and
4. **Restorative justice**, which underscores the duty of energy sector actors to rectify past injustices.

In *Revolutionary Power*, Shalanda Baker urges her readers to pursue a justice-first framework, rather than prioritizing climate first and leaving justice for later (Baker 2021). As climate considerations are increasingly incorporated into technical decision-making processes that have always been dominated by cost-motivated metrics, so too should principles of justice (Peluso 2021).

Similarly, the White House Environmental Justice Advisory Council (WHEJAC) released interim findings related to funding priorities to support environmental justice initiatives that offers a clear path forward for policymakers considering environmental justice activities, with a particular focus on how to consider the community benefits of potential investments.

What is clear from these important works and engagement with affected communities is that there is a tension between the ability to deliver on environmental justice goals and select potential technical and economic pathways to rapid decarbonization. Baker (2021) tackles this head-on, stating explicitly that there are different priorities for climate initiatives and justice initiatives, and WHEJAC (2021) raises concerns about the build-out of carbon capture, hydrogen, and advanced nuclear technologies that perpetuate existing economic and industrial systems. At the heart of these concerns is the reality that traditional market-based, cost-benefit-driven energy interventions have failed to deliver positive outcomes for frontline communities.

This context, therefore, motivates additional consciousness around specific Roosevelt Project recommendations that may seem to perpetuate these systemic failures. It is important that initiatives promoting specific technical pathways (be they hydrogen, carbon capture, nuclear, or others) are paired with specific policy initiatives targeted toward at-risk communities—this is a key thesis of the Roosevelt Project. Across case studies, opportunities to invest in and develop hydrogen or carbon capture economies are recommended to be paired with specific and inclusive community engagement initiatives that enable frontline and other at-risk communities to benefit, not only from the environmental improvement and economic gains associated with potentially lower-cost carbon-free energy but also from the growth of new industries, jobs, and community-level spillovers that accrue from the transition.

For example, the Roosevelt Project modeling exercise demonstrates the economic benefits of allocating carbon dividends according to regional and local need and the importance of targeted workforce development policies for those likely to be displaced by the transition away from fossil fuels. As the country embarks on the most ambitious infrastructure expansion since the New Deal, the United States has the opportunity to correct historical patterns of underinvestment while simultaneously upgrading the nation's core public assets (Ulama 2021).

A principal finding of the Roosevelt Project's phase 2 work is that a diversity of EJ issues must be centered in each case's local decarbonization strategy. The Roosevelt Project takes seriously the popular adage that "All politics is local"; local political processes, grassroots advocacy, and coalition-building will remain important levers through which justice will be incorporated into the energy transition. The section below highlights critical EJ themes that have emerged from each of the case study regions.

The Industrial Heartland

The Heartland case evaluates the energy transition from the perspective of a single sector: motor vehicles. Motor vehicle prominence in the Midwest was

forged by major companies like Chrysler, Ford, and General Motors, but the story of the auto sector cannot be told without equal attention to the suppliers, component manufacturers, dealers, and other players in the automotive supply chain. Beyond the private sector, organized labor and the communities surrounding auto production were integral to shaping the heyday and restructuring of American industrial production. The auto sector also provided high-paying union jobs to millions, creating a secure path to the middle class, though there still exists pervasive bias throughout industry operations. In Detroit, Mayor Coleman Young's focus on diversifying the supply chain in the automotive industry was a boon to many small business owners of color who generated wealth as equipment and part suppliers or maintenance service workers.

The transition to electric vehicles presents challenges and opportunities from the perspective of autoworkers and the communities that have hosted American auto manufacturing. On the one hand, the region's manufacturing legacy and bold federal and private sector commitments present exciting opportunities for economic and technological revitalization. EV-related infrastructure investments could be structured to correct historical patterns of transportation inequality, embodied in public transit deserts and disruptive highway construction (e.g., electrifying bus routes and providing incentives for EV scooters). On the other hand, EVs may reduce the number of auto manufacturing jobs because their technology relies on fewer parts and requires less maintenance than internal combustion engines (ICEs). Appropriate workforce transition and retraining, along with small business retooling, are critical to success in the Industrial Heartland. Auto workers and industry informants expressed concern that EV production caters to younger employees with different skill sets and has relied increasingly on contract employees and reduced salaries. There may be a need to address sectoral bargaining to stop this downward pressure on wages, as this creates a perverse disincentive for workers in their late thirties, forties, and older to retool or retrain for lower-paying jobs. On the consumer side, expensive EVs remain out of reach for many Americans, and incentives for EV purchases often only benefit higher-income buyers. Some vulnerable communities also have concerns about new modes of EV production and the potential for as-yet-unseen pollution or environmental hazard. Communities in the Industrial Heartland have long shouldered the environmental burden of their states' industrial success, and ensuring safety during this transition is paramount.

This case concludes with the following set of recommendations, articulated further in White-Newsome et al. (2021):

1. Prioritize worker safety (e.g., in EV supply chain and manufacturing);
2. EV corporate responsibility for EJ (e.g., collective industry waste management, infrastructure and lemon laws);
3. Equitable EV incentive program (e.g., used EV incentives, income-based rebates and discounts);
4. Ensure quality jobs, quality benefits and livable wages for frontline auto communities;
5. Accounting for environmental injustice/pay to pollute;
6. Protective energy pricing;
7. Community benefits agreements;
8. Intergenerational workforce investment and development;
9. Transparency (chemical use, process, risk assessment); and
10. Require a cumulative impacts assessment on environment and community health.

Southwest Pennsylvania

In Appalachia, the industrial legacy demonstrates how disparities commonly linked to race are also inherently linked to socioeconomic status. While there are racial dimensions of environmental justice in Southwest Pennsylvania, the transition from coal mining and natural gas fracking to other industries will primarily impact white, blue-collar workers. There is also a stark urban-rural divide between metropolitan Pittsburgh, which hosts the region's major educational and business hubs, and the rural jurisdictions whose economies are much less diversified.

The Roosevelt Project is grappling with “promise fatigue” as a major theme of the Southwest Pennsylvania case. Promise fatigue results when policymakers inflate promises to communities to spur economic activity, generate jobs, and catalyze prosperity in the region. They lose broad social trust when those promised benefits do not materialize, which has lasting implications for future policy proposals and interventions. Promise fatigue is also tied to ignoring the environmental harms that accompany these projects, as is the case at U.S. Steel's Clairton Works, a coke oven, which continues to run without the proper abatement technologies. Confronting promise fatigue in the region requires building trust, investing in open and transparent communication, and recognizing mutual respect.

This case concludes with six specific recommendations, a few of which will help to ensure a just transition in Southwest Pennsylvania:

1. Establish a substantial remediation program with the objective of cutting greenhouse gas emissions from leaking wells in half within 10 years;
2. Develop a region-wide infrastructure for carbon capture and storage and, eventually, hydrogen at industrial scale;
3. The federal government should establish a research-driven CCUS innovation hub in Southwest Pennsylvania;
4. Develop a comprehensive approach to wind, solar, biofuels, nuclear power, and other energy sources in order to build a more diverse energy portfolio;
5. Launch a workforce development initiative; and
6. Invest in developing the capacity of local communities.

There is a tremendous opportunity to assuage these promise fatigue concerns and address environmental justice in concert by remediating soil and water contamination and abating methane leaks by capping or removing orphaned wells.

Gulf Coast Case

Similar to the Southwest Pennsylvania case, fenceline communities in the Gulf Coast are often presented with the false choice between healthy communities or decent jobs. This should not be an either-or proposition, but often the discourse of the energy transition has played out under this pretense in communities across Texas and Louisiana. Case study interviews reveal how deeply traditional energy employment is tied to identity, familial and community relationships, and sense of place in the Gulf Coast. The petrochemical and fossil industries have had indelible physical, environmental, and socioeconomic impacts across the region. While these industries have served as economic hubs of investment and job opportunity, they have also produced remarkable environmental and ecological consequences that disproportionately affect communities of color and other frontline groups. Moving forward, the region will also contend with more pronounced climate impacts, from sea level rise to land subsidence to hurricanes, that will burden poor communities more than others.

This case concludes with recommended action in eight areas to ensure a just transition in the Gulf Coast:

1. Initiating a regional Gulf Energy Transitions Council—community, industry, and policy leaders—that would be charged with setting energy transition goals, monitoring progress, building trust among polarized communities, and facilitating accountability;
2. Establishing a regional training consortium of employers, colleges, and policymakers to build new training programs to meet the rapidly changing needs of energy employers;
3. Pursuing nature-based carbon management for carbon storage, environmental justice, and storm resilience—a true win-win-win;
4. Supporting social equity, entrepreneurship, and workforce development via an inexpensive Clean Energy Internship Program for Environmental Justice, which could be supported by federal dollars under the Justice40 guidelines;
5. Implementing low-level but predictably increasing renewable portfolio standards to incentivize investment in renewable energy for complementary transitional power;
6. Enabling the region to use all of its natural resources in energy transitions, including wind, solar, geothermal, tidal, and hydrogen energy, in addition to traditional sources;
7. Using onshore and offshore carbon sinks to profit from the current federal 45(Q) carbon incentive, verifiably reduce greenhouse gas emissions, and support land stewardship; and
8. Demonstrating new technologies with local incubators and presentations by the National Renewable Energy Laboratory to local stakeholders, including industry associations, as well as environmental justice communities.

New Mexico Case

In New Mexico, the energy transition has been supercharged by the state's Energy Transition Act, which mandates aggressive statewide targets in electric power. However, because the state's public revenues rely heavily on fossil fuel development, the state's decarbonization trajectory carries significant economic and distributional implications. New Mexico is a minority-majority state, with a number of Indigenous tribes and a substantial Hispanic population. It is also a rural state with a rich heritage in natural resources and both conventional and renewable energy production. The case considers potential options to address distributional inequities as New Mexico's energy transition moves beyond the power sector. It also considers ways to strengthen public decision-making and consultative processes in order to build broader support for policies that enable the transition.

This case concludes with two specific recommendations to ensure a just transition in New Mexico:

1. The creation of a Transition Advisory Council, which would bring in industry, academia, and advocacy groups to consult state agencies on energy transition policies; and
2. The creation of a People's Transition Assembly for greater public input, following examples in the UK and Canada.

Designing Industrial Policy for the Energy Transition

Whereas the transition paradox and distinct regional economies highlight the need for context-specific policy interventions and economic development

strategies in fossil-dependent communities, equally important is the broader role of the federal government in targeting and supporting strategic industries to enable the energy transition. The Roosevelt Project's analytical work suggests that bold government action at the national level is needed to mitigate the disruptive and uneven processes of deep decarbonization. Federal support in particular is necessary to spur competitive industries such as battery production and electric vehicles, mandate economy-wide electrification and renewable energy targets, invest in and scale the concomitant infrastructure, and implement effective social policies to protect workers and communities; it is therefore important to evaluate the opportunities and limitations of industrial policy (IP), particularly in the context of American political economy and its policy landscape. Successful industrial policy requires that the suite of initiatives is designed to be expressively transitory, with a clear exit strategy and options for policy reevaluation over time.

The literature points to three primary reasons for IP's historically lackluster reputation: (1) the fallacy of win-win scenarios, (2) the easy-entry, difficult-to-exit nature of IP, and (3) political capture. Each is instructive in thinking through the limits of IP in the context of the Roosevelt Project. For example, economic modeling and the extant literature provide ample evidence that win-win scenarios, while not impossible, are rare and that the burdens of large-scale transition are often borne unevenly once they are implemented.

Historically, many of the industrial policy opportunities have produced wealth but at a cost to other segments and sectors of society. This is made even more challenging by the fact that transfers and redistribution in the United States are channeled through relatively weak safety net structures and institutions. In light of this, the Roosevelt Project case studies are investigating complementary social policies in labor and workforce development, environmental and racial justice, and other policy domains that would complement the IP of decarbonization.

The “barriers to exit” of IP also present complex challenges to policymakers, especially because of the uncertainty in the timeline, technology development, and cost of certain opportunities like hydrogen and carbon capture, alongside the uneven timelines of decarbonization efforts across geographies and jurisdictions. Moreover, developments outside the United States will shape key pieces of the domestic decarbonization trajectory, from supply chains of resources to international competition in emerging energy sectors. Defining an appropriate ramp-down of IP and designing plans to deal with unintended consequences of policy choices are critical to successful implementation.

Capture by interest groups—the winners from IP—could distort the efficacy of good policies and may work to lengthen IP beyond its useful life. The development of independent institutions and institutional arrangements, such as the Federal Reserve and its role in setting monetary policy, are crucial for enabling effective and long-term environmental policy. Such moderating institutions are needed across jurisdictional scales, from the community/metropolitan level to the regional and federal levels.

From the perspective of decarbonization, the challenge of competition in certain sectors, provision (or under-provision) of public goods, and dealing with externalities are among the most important considerations of market failures. For example, a suite of targeted subsidies, securing supply chains, and R&D support will likely be needed to protect domestic activities in, for example, battery production and electric vehicle manufacturing. Updated federal regulation and legal rules will

need to be developed for CCS projects and hydrogen technologies, thereby providing signals to and lowering regulatory uncertainty for investors and firms.

Several challenges are worth emphasizing in implementing industrial policy to enable deep decarbonization. For example, targeting is critical to ensuring programs and policy mixes are matched to the appropriate groups. This is especially relevant for mitigating policies such as workforce retraining, reskilling, or compensation or in selecting and championing specific industries. However, the risk of incorrect targeting or capture show the limitations of targeting in industrial policy. Second, unlike in many European states, where a more generous and redistributive welfare state has developed, the United States relies on smaller-scale social programs and welfare institutions. Political scientists and economists have offered a range of reasons for this divergence, but generally the United States is characterized by market dominance whereby government provision is means-tested and targeted to the neediest. Many social benefits—from health care to retirement—are tied to employment, a key feature of American social policy. The U.S. approach may be better equipped to discourage moral hazards and encourage competition, but it also leads to much weaker social protections for workers unable to participate in the labor market. As the energy transition disrupts and restructures the U.S. economy, large segments of the labor force, and their communities, are at risk.

Nonetheless, our times demand both a timely, coherent, and amply reviewed industrial policy matched with properly designed supportive policies to ensure that we can rise to the challenges presented by the regional variances described in our case studies. States and municipalities have played leading roles in developing and implementing climate policies that are deeply attuned to their local needs and will remain crucial in the country's decarbonization strategy. It is clear, however, that the scale and speed required to achieve carbon reduction targets necessitates significant and sustained action at the federal level.

5. Conclusion

There is an emerging consensus that the threat of climate change necessitates far-reaching transformations across the entire energy sector, the effects of which will impact every aspect of civil society and industry. The Roosevelt Project's phase 2 case studies offer grounded perspectives and nuanced analysis to put forth critical questions regarding the uneven nature of decarbonization and environmental change, the social and economic risks faced by fossil-dependent communities, and how to enable pathways that preserve livelihoods and bring the country toward a low-carbon future. Much can be learned from the case study findings as the United States navigates its next industrial transition: the future of EVs in the Industrial Heartland speaks to the future of American manufacturing competitiveness; the decline of coal in Pennsylvania and the uncertain future of oil and gas in the Gulf Coast region underscore the need to protect communities whose histories were forged by these sectors; and the stark urban-rural divide in infrastructural services and economic development in New Mexico exemplify the spatial dynamics playing out across the country. These case studies show that the United States is not undergoing a singular energy transition but rather multiple, overlapping energy transitions.

Several themes cut across the four case studies and supporting analytical work. First, issues related to justice can and must be centered and incorporated into all aspects of managing the energy transition. The Roosevelt Project's environmental justice framework has emphasized the ways in which communities of color, frontline groups, Indigenous peoples, and displaced workers are disproportionately affected by both the causes and consequences of climate change. The Gulf Coast provides a telling example: the environmental burdens of petrochemicals have been borne by neighborhoods of color, members of which have also built livelihoods from the oil and gas sector. Many now face the compounded risk of job displacement from the transition and growing climate impacts in their communities. The Roosevelt Project highlights the need and opportunity for policy responses and institutions that enhance procedural and consequential equity.

Second, there is a clear need to manage and respond to the economic dislocation from the tectonic shifts in the energy landscape. Across the case study areas, fossil fuel and related sectors are deeply embedded in the local industrial base, labor market, and state and municipal budgets. Jurisdictions will need to evaluate the appropriate suite of strategies, including economic diversification, worker reskilling and assistance, and investments in innovative capacity, to weather the transition. There is also ample promise in the opportunities created by this historic shift. The Midwest, for example, has the chance to capitalize on its manufacturing legacy to be a leader in electrified transportation. Remediation and environmental cleanup in Southwest Pennsylvania and New Mexico double as workforce and environmental justice strategies. National decarbonization will clearly entail a fundamental restructuring of the American economy, starkly spelled out by the scenario choices in the Gulf Coast.

Third, the multi-tiered level of analysis undertaken by the case studies demonstrates the importance of coordinated policy interventions across jurisdictional scales, from the local to the federal level, and across siloed policy domains. The federalist structure of U.S. policymaking presents both challenges and opportunities to meeting the energy transition moment. Moreover, the

growing politicization of climate issues will remain a persistent challenge in developing and implementing effective transition planning. Policy sequencing to build coalitional support and reduce the cost of decarbonization may prove essential to overcome political and economic roadblocks. The case studies also suggest the energy transition has created opportunities for regional collaboration, particularly in emerging sectors such as large-scale hydrogen and carbon capture, storage, and utilization. Regional collaboration will also prove effective in climate adaptation, from ecosystem restoration to disaster response, and in dealing with infrastructure reuse and remediation efforts.

Fourth, the localized nature of the energy transition underscores the importance of grassroots efforts and local leadership in government, business, and advocacy sectors. Ultimately, Americans will experience the broad shifts of the energy transition in their neighborhoods and workplaces, and policy responses must be tailored to a community's distinct needs and constraints. Federal spending across a variety of programs will be implemented locally, and crucial policy choices that influence environmental outcomes, from land use to transportation planning to building codes, occur at the local level. Mayors, governors, local business and industry leaders, councilmembers, commissions, and community advocates are best positioned to shape the course of climate and energy policy in their jurisdictions and will play leading roles in the implementation of U.S. decarbonization.

Finally, it is evident that strong federal involvement will play a central role in managing society-wide decarbonization. The regional economic modeling illustrates the crucial role of federal-level policies that mitigate the disruptions of decarbonization, from expanding infrastructure investments to protecting energy-intensive trade-exposed industries. Industrial policy, crucially, will determine the technology pathways of the domestic energy system and will be instrumental in spurring domestic capabilities in hydrogen, carbon capture and storage, offshore wind, electric vehicles, batteries, and other energy solutions. New regulatory regimes will need to be developed, and social policies in labor and community development may have to be reformed or expanded. Federal research and development and policy instruments such as subsidies and grants will help complement state and local efforts and encourage robust private sector participation.

Renewed commitments to climate at the federal level, layered with growing state and local efforts and accelerating private sector involvement, suggest the United States is at a crucial juncture in its climate strategy. The next decade may prove to be the most consequential in the collective effort to stave off catastrophic climate change. The stories of the energy transition taking place in the Industrial Heartland, the Gulf Coast, Southwest Pennsylvania, and New Mexico are a preview of this transformation.

Appendix A. Modeling Memorandum

This memorandum summarizes and documents the input assumptions used in modeling the economic impact of deep decarbonization for the Roosevelt Project. This document includes several different sections for different segments of the modeling effort, including the inputs to the PLEXOS power sector model, assumptions regarding the electrification of fossil energy demand in the middle of the 21st century, and the policy design of the two scenarios. It also recaps the inputs to the Carbon Tax Assessment Model (CTAM) and the REMI economic model.

PLEXOS Assumptions and Inputs

Table 2: PLEXOS assumptions and inputs

Category	Sluggish Scenario	Paris Scenarios
Wind Costs	NREL	80% decrease by 2050
Solar Costs	NREL	80% decrease by 2050
Storage Costs	NREL	50% decrease by 2050
Nuclear Costs	NREL	50% decrease by 2050
CCUS for Power Generation	NREL	50% decrease by 2050
RPS Policies	Current law only	4% annual acceleration incremental to the Sluggish scenario for top 30 states with RPS from 2025
Renewable Capacity and Storage Build Limits	Historical 10-year regional and zonal annual maximums	Double zonal build limits by 2030 and, in later years, add a second tranche of solar build limits at 50% increased capital costs to increase builds
NO _x Valuation	N/A	\$2.26 per kilogram ²
SO ₂ Valuation	N/A	\$8.18 per kilogram ³

Energy Demand and Efficiency Assumptions

- Energy demand in the Sluggish scenario for liquid and gaseous fuels is defined by the AEO 2020 Reference Case.⁴ For PLEXOS, regional electricity load in the Sluggish scenario is based on the forecasts developed by the individual regions for FERC Form-714.⁵
- In the Paris scenarios, assumed residential, commercial, and industrial demand for energy would decrease to 75% of their AEO Reference case levels by 2050. For energy types besides electricity, this begins in 2021 and proceeds at 0.83% per year.⁶ This introduces a higher level of energy efficiency than the one present in the AEO Reference case. There are several exceptions to this process, which will be described in their individual sections.
- For PLEXOS, the Paris scenarios include only 75% of the underlying load by 2050. To avoid a “dip” in load in the short term but an increase in the long term for PLEXOS, this increase in energy efficiency comes online starting in 2036 instead of 2021.⁷
- This implies some states, and especially southerly ones with substantial air conditioning load though limited heating load (e.g., Florida and Texas), will have only modest net impacts on its load in the Paris scenarios. Conversely, northerly states with heating load coming online and relatively inefficient conversion of the same will have large net impacts.

Electrification Assumptions and Inputs

The first step in determining the electrified load for all three sectors involved developing an hourly temperature series by state (a “shape” for 8,760 hours per year).⁸ The data source to do this was the Climate Data Online Search from the National Centers for Environmental Information.⁹ This data is maintained by the National Oceanic and Atmospheric Administration (NOAA).

The data includes heating degree days (HDDs) and cooling degree days (CDDs) for weather station sites in each state, typically including major cities, airports, and military installations. To transform this data into temperatures, HDDs by hour were subtracted from 65° (25 HDDs implied a temperature of 40°), and CDDs by hour were added to 65° for the average of all the weather stations in a particular state. NOAA has no data for the District of Columbia—Maryland was its proxy.

This produced temperature shapes by state, which became useful inputs into the sector-by-sector analysis of electrified load. These inputs include hourly heating demand by state, the efficiency of electric heat pumps, and the efficiency of the batteries powering electrified vehicles.

The next three subsections walk through the assumptions for each of these sectors. Load from the electrification of heating, industrial processes, and transportation was added to the existing load for PLEXOS (after energy efficiency assumptions) to update load by region.

Residential and Commercial Heating

- By 2050, assumed all the remaining fossil energy demand (after energy efficiency adjustments) for residential and commercial customers would be electrified.
- The electrification would begin in 2031 and proceed at 5% per year over 20 years. This reflects an estimated technical lifespan of space- and water-heating equipment. By implication, no heating systems in working order are replaced before obsolescing.
- Used the share of HDDs by hour and by state to allocate the remaining (after efficiency) annual energy demand totals from the AEO Reference case to individual hours. This yields existing demand for heating in each hour but not the efficiency of conversion.
- Used a report from the American Gas Association (AGA) to estimate efficiency of conversion.¹⁰ Heat pumps are more efficient with the warmer temperatures in the southerly states and less efficient with the colder temperatures in the northerly states. This allows, for instance, for the electrification to be less efficient in Minnesota compared to Georgia.
- Based on the AGA data, modeled heat pumps as 100% efficient at 5° and 400% efficient at 55° and used a linear interpolation between them and for higher temperatures. For temperatures below 5°, assumed that heat pumps would still have 100% efficiency.
- Multiply calculated hourly energy demand for heating by state by the efficiency implied by temperature in the same hour for the same state. The conversion includes a 7% increase to account for transmission and distribution losses in the electrical system.
- For example, Alabama demanded 0.059 quadrillion BTUs of residential and commercial heating from fossil sources in 2050, according to the AEO Reference case and energy efficiency inputs. The share of heating demand for

the first hour of the year is roughly 1/2,800th of the annual total,¹¹ which equals 21,039 MMBtu.¹² The temperature in this hour is 42°, which implies an efficiency for the conversion of 332.0% (or only needing 31.1% of the energy required if the heating demand was coming from a fossil heating system).

- Multiplying together, converting to MWh, and adding the 7% adjustment for losses yields an increase in electricity demand from Alabama for this hour of 2,049 MWh.¹³ This process is repeated for all other hours between 2020 and 2050 and for all states.

Industrial Processes

- Electrification of fossil energy demand from industrial processes follows a similar means and uses some of the same data as the means for residential and commercial customers. On the other hand, there are some different assumptions and datasets as well.
- Instead of 100% of fossil energy demand undergoing electrification with the industrial sector, a maximum of 40% of fossil energy demand would be converted. This accounts for the fact that a certain segment of industrial processes is unsuitable for electrification. Hence, their emissions would remain and need offsets elsewhere. The timing of the conversions would be the same, though the rate of conversion is slower with the industrial sector.¹⁴
- The assumptions regarding energy efficiency in the industrial sector are the same as the ones in the residential and commercial sectors, with one exception. Six states are presumed to have double the energy efficiency gains compared to the others—down to 37.5% instead of 75% of 2050 demand. Those six are Alaska, California, Illinois, Louisiana, Pennsylvania, and Texas. These six have large petroleum-refining sectors relative to the size of their manufacturing sectors, warranting a further decrease in their fossil energy demand because the petroleum-refining sector would be significantly smaller in the Paris scenarios.
- The hourly shape for demand in the industrial sector comes from the Electric Power Research Institute (EPRI).¹⁵ The EPRI has data on the shape for industrial process heating for peak season, off-peak season, average weekday, and average weekend and for the 13 NERC regions, such as ECAR and ERCOT.¹⁶ This data was spread across 8,760 hours, and states were associated with NERC regions (such as Texas and the Texas Reliability Entity).
- From there, the calculation is like the one for residential and commercial customers. Fossil energy demand undergoing electrification (from the AEO Reference case's annual totals) is allocated across 8,760 hours based on the EPRI data by state. The efficiency of conversion in any given hour derives from the hourly temperature data by state and the AGA efficiency numbers for heat pumps—the same as residential and commercial. Electrified load from industrial processes also includes the 7% upcharge for losses.
- In general, industrial load has much less seasonality than heating load, which tends to come strongest in winter months. Industrial load exists at night, but it is strongest during the day, while heating load has the opposite pattern of being strongest at night.

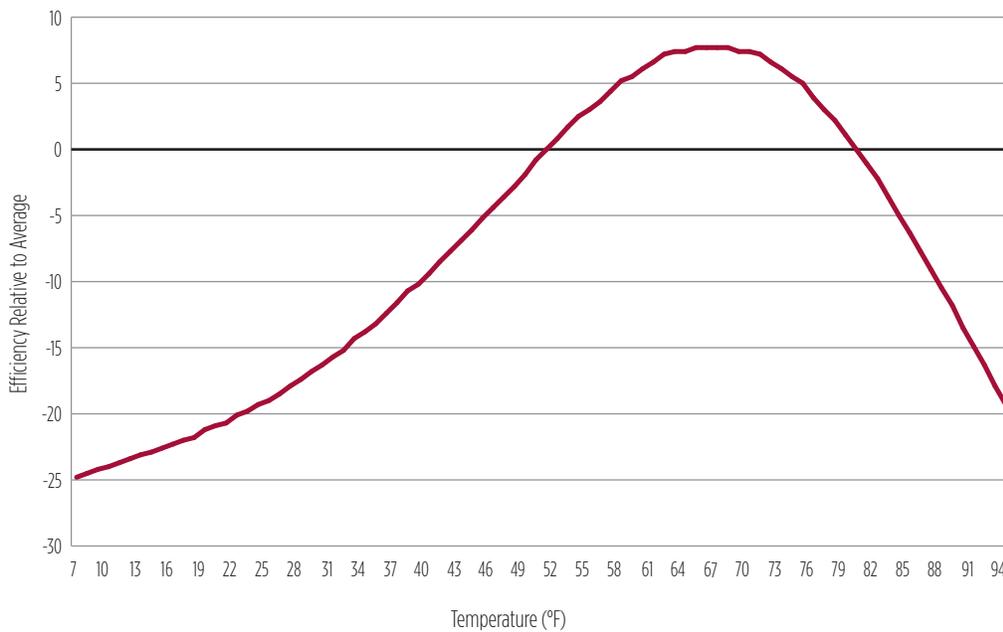
Electric Vehicle Fleet

- The assumptions in the transportation sector derive entirely from the AEO Reference case, including demand for vehicle miles traveled (VMT), the number of new cars and vehicles purchased by year by type, the rate of fleet

turnover for existing cars, and the demand for energy (either fossil or electricity) by the average vehicle on the road. The only parameter amongst these that changed was electric vehicles' share of new sales.¹⁷

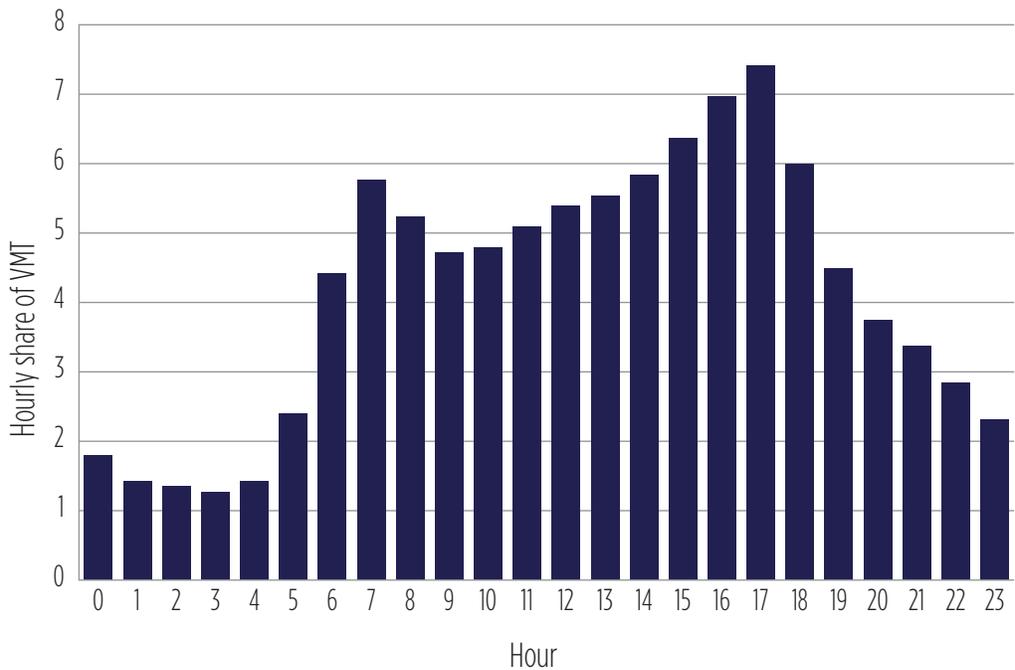
- For light-duty vehicles (LDVs), the Paris scenarios assume the same penetration rates for electric vehicles (EVs) as the AEO Reference case through 2025. Starting in 2026, market shares for EVs escalate to 80% by 2030¹⁸ before reaching an inflection point and increasing more slowly to 100% by 2035.¹⁹ This accounts for rapid (though not yet complete) adoption of EVs in the late 2020s with some holdouts, likely in rural areas, into the 2030s.
- For heavy-duty vehicles (HDVs), the Paris scenarios assume the same penetration rates for EVs as the AEO Reference case through 2025. Starting in 2026, the market share for EVs would increase rapidly to 60% by 2030 and then plateau.²⁰ It would not subsequently increase. This accounts for, like with industrial processes, the fact that certain HDVs, such as long-haul freight trucks and certain types of construction equipment, are inappropriate for electrification because of issues with energy-to-weight ratios that batteries are unlikely to meet.
- The bedrock assumption in calculating the new load associated with charging millions of new EVs was that VMT—travel demand, either for commutes, leisure travel, or deliveries—would not change in the Paris scenarios. To make VMT into demand for electricity, LDVs require 0.3 kWh per VMT,²¹ while HDVs require approximately 1.8 kWh per VMT.²²
- The hourly shape for vehicle charging load accounts for four factors. These include (1) the monthly pattern of VMT across states, (2) the efficiency of discharge from EV batteries at different temperatures, (3) hourly shape of VMT throughout the day, and (4) hourly shape of EV charging based on historical and projected data from California.
- The monthly pattern of VMT across states comes from the Federal Highway Administration (FHWA) and its Office of Highway Policy Information.²³ The analysis used all the data from 2010 through 2019 to avoid any anomaly years for any states, such as extreme winters in northerly states or natural disasters (e.g., hurricanes in Florida).
- The FHWA allowed for the creation of a monthly shape of driving patterns across the U.S. by state. Generally, northerly states have a more pronounced seasonal pattern, with more VMT concentrated in a “summer driving season” and relatively fewer VMT in the winter. Regions without consistently harsh winters, such as California and Florida, have fewer patterns and more consistent monthly shares for VMT across the months. This allows for national VMT from the AEO Reference case to be allocated to states and to months.
- EVs operate more efficiently at moderate temperatures—the efficiency of their batteries decreases with either hot or cold temperatures. To represent this, data from the Union of Concerned Scientists (UCS) on the efficiency (described as the share of the EVs' maximum range available at different temperatures) of a Nissan Leaf was used.²⁴
- Figure 15 summarizes this input. The Nissan Leaf (and by extension all EVs in this analysis) operate at better than its average efficiency at moderate temperatures from 52° to 79°. Efficiency declines with lower temperatures. Efficiency also declines with higher temperatures, increasing the effect of vehicular charging load on warmer southerly states, such as Arizona or Texas, compared to middle tier states with moderate temperatures.

Figure 15: Efficiency by temperature for EVs from UCS.



- The main purpose of the data in Figure 15 is to combine the hourly temperature data by state described earlier and other data on the average hourly driving shape. Together, this allows for an estimation of the average daily temperature—weighted by the actual hours of driving throughout the day—in any given day and in any given state.
- The hourly driving shape comes from the U.S. Department of Transportation (USDOT).²⁵ Figure 16 summarizes the hourly driving shape. Relatively few VMT happen in the middle of the night and early morning, before a large increase for the morning commute. VMT then dips slightly in the middle of the day before increasing again in the evening for the commute home and for the leisure and personal trips unrelated to work. VMT then decreases throughout the rest of the evening before hitting its trough at 3:00 a.m. to start again.
- The result produces daily average temperatures during the hours in which most VMT takes place, which is biased most heavily towards the midmorning and late afternoon. This data informs the demand for vehicle charging the next night and next day.

Figure 16: Hourly driving shape from USDOT.

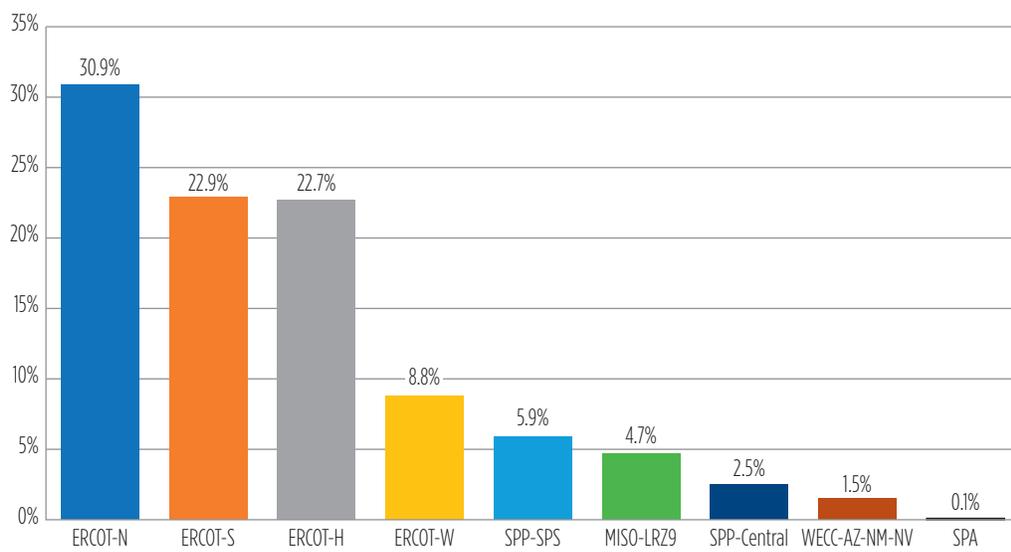


- The data from FHWA and from Figure 16 combine to yield VMT by month, day, and hour for every state and VMT-weighted average temperature for each day and state. The next step in the calculation is using the data from Figure 15 to calculate the need for vehicle charging based on the VMT and VMT-weighted temperatures the previous day.
- This adjusts the 0.3 kWh per LDV VMT average and the 1.8 kWh per HDV VMT average based upon the differences in temperature and VMT by season and state. For instance, Minnesota generally has cold conditions in the winter, reducing the efficiency of EVs and demanding more vehicle charging load of the MISO system. However, Minnesotans have very seasonal driving patterns, reducing the impact of this inefficiency because of the reduced VMT in the winter. Come the summer, Minnesota has comparatively moderate temperatures but higher-than-average VMT, the two factors again somewhat offsetting each other. Every state has its own calculation of this for each month based on temperature and VMT.²⁶
- The hourly charging shape within the day comes from research prepared for the California Public Utility Commission (CPUC).²⁷ The shape generally allocates most charging to late evenings and the middle of the night before the morning commute, has a brief increase in hourly shares of vehicle charging load in the middle of the day as vehicles are parked, and then has a rapid escalation in the late evening once drivers arrive at home. In aggregate, the charging shape from CPUC is close to the inverse of the data from Figure 16.

Building Load into PLEXOS

- The next step is adding the load from residential and commercial heating, industrial processes, and electric vehicle charging to the existing projected load in PLEXOS. As mentioned earlier, this load is adjusted down to 75% by 2050 to account for energy efficiency.
- CTAM works on a state-by-state basis, while PLEXOS works on a zonal level. To map between the two, the data source was ABB's Ventyx.²⁸ Ventyx is a subscription-based data service with information on different commodity markets, including electricity.
- Ventyx provides historical load by zone and by state. These underlie an analysis to map the PLEXOS zones to states (and vice versa). This allows for the transformation of outputs from PLEXOS or CTAM into inputs into the other, such as the new load from electrification in this section out of CTAM entering PLEXOS as additional electricity demand. The exact mapping is based on 2018 data because it was a neutral year in terms of weather.
- Figure 17 provides an example of this process for Texas. Most of Texas's load resides in ERCOT, including the three easterly zones and ERCOT-W. The rest of Texas resides in the SPS zone of SPP, MISO LRZ-9, and SPP-Central, with trace amounts in WECC and SPA.²⁹

Figure 17: Texas load share (and allocation) by zone.



Policy Design

Table 3 documents the assumptions used in CTAM in building inputs to the REMI model. While the outputs of the Paris scenarios from PLEXOS were the same between the Decarbonized scenario and the Roosevelt scenario, there were variations between them in CTAM and REMI.

There were no alternations made to the default REMI model, save for updating the macroeconomic forecast from the University of Michigan³⁰ and the Congressional Budget Office before finalizing the simulations. These updates reflect the developing macroeconomic situation across the United States with the COVID-19 pandemic and recovery from the same. However, this update does not change much of the long-term structure of the U.S. economy during the deep decarbonization.

Table 3: List of policy design considerations in CTAM and REMI.

Policy Design	Sluggish	Decarbonized	Roosevelt
Emissions Goal	None	0% of 1990 emissions by 2050 (achieved on a linear trend)	0% of 1990 emissions by 2050 (achieved on a linear trend)
Carbon Pricing	None	\$40 per metric ton beginning in 2025 and escalating at 8% per year (in real terms)	\$40 per metric ton beginning in 2025 and escalating at 8% per year (in real terms)
Revenue Recycling	N/A	Per capita dividends	Per capita dividends adjusted for regional carbon intensity
Border Adjustment	None	None	Included for “heavy” manufacturers
Administrative Expenses	None	Assumed to be 1% of carbon tax revenues ³¹	Assumed to be 1% of carbon tax revenues ³²
Infrastructure Investments	None	None	\$1.5 trillion over 10 years starting in 2025 ³³
Worker Retraining	None	None	1% of carbon tax revenues set aside for working retraining ^{34,35}
Domestic Battery Production	N/A	Assumed 10%	Assumed 40%
Cost of Offsets	None	Starts at \$400 per ton, declines to \$200	Starts at \$400 per ton, declines to \$100 ³⁶
Offset Type	None	Direct air capture	Direct air capture
Energy Efficiency	AEO Reference case	75% of AEO Reference case demand achieved by 2050 (linear trend) ³⁷	75% of AEO Reference case demand achieved by 2050 (linear trend) ³⁸
Heating Electrification	AEO Reference case	5% of residential and commercial heating load converted between 2031 and 2050 each year	5% of residential and commercial heating load converted between 2031 and 2050 each year
Industrial Process Electrification	AEO Reference case	2% each year converted between 2031 and 2050	2% each year converted between 2031 and 2050
LDV Electrification	AEO Reference case	80% adoption by 2030, 100% by 2035	80% adoption by 2030, 100% by 2035
HDV Electrification	AEO Reference case	60% adoption by 2030, goes no higher	60% adoption by 2030, goes no higher
Carbon Intensity of Transportation Fuels	AEO Reference case	AEO Reference case	25 lower carbon intensity by 2050

Vehicle Electrification Costs³⁹

Table 4. List of electric vehicle electrification costs for LDVs.⁴⁰

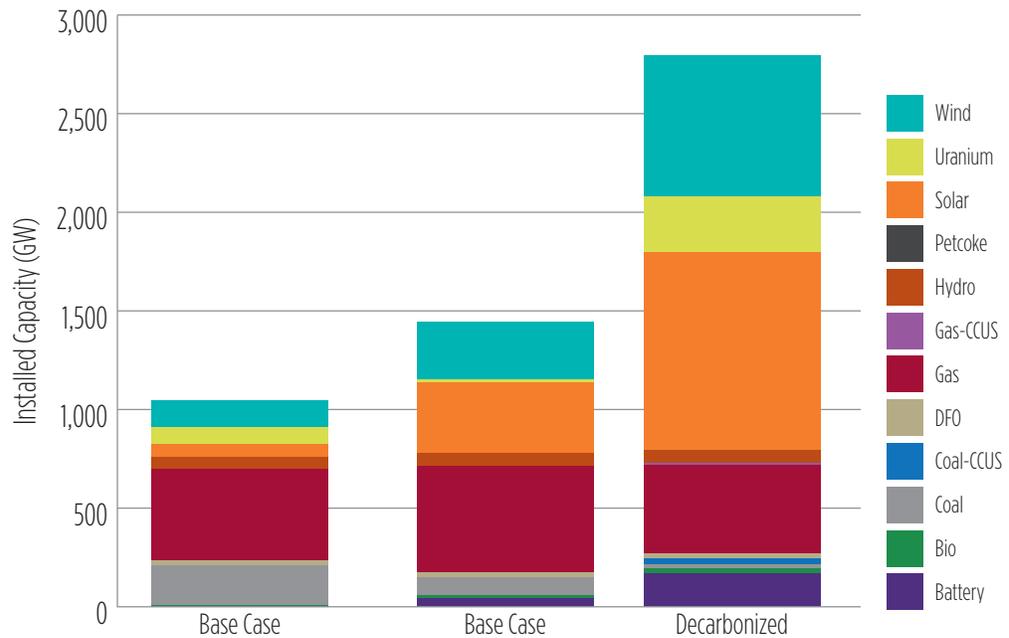
Cost Type	2019	2031 and thereafter
Charting Infrastructure Costs ⁴¹	\$5,100 per vehicle	\$5,100 per vehicle
Average ICE Powertrain	\$3,918 per vehicle	\$4,491 per vehicle
Average Electric Motor	\$701 per vehicle	\$198 per vehicle
Average Vehicle Batteries	\$16,464 per vehicle	\$4,293 per vehicle
Average Maintenance	\$300 per year per LDV	\$300 per year per LDV
HDVs	5x average LDV	5x average LDV

Generating Capacity Assumptions. To determine macroeconomic changes, the analysis used PLEXOS to assess what a decarbonized future might look like in the electricity sector, relying on two scenarios. The first is the Base Case, which mirrors the EIA 2020 Annual Energy Outlook base case. This scenario assumes that demand will continue to grow, that cost declines in renewable technologies are relatively modest, and that electrification is not widespread. Further, the Base Case assumes that clean energy policies will remain at current levels through 2050 and limits new renewable and storage construction to the historical 10-year regional maximum.

The second scenario, Decarbonized, was designed to meet an emissions reduction goal of zero percent of 1990 emissions by 2050, via significant economy-wide electrification, including substantial shifts in both the transportation and building sectors. This scenario primarily relies on a nationwide, escalating carbon price to meet that goal. It also assumes steeper cost declines and aggressive state-level mandates for low-carbon technologies, and it allows substantially more renewables construction above the historical level. The Decarbonization electric sector scenario is used as a foundation for both the Decarbonized and Roosevelt scenarios described in the preceding sections.

In both the Base Case and Decarbonized scenarios, PLEXOS chooses to build new wind, solar, and battery resources as demand increases due to electrification and legacy coal plants retire. However, the Decarbonized scenario builds substantially more capacity overall, which includes wind and solar, as well as more battery and new nuclear capacity. Natural gas resources are kept online to maintain grid reliability, and the model achieves net zero emissions via a set of offsets representative of the cost of direct air capture. Figure 18 illustrates the installed capacity across the United States in 2021 compared to 2050 in the Base Case and the Decarbonized scenarios.

Figure 18: U.S. installed generating capacity in the Base Case and Decarbonized/Roosevelt PLEXOS scenarios, 2021 and 2050.



Of course, no energy analyst has a crystal ball that will perfectly (or even imperfectly) predict the makeup of the electricity grid in 2050. The renewable resources that currently reign, wind and solar, may compete at substantially different levels. Nuclear power may reemerge as a low-cost, zero-carbon baseload resource in the coming decades, or it may continue to face major capital cost and regulatory barriers in the United States. New types of battery storage and other emerging technologies such as hydrogen are showing promise in terms of filling the grid reliability role that natural gas resources currently occupy. Carbon capture and sequestration may likewise play a major role. Many scholars are doing important work on how exactly the many competing factors in these sectors can lead to the cleanest, most affordable, and most reliable grid.

Notes

- 1 The modeling contained in this section is supported by the work of Scott Nystrom, Mitch DeRubis, Ken Ditzel, Fengrong Li, and Ran Li of FTI Consulting, Inc., an independent global business advisory firm. The conclusions expressed herein are those of the authors and not necessarily the views of FTI Consulting, Inc., its management, its subsidiaries, its affiliates, or its other professionals.
- 2 From REMI model.
- 3 From REMI model.
- 4 <https://www.eia.gov/outlooks/archive/aeo20/>.
- 5 <https://www.ferc.gov/industries-data/electric/general-information/electric-industry-forms/form-no-714-annual-electric/overview>.
- 6 A linear slope of 0.83% per year starting in 2021 over 30 years ending at 75% in 2050.
- 7 A linear slope of 1.67% per year starting in 2036 over 15 years ending at 75% in 2050.
- 8 Leap years accounted for by repeating the data from February 28 for February 29.
- 9 <https://www.ncdc.noaa.gov/cdo-web/search>.
- 10 https://www.aga.org/globalassets/research--insights/reports/AGA_Study_On_Residential_Electrification, p. 16.
- 11 A disproportionate amount compared to 1/8,760th, which is sensible for the middle of the night in early January.
- 12 $0.059 \text{ quadrillion BTUs} * 1/2800 = 0.000021 \text{ quadrillion BTUs} = 21,039 \text{ MMBtu}$.
- 13 $21,039 \text{ MMBtu} * (1/332.0\%) = 6,534 \text{ MMBtu} * (1 + 7\%) = 6,991 \text{ MMBtu of power} = 2,049 \text{ MWh}$.
- 14 A linear slope of 2.0% per year starting in 2031 (instead of 5.0% per year) over 20 years ending at 40% in 2050.
- 15 <https://loadshape.epri.com/enduse>.
- 16 Roughly corresponding to https://www.eia.gov/electricity/data/eia411/images/nerc_old.jpg.
- 17 Thereafter modeling the electric vehicle fleet using AEO Reference case assumptions.
- 18 At 16% per year from the AEO Reference case's low baseline near 0%.
- 19 At 4% per year, from 80% in 2030 to 100% in 2035.
- 20 At 12% per year from the AEO Reference case's low baseline near 0%.
- 21 <https://pluginamerica.org/how-much-does-it-cost-charge-electric-car/>.
- 22 Implied by the AEO Reference case.
- 23 https://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm.
- 24 <https://blog.ucsusa.org/dave-reichmuth/electric-cars-cold-weather-temperatures>.
- 25 <https://www.volpe.dot.gov/sites/volpe.dot.gov/files/docs/Estimating-Vehicle-Hours-of-Travel.pdf>.
- 26 Florida, for instance, has little seasonality in its VMT, but its high temperatures in the summer decrease the efficiency of its EV fleet, which therefore means a larger increase in FRCC's summer load than its winter load.
- 27 https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2019-2020-irp-events-and-materials/inputs--assumptions-2019-2020-cpuc-irp_20191106.pdf.
- 28 <https://global.abb/group/en/about/history/heritage-brands/ventyx>.
- 29 Southwestern Power Administration.
- 30 <https://lsa.umich.edu/econ/rsqe.html>.
- 31 Allocated between states based on their share of federal civilian employment, which, practically, means most of these expenditures would be in the District of Columbia, Maryland, and Virginia.
- 32 Ibid.
- 33 Allocated between regions based 100% of regional emissions from 2025 through 2029 and then 50% based on regional emissions and 50% based on regional population from 2030 through 2034.
- 34 Worker retraining expenditures allocated between regions based on their share of direct fossil employment (defined to include oil and gas extraction, coal, drilling oil and gas

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- wells, support activities for oil and gas, electricity from fossil, gas distribution, petroleum refineries, oil and gas equipment manufacturing, and pipeline transportation).
- 35 Workers retrained for \$50,000 each, leading to 1.2 million retrained by 2050, and allocated with 25% for utilities; 20% for construction; 5% for professional, scientific, and technical services; and 12.5% each for motor vehicles, fabricated metals, chemicals, and waste management and remediation services.
 - 36 Expenditures on offsets modeled as direct air capture (DAC) technology, including 50% for the REMI sector for chemical manufacturing, 25% for the construction sector, and 25% for the utility sector.
 - 37 Preexisting electricity load begins its decrease in 2036 instead of 2021 to avoid short-term reductions in load.
 - 38 Preexisting electricity load begins its decrease in 2036 instead of 2021 to avoid short-term reductions in load.
 - 39 Assumptions for vehicle electrification costs derive from Sanya Carley's email of Monday, August 10, 2020, unless noted.
 - 40 Linear trend from 2019 costs to 2031 costs.
 - 41 FTI analysis.

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