AFL-CIO
AMERICA'S UNIONS

ENERGY FUTURES INITIATIVE

Energy Transitions

Labor Energy Partnership

The Labor Energy Partnership (LEP) is based on a shared commitment of the AFL-CIO and the Energy Futures Initiative to federal, regional and state energy policies that promote economic, racial and gender equity based on quality jobs and the preservation of workers' rights while also addressing the growing climate crisis.

AFL-CIO Energy Committee

The Energy Committee of the AFL-CIO Executive Council was formed in 2013. The committee is chaired by Cecil E. Roberts, who has been president of the United Mine Workers since 1995 and is a sixth-generation coal miner. The committee's vice-chair is Lonnie R. Stephenson, International President of the International Brotherhood of Electrical Workers, who began his IBEW career in 1975 as an apprentice wireman in Rock Island IL. The committee also includes the Laborers International Union of North America, the United Association of Plumbers, Fitters, Welders & Service Techs, the International Union of Operating Engineers, the United Steelworkers, the Utility Workers Union of America, the International Brotherhood of Boilermakers, the International Federation of Professional and Technical Engineers, the International Association of Bridge, Structural, Ornamental and Reinforcing Iron Workers Union, and North America's Building Trades Unions.

Energy Futures Initiative

The Energy Futures Initiative advances technically grounded solutions to climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, EFI conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. EFI, based in Washington, DC, maintains editorial independence from its public and private sponsors.

www.energyfuturesinitiative.org

Abbreviations

AFL-CIO	American Federation of Labor and Congress of Industrial Organizations
ASCE	American Society of Civil Engineers
BECCS	bioenergy with carbon capture and sequestration
CCS	carbon capture storage
CCUS	carbon capture, utilization, and sequestration
CO_2	carbon dioxide
DOE	Department of Energy
EFI	Energy Futures Initiative
EIA	Energy Information Administration
EU	European Union
FERC	Federal Energy Regulatory Commission
GDP	Gross Domestic Product
GHG	greenhouse gas
H_2	hydrogen
GNA	Good Neighbor Agreements
GREEN	Growing Renewable Energy and Efficiency Now
GW	gigawatts
HVAC	heating, ventilation, and air conditioning
HVDC	high voltage, direct current
IEA	International Energy Agency
ISO	Independent System Operators
ITC	Investment Tax Credit
LEP	Labor Energy Partnership
LNG	liquefied natural gas
MMmt	Million Metric Tons
NAFTA	North American Free Trade Agreement
PNTR	Permanent Normal Trade Relations
RD&D	research, development, and demonstration
RTO	Regional Transmission Organizations
SMR	Small Modular Reactors
UK	United Kingdom
USEER	U.S. Energy and Employment Report
USGS	U.S. Geological Survey

Introduction

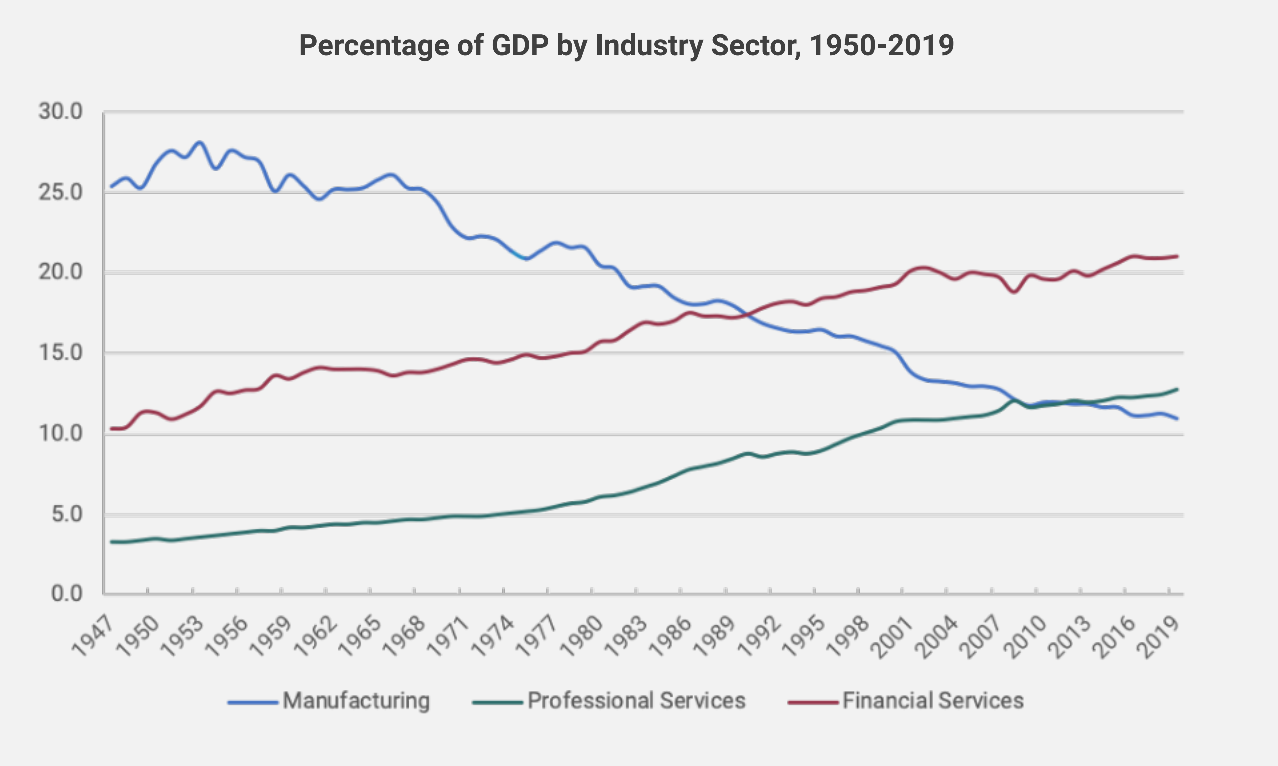
The Framework for Good Jobs in a Low-Carbon Future

Industrial transitions have rarely been smooth. They have been typically marked by community and worker dislocations with significant regional disparities, disproportionate impacts on minority communities, and the fraying of existing social institutions, including public education systems, local government services, unions, and even religious organizations.

In addition to macro-factors such as consumer preferences or globalization, industrial transitions have typically been triggered by disruptive technologies that radically changed cost structures and rendered previous modes of production obsolete. However, other have been caused by significant policy shifts such as the free trade agreements, NAFTA and PNTR, in the 1990's and early 2000's. Whether technology or policy driven, the US has had an uneven track record of managing these industrial transitions in ways that provided the impacted employees and their communities with the tools and resources to rebuild. Too often, total reliance on free market forces to manage the economy has resulted in avoidable economic harm to workers and communities.

The U.S. economy from 1950 to 2019 provides an example. Over the course of two short generations, the relative roles of manufacturing and financial services flipped. Manufacturing was 28.1% of GDP in 1953

Figure 1 | Changes in Sector Contributions to GDP Over 70 Years



and 11% today; its workforce has declined from its high point of 21 million in 1979 to its current 12 million, even as its actual contribution to GDP measured in dollars rose from $1.035 trillion in 1990 to $2.4 trillion today. Meanwhile, the financial sector rose from 10.9% of GDP in 1970 to 21% today and is now our economy's largest sector. Professional services, now the second largest, rose from 3.5% of GDP in 1950 to 12.8% today (see Figure 1).

Education or "re-education" is often offered as the primary response to this shift, and while the percentage of the work force that is college-educated rose from 10% in 1970 to 33% today, inequality also rose to historic levels, and in many sectors job quality declined significantly. What worked well for some people and for cities where the technology, financial and professional services sectors are concentrated clearly did not help many others. But for the regions of America that were hardest hit by the downward trajectory of the manufacturing sector, there was no effective transition: household incomes declined, populations shrank, health disparities increased, and life expectancy contracted.

Today's Transition is Both Different and Urgently Needed

There is a clear difference between today's imperative for a transition to a low carbon economy and other past industrial dislocations. This transition is being enabled by the growing competitiveness of new technologies, and will be shaped by trade agreements and other public policies, but these are not its primary causes..

Instead, the origins of this transition are grounded in the need to address the existential threat of climate change and will be driven in large part by public actions, programs, policies and investments, designed and implemented by federal and state governments to regulate and subsidize the growth of low carbon technologies. As such, *it is the duty and obligation of policy makers to embrace solutions to industrial dislocation as fundamental to a clean energy economy transition's design and implementation, technological evaluation, and how regions and localities are supported*.

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The Labor Energy Partnership

It is in this context that on Earth Day, 2020, the AFL-CIO and the Energy Futures Initiative announced the formation of the Labor Energy Partnership (LEP). This partnership is based on four core principles:

1. Energy policy must be based on solid scientific review that acknowledges that climate change is real, anthropogenic, and represents an existential threat to human society.

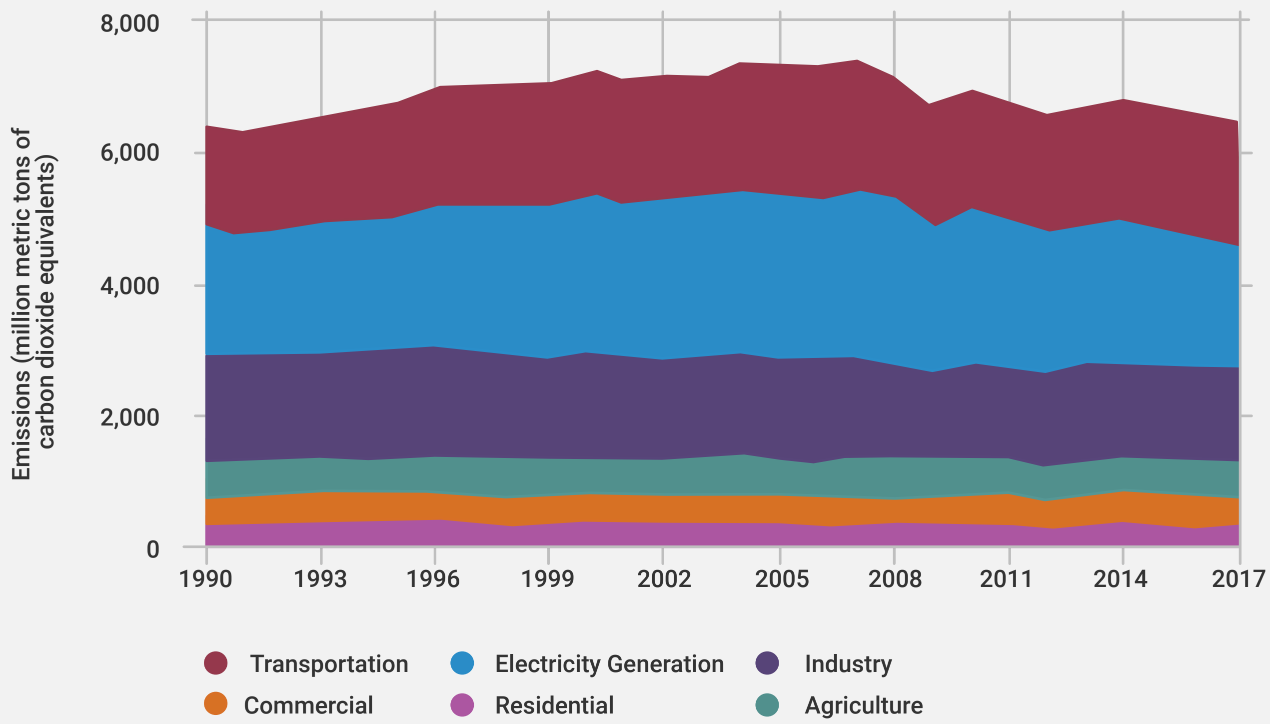
2. Successful solutions to social equity and other social implications of deep decarbonization must be based on an energy source strategy that is regionally focused, flexible, preserves optionality, and addresses the crisis of stranded workers.

3. An essential priority of all climate policy solutions is the preservation of existing jobs, wherever possible, and the creation of new ones that are equal to or better than those that are displaced.

4. Climate policy represents an economic opportunity to the United States when the benefits of new technology deployment result in the creation of quality jobs and the creation of competitive domestic supply chains.

This is the LEP's inaugural document, *Energy Transitions: The Framework for Good Jobs in a Low-Carbon Future*. It summarizes ten key areas of analysis, the results of which will help guide us as we launch a multi-decadal effort to create a clean energy economy that is more equitable for all Americans and can be

Figure 2 | U.S Greenhouse Gas Emissions by Economic Sector, 1990-2017



Source: Adapted from U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2017. EFI, 2020.

sustained across our diversity of political views, regional differences, and economic challenges for the next thirty years. This document and the analytical framework that it articulates for creating new jobs and advancing social equity in a deeply decarbonized economy, will focus on emissions from all economic sectors, a critical distinction between the LEP and other groups that tend to focus only on electricity, which only accounts for a third of US emissions (Figure 2).

While we do not address the wider set of social issues that our country is currently grappling with—access to healthcare, systemic racial disparities, and gender equity, to name a few—we do strive to create a path forward on climate solutions that can contribute to improving social equity.

The leadership of the LEP has identified ten key areas that are critical to creating a unified path forward for the implementation of climate solutions in the United States. Each element requires an unbiased analysis that identifies challenges, opportunities, needed investments, and policy options. These 10 critical elements are:

1. A national action plan for the deployment of carbon capture, utilization, and sequestration technology;
2. A priority energy infrastructure analysis that provides a roadmap for key energy infrastructure needs, financing mechanisms, and approval and permitting pathways;
3. Policies needed to site and permit new electricity transmission projects in the near-term;

4. Options for safe and affordable preservation of the existing nuclear fleet and the deployment of next generation nuclear technologies;

5. Development of technology and policy pathways for the use of natural gas consistent with meeting climate goals;

6. An exploration of the economic challenges and costs and benefits of developing hydrogen as an alternative fuel for transportation, power, and industrial sectors

7. The expansion of energy efficiency finance mechanisms and policy recommendations to enable the full utilization of energy efficient technologies in commercial and residential buildings, industrial processes, and transportation;

8. An assessment of the capacity of the United States to mine, process, and manufacture the critical minerals and materials necessary for the domestic production of low-carbon technologies including, but not limited to, rare earths, lithium, cobalt, copper, nickel, and palladium;

9. An analysis of the offshore wind supply chain, including its raw material requirements, manufacturing technologies, and geographical differences between the East Coast, West Coast, and Great Lakes' resources and policy options to encourage domestic development; and,

10. A roadmap for implementing natural and engineered carbon dioxide removal at scale.

This paper offers a short summary of the critical nature of each of these elements of the LEP. In the months ahead, it is the goal of the LEP to provide an analytical framework for the technological and social criticality of these issues.

To be clear, these are not the only critical issues that need to be addressed in order to mitigate the climate crisis. For instance, we need to drive down the costs of renewable energy technologies like wind and solar over the next two decades while increasing battery storage capacity. Without addressing these ten issues, however, it will be significantly more difficult to build the social, regional, and economic coalitions necessary to sustain a thirty-year effort to move our country into its low carbon future.

Element No. 1

A national action plan for the deployment of carbon capture, utilization, and sequestration technology.

Carbon capture, utilization, and sequestration technologies (CCUS), removes carbon dioxide, the primary greenhouse gas (GHG) emission from combustion streams, preventing it from being released into the atmosphere and allowing it to be permanently stored underground or used in other chemical or manufacturing processes.

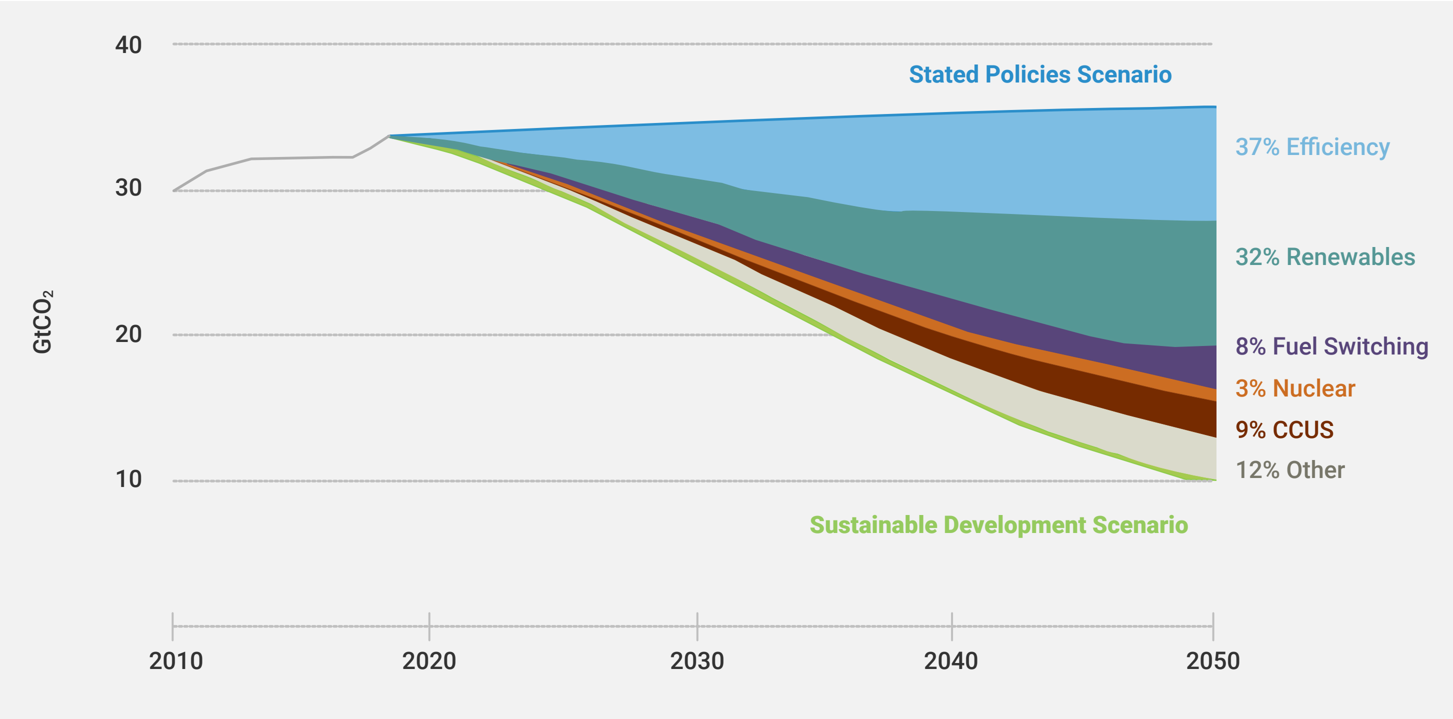
CCUS technology is currently in use or development in over 170 projects or pilot plants around the world, including several in the United States and Canada. These projects include the Boundary Dam power plant in Alberta, CA, the Illinois Industrial CCS facility at a biofuels plant in Decatur, IL, and the Great Plains Synfuels plant in North Dakota.[1]

More importantly, the International Energy Agency, the pre-eminent agency monitoring global GHG emissions and tracking pathways to meeting the Paris Climate Agreement reduction targets has found, in its Sustainable Development Scenario relative to it States Policies Scenario (fundamentally Paris commitments), that 9% of global emission reductions must come from CCUS applications (see Figure 3).[2]

CCUS is the only technology currently capable of decarbonizing the high-grade process heat required in energy intensive industries, including steel, aluminum, pulp and paper, chemicals, cement, and a handful of others. These five industries produce 70% of industrial GHG emissions both in the U.S. and globally. Industrial emissions make up about 20% of all emissions.[3]

In addition, CO_2 can be used in other industrial processes such as the production of

Figure 3 | Emissions Reductions in IEA's Sustainable Development Scenario Relative to its State Policies Scenario and Technologies Needed for Mid-Century



Source: Adapted from IEA, 2019. EFI, 2020.

methanol and fertilizers. CCUS technology could also repurpose some of the pipeline infrastructure that currently supports oil and gas transmission, providing continued employment for this sector. Energy intensive industries in the United States employ over 1.7 million Americans with 68% of those jobs concentrated in just 15 states, including Texas, California, Ohio, Pennsylvania, Indiana, Illinois, North Carolina, and Michigan. These capital-intensive, durable manufacturing industries have high job multiplier impacts in the communities where they are located, generally creating 7.4 indirect jobs in addition to each direct job.[4]

Unlike other sectors of the economy, these industrial sectors cannot be electrified since electricity cannot create the high-grade process heat necessary for manufacturing these products. In addition, CCUS can have important applications in other sectors, including the power sector, where it can be used in both natural gas and coal-fired plants. The cost-effective development of these technologies will be especially important in lesser developed countries where it may represent the cheapest way to introduce low carbon electricity at a broad scale. India, for instance, currently produces 84% of its electricity from coal-fired electricity generation.[5]

CCUS is also considered to be a critical technology for reducing emissions around the world. The UK is the first European country to adopt net zero emissions targets. The EU net zero plan notes that "[c]arbon capture and storage (CCS) in industry ... and very likely for hydrogen and electricity production ... is a necessity, not an option."

CCUS technologies are at varying stages of development. Advancing the associated technologies could provide a critical pathway for industrial and power generation emissions reductions. It would also create a global market for these technologies. Figure 4 shows the range of options for CCUS; investments and incentives should be

Figure 4 | Technology Readiness Levels Along the CCUS Value Chain

Large Prototype

CO_2 Capture in Iron & Steel
- Direct Reduction - Oxygen Rich Physical Adsorption
- Blast Furnace - Process Gas Hydrogen Enrichment - Chemical Absorption

CO_2 Capture in Cement
- Cement - Oxy Fueling
- Cement - Physical Adsorption
- Cement - Direct Separation

CO_2 Capture from Air
- Direct Air Capture - Solid
- Direct Air Capture - Liquid

CO_2 Capture in Chemicals
- Bioethanol from Lignocellulose with Carbon Capture
- Hydrogen from Coal with Carbon Capture
- Ammonia - Physical Adsorption

CO_2 Transport
- Ship - Port to Offshore

CO_2 Use
- Synthetic Liquid Hydrocarbons

Demonstration

CO_2 Capture in Iron & Steel
- Smelt Reduction - Oxygen - Rich Physical Absorption

CO_2 Capture in Cement
- Cement - Chemical Absorption
- Cement - Calcium Looping

CO_2 Capture in Chemicals
- Methanol - Physical Absorption
- Methanol - Physical Adsorption
- High-value Chemical - Physical Absorption
- High-value Chemical - Chemical Absorption

CO_2 Capture in Fuel Prod.
- Biomethane with Carbon Capture
- Bioethanol from Sugar/ Starch with Carbon Capture

CO_2 Capture in Power Gen.
- Coal - Oxy-fueling
- Coal - Pre-cumbustion
- Natural Gas - Chemical Absorption
- Biomass - Chemcial Absorption

CO_2 Transport
- Ship - Port to Port

CO_2 Storage
- Depleted Oil Reservoirs

CO_2 Use
- Methanol
- Synthetic Methane

Early Adoption

CO_2 Capture in Iron & Steel
- Direct Reduced Iron - Chemical Absorption

CO_2 Capture in Chemicals
- Ammonia Tanker
- Methanol - Chemical Absorption

CO_2 Capture in Fuel Prod.
- Hydrogen from Gas with Carbon Capture

CO_2 Capture in Power Gen.
- Fossil-based Methanol with Carbon Capture

CO_2 Transport
- CO_2 Pipelines

Mature

CO_2 Capture in Chemicals
- Ammonia - Chemical Absorption

CO_2 Use
- Enhanced Oil Recovery

CO_2 Storage
- Urea

Source: EFI, 2020. Adapted from IEA, 2020.

analyzed to address each development stage of the various technologies.

Cost is a major roadblock to moving CCUS technology through the innovation pipeline in the U.S. A key factor in the development of CCUS technology will be long-term, stable incentives for the development of this industry. Currently, the 45Q tax credit provides an incentive to capture CO_2 (Figure 5); however, any projects must start construction prior to 2024.

Finally, U.S. leadership in the deployment of CCUS technology will create a new and important manufacturing industry in the U.S. with significant export potential. One Norwegian study estimated that if Norway became a leader in manufacturing and installing CCUS technology and storing CO2, they would preserve 80,000 to 90,000 jobs and create 30,000 to 40,000 new jobs. IEA, in its sustainable development scenario, estimates that over 2,000 CCS facilities would need to be in operation by 2050, requiring a build rate of 70-100 facilities per year and supporting 70-100,000 construction workers and over 30,000 to 40,000 facility operators.

In another recent study, the Carbon Capture Coalition estimates that the CCUS industry in the United States could employ between 100,000 and 140,000 employees in construction and operations, while also creating additional jobs in pipeline transportation and storage.[6]

Given the importance of CCUS technology to the decarbonization of the industrial sector, its strategic value to the global economy, and its regional importance to in the United States, creating a roadmap to its deployment in the United States is of key importance. The LEP will focus its efforts to identify strategies to accelerate the pace of CCUS deployment, with attendant GHG emissions reductions and job creation. The LEP will consider, for example, opportunities to piggyback on existing rights of way for new CCUS infrastructure, address liability risk, promote new business models and identify more effective financial incentives.

Element No. 2

A priority energy infrastructure analysis that provides a roadmap for key energy infrastructure, financing mechanisms, and approval and permitting pathways in a deeply decarbonized economy.

American infrastructure needs are a sore point in almost every part of the country. When Gretchen Whitmer ran for Governor of Michigan in 2018 on the slogan, “fix the damn roads!” it resonated with every American. Energy infrastructure is no different.

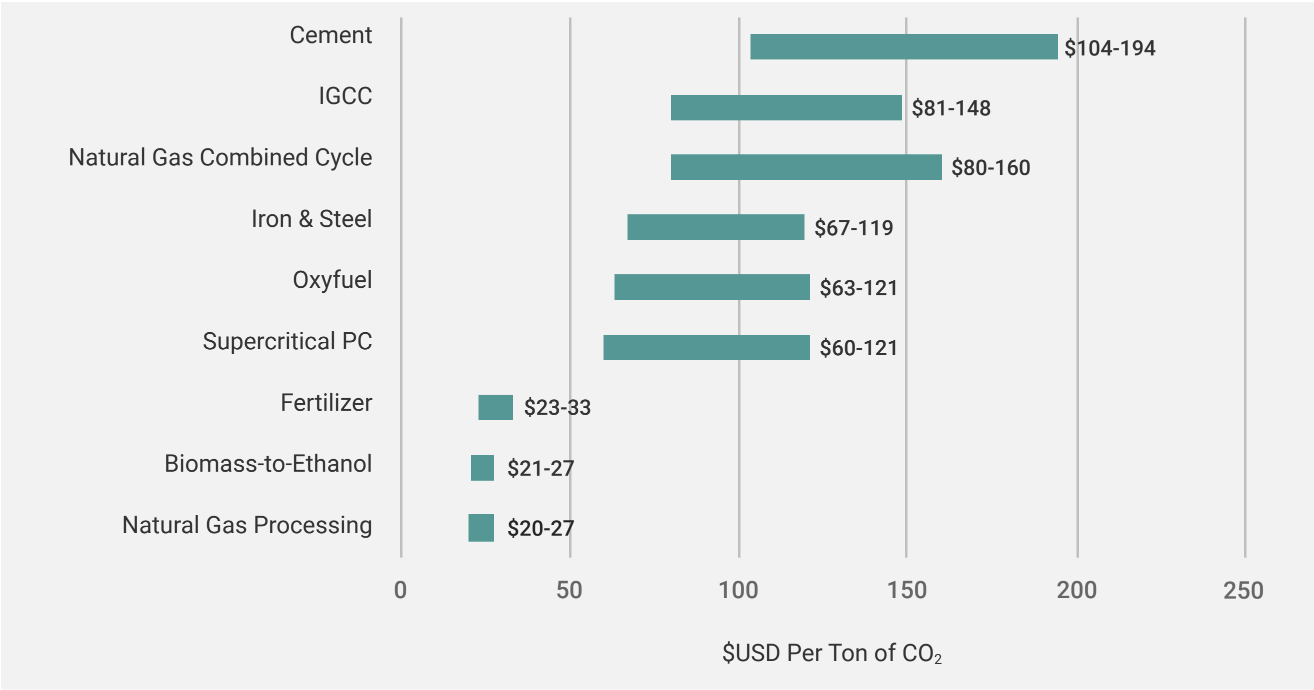
Existing transmission, distribution, and storage infrastructures link energy supplies to intermediate and end users. They include:

- 2.6 million miles of interstate and intrastate pipelines;
- 414 natural gas storage facilities;
- 330 ports handling crude petroleum and refined petroleum products;
- 140,000 miles of railways that handle crude petroleum, refined petroleum products, liquefied natural gas (LNG), and coal;
- 642,000 miles of high-voltage transmission lines;
- 6.3 million miles of distribution lines[7]

Every four years the American Society of Civil Engineers (ASCE) issues a report card on American infrastructure. The 2017 ASCE report gave U.S. energy infrastructure a D+. Currently, the electricity portion of energy infrastructure would need to spend $177 billion dollars over a decade in addition to the $100+ billion it already spends annually to raise our electricity infrastructure to a B level. This additional spending would improve the efficiency and reliability of the system, but it does not include a focused plan to decarbonize the electrical system over the coming decades.[8]

Analyses suggest the costs of decarbonizing the U.S. electrical system, ranging from $4.5 trillion to achieve 100% renewables in 12 years[9] to $5 trillion[10] to various hybrid

Figure 5.1 | Estimated and Measured First-of-a-Kind Costs for CCS Applied to Different Plants



Source: Adapted from Global CCS Institute, 2017. EFI, 2018.

Figure 5.2 | Tax Credit Value Available for Different Sources and Uses of CO_2

	Minimum Size of Eligible Carbon Capture Plant by Type ($ktCO_2$)			Relevant Level of Tax Credit in a Given Operational Year ($USD/$tCO_2$)									
Type of CO_2 Storage/Use	Power Plant	Other Industrial Facility	Direct Air Capture	2018	2019	2020	2021	2022	2023	2024	2025	2026	Beyond 2026
Dedicated Geological Storage	500	100	100	28	31	34	36	39	42	45	47	50	Indexed to Inflation
Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35	
Other Utilization Processes[1]	25	25	25	17[2]	19	22	24	26	28	31	33	35	

[1] Each CO_2 source cannot be greater than $500ktCO_2$/yr
[2] Any credit will only apply to the portion of the converted CO_2 than can be shown to reduce overall emissions

Source: EFI, 2018.

Table 1 | Opportunities for Using Existing Carbon Infrastructure for Decarbonization

	Oil Refining & Natural Gas Processing	Natural Gas Generation	Oil & Gas Pipelines	Waterborne Transport & Ports	Storage
Biofuels	Conversion of oil refineries to bio-refineries Upstream blending of oils with drop-in biofuels Applying industry expertise	See renewable natural gas example below	Transporting biofuels in petroleum product pipelines Leveraging pipeline rights-of-way	Using fuel storage and transportation hubs	Using underground storage tanks for biofuels and petroleum-biofuel blends
Hydrogen Fuel or Feedstock	Leveraging industry expertise using hydrogen safety Producing hydrogen Redirecting hydrogen currently produced for refining petroleum to perform other energy services	Co-firing hydrogen (up to 50 percent) with NG Gas turbine combined-cycle plants with expect efficiency ≥ 60 percent	Doping in NG pipelines (≤ 15 percent with minor pipeline upgrades needed) Leveraging pipeline right-of-way	Using fuel storage and transportation hubs	Using salt caverns and other geologic formations Capitalizing on industry expertise with NG storage
Negative Emissions Technologies, CCUS	Applying industry expertise to CCUS technologies for DAC and BECCS	Applying industry expertise: CCUS technologies for DAC and BECCS	Using compression technologies similar to those in NG infrastructure for CO2 Rail and roadway = existing infrastructure Leveraging pipeline rights-of-way	Using industry expertise in liquefaction and transport of LPG/LNG for liquid CO2 Marine vessels for CO2 using the same technology as existing LPG or LNG tankers Port infrastructure for loading Offshore facilities for subsea injection	Using saline formations, depleted O&G reservoirs, un-mineable coal seams, basalt formations Using industry expertise in large-scale CO2 separation and sequestration Applying technologies for drilling and injection, subsurface characterization, and site monitoring, same as in the O&G sector Leveraging similarities with NG storage, acid gas disposal, and CO2EOR
Renewable Natural Gas	Processing technologies are similar to NG processing	Minimal processing for using RNG for power generation in gas turbines	Doping in NG pipelines Leveraging pipeline rights-of-way	Utilizing existing fuel storage and transportation hubs	Leveraging industry expertise with NG storage
Smart Systems/ Platforms	Applying process automation for improved refinery performance	Creating smart generation solutions: NG-battery and NG-solar hybrids	SCADA expertise Improving the efficiency of transport of RNG, H2, CO2 Leverage pipeline rights of way	Using transport management systems and other IoT applications Data tracking of supply chains	Optimizing revenues from grid-scale systems

Source: EFI, 2019.

systems that rely on lowering the costs of new technologies such as next generation nuclear and CCUS to avoid the higher costs that result from relying solely on intermittent renewables and storage.

The LEP energy infrastructure analysis will utilize an “all-of-the-above” hybrid approach to pinpoint the key transmission, distribution, and storage opportunities to reduce GHG emissions while also identifying regions of the country that are vulnerable to climate-induced weather events and energy assets in need of hardening. Other key subjects to be addressed include the replacement of aging pipelines responsible for methane leakage, deployment of new high-voltage, direct-transmission lines, incentives for the installation of smart grids, and the repurposing of existing infrastructure.

The analysis will also review financing mechanisms for energy infrastructure investments at the state, local, regional, and national levels, including a review of the U.S. Department of Energy’s Loan Program Office.

Using the job multiplier formula updated by the Economic Policy Institute in 2019 for the utility sector, we estimate that this spending would produce 11.4 direct, indirect, and induced jobs for every $1 million of additional spending.[11] For instance, increasing the capital expenditures of the utility sector annually by the 15-20% recommended by ASCE would create 20,000 new utility jobs; 90,000 indirect jobs; and 118,000 induced jobs for a total of almost 240,000 new jobs.

Data collected by the 2020 U.S Energy Employment Report found the highest levels of unionization and wage rates in the entire energy sector are in the Transmission, Distribution, and Storage sector. There, unionization rates are 17%, more than two and a half times higher than the national rate, 6.4%. As a result, investments in this sector will pay substantial social benefits to the recipients of these employment opportunities. Expanded apprenticeship programs and inclusive community benefits’ agreements can guarantee that all communities and regions of the country benefit from investments in energy infrastructure that increase line efficiency and reduce GHG emissions.

Element No. 3

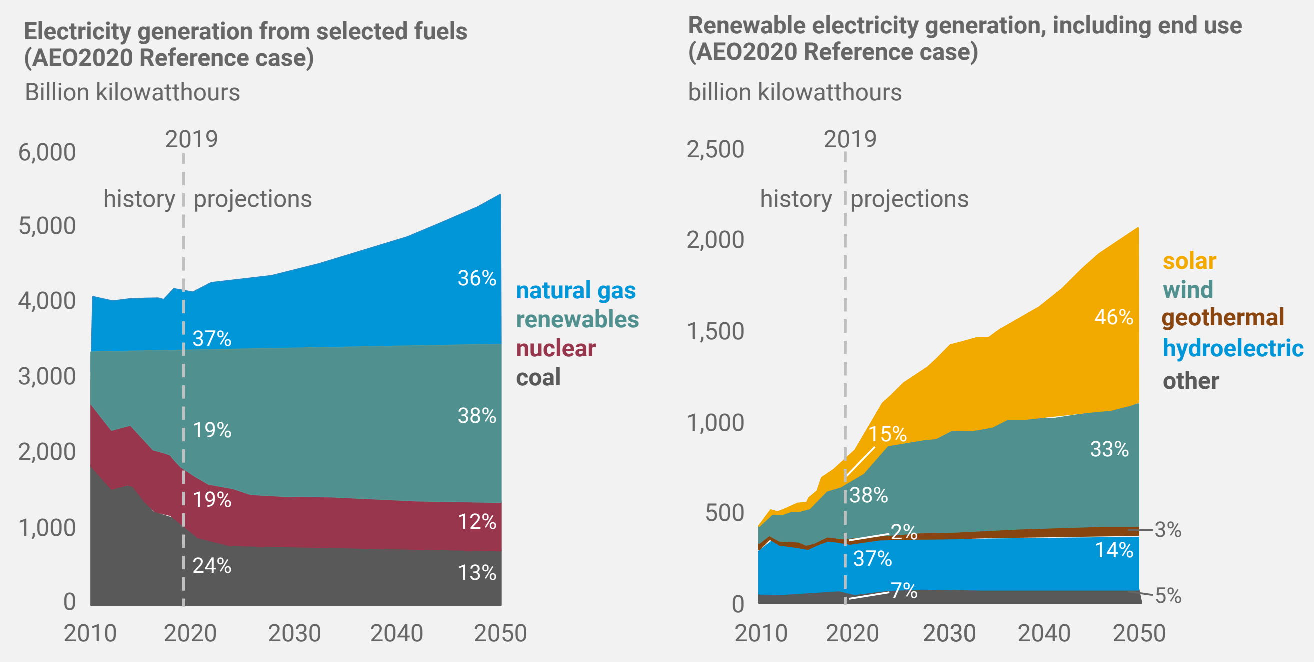
Policies are needed to site and permit new electricity transmission projects in the near-term.

One of the impediments to the rapid ramp-up of clean new and modernized energy infrastructure and technologies is the cumbersome and lengthy review process for permitting infrastructure projects. There are currently multiple jurisdictions for different kinds of transmission projects depending on the source, whether international boundaries are crossed, affected state utility commission jurisdictions, and the requirements of Independent System Operators (ISO’s) or Regional Transmission Organizations (RTO’s). In addition, some fuel sources are subject to additional permitting restrictions such as natural gas pipelines or nuclear fuel and waste transportation.

While the need for high voltage, direct current transmission (HVDC) is clearly necessary to transmit cost-efficient renewables to urban centers, the process to get approvals across multiple jurisdictions is unwieldy and unworkable, if Paris targets are to be met. According to the Transmission Agency of Northern California, approval processes for most high voltage transmission lines take over a decade.[12] The recent effort to permit Clean Line Energy’s projects is a case in point. Founded in 2009, none of the company’s five proposed projects has entered the construction phase. In 2019, the company announced the sale of three of its projects, while the company itself was liquidated.[13]

Currently, many proposals have been floated to expedite permitting. Among these are the reform of the National Energy Policy Act, the creation of a pre-approval optional process for state and local authorities, and the transfer of certain kinds of transmission permitting to a single authority such as FERC. This LEP analysis will identify policies and procedures on expediting or restructuring transmission permitting. It will also examine the possible use of existing rights-of-way such as railroads and other infrastructure, to expedite the siting and construction of new transmission lines.

Figure 6 | U.S Electricity Generation Mix Through 2050 in the EIA Reference Case



Source: Adapted from IEA, 2019. EFI, 2020.

Element No. 4

Options for safe, affordable preservation of the existing nuclear fleet and the deployment of next generation nuclear technologies.

The fourth major issue that the LEP analysis will address is the future of nuclear generation in the electricity system of the future. Since the needs of electricity consumers cannot be met economically by reliance on any single source of generation, a mix of low carbon technologies must be developed to meet consumer demands.

Some level of reliable base-load power will be necessary, especially in certain regions of the country. Currently, nineteen percent of all U.S. electricity and 50% of all zero-emissions generation comes from nuclear power plants. The balance of zero emissions electricity is supplied by wind (19%), hydro (18.5%), solar (7.5%), and geothermal and other (5.5%). The average age of the current nuclear fleet is 38 years with a planned life expectancy of another 22 years, including 20-year extensions of the original 40- year licenses.[14]

Nuclear generation provides carbon-free, baseload power for a wide range of U.S. consumers with significantly different needs. For instance, some industrial customers, operating 24 hours a day, 365 days a year, require reliable sources of electricity and could not operate if forced to consume only variable sources of electricity. Unfortunately, the rapid and unplanned retirement of the existing nuclear fleet would most likely result in a large expansion of natural gas-fired generation, thus driving up the rate of GHG emissions at the precise moment that climate solutions demand their reduction. Despite these benefits, nuclear energy has high costs and significant safety and security costs, leading to EIA forecasts that show a decline in nuclear generation, absent new policies and technologies to enhance its role in a low carbon future (Figure 6).

The LEP will evaluate alternative electricity market design policies that would enable the safe extension of operations at those facilities and a phased-in retirement plan that allows their replacement with new zero carbon generation, including opportunities to replace existing nuclear power plants with advance nuclear technologies. Currently, the workforce in the nuclear power generation sector provides the highest average pay rates, employs the greatest percentage of women, and is the most diverse workforce in the entire electric generation sector. It is also highly unionized at twice the national rate.[15]

The LEP will also evaluate the role of accelerated development and deployment of advanced nuclear power generation technologies. The analysis will consider differences in regional energy circumstances, to ensure that a mix of low carbon electricity technologies will be available to meet the diversity of customer demands in an economical manner, such as providing 24/7 electricity generation where needed to meet the demands for heavy industrial users.

Small modular reactors (SMR's) have been under development for a number of years through both private and publicly funded research efforts. Companies, such as NuScale, are currently building pilot plants in partnership with the Idaho National Laboratory and local utilities to demonstrate the feasibility of producing replicable, common-design facilities that eliminate the need for unique design and expensive construction costs of our first-generation nuclear fleet. A recent study by NuScale projects 110,000 construction, operations, and maintenance jobs from installing 70+ units in the United States. Around 13,500 manufacturing jobs would also be created in their modular fabrication and assembly.

In addition to SMR's, the LEP analysis will address the research and deployment needs of other advanced nuclear technologies that could contribute to the generation of reliable, carbon-free, baseload power such as light water reactors and nuclear fission.

Element No. 5

Development of technology and policy pathways for the use of natural gas consistent with meeting climate goals.

During the last five years, two significant changes have affected the U.S electricity generation system and its workforce. Natural gas has displaced coal as the largest source of generation. Currently, 37% of U.S. electricity is generated from natural gas and 24% is generated from coal.

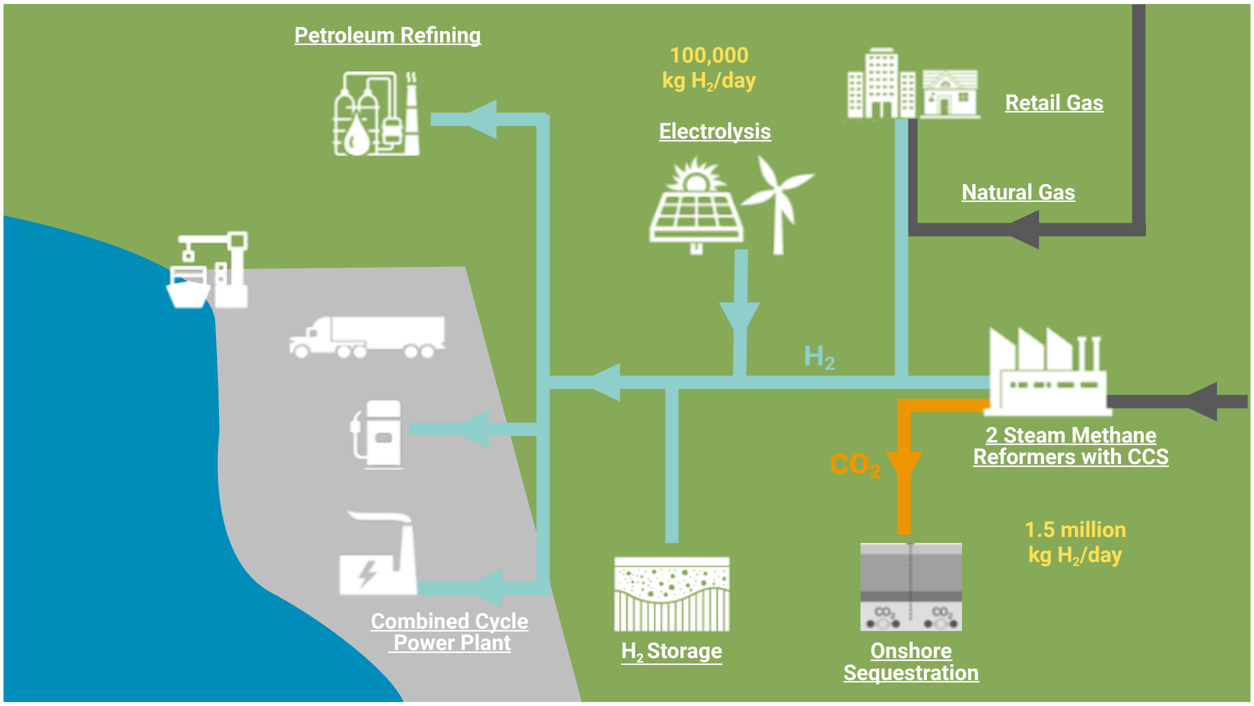
Natural gas has also displaced coal as the largest source of utility employment within the generation sector. These two changes were driven by a combination of factors including new extraction technologies (hydraulic fracturing and horizontal drilling), the relatively low capital costs of combined cycle natural gas power plants, and their adaptability for use with variable renewable power.

In addition to its employment impacts in the electric power generation sector, the "Shale Gas Revolution" as it came to be known, changed the U.S. from being a net importer of energy to becoming a net exporter again and, in 2019, the world's largest producer of petroleum. Cumulatively, these changes have led to a significant increase in employment over the last decade in natural gas production, its transmission and distribution infrastructure, and its use as an industrial feedstock for chemical manufacturing. The American Chemistry Council predicts new manufacturing investments of $204 billion in the U.S. as the low-cost producer of natural gas.[16]

Low-cost natural gas has also had an important impact on lowering manufacturing costs in the U.S. and reducing GHG emissions in a wide range of manufacturing processes that previously relied on more carbon-intensive forms of fuel such as petroleum and coal.

An important consideration in the future will be the role of natural gas in a low carbon economy. Currently, 40% of natural gas is consumed by industry, both for process heat and as a feedstock, while 37% is used for electric generation. The balance is used in commercial and residential buildings. Across

Figure 7 | Example of a "Hydrogen Hub": Ports of LA and Long Beach



One central steam methane reforming facility and one central electrolysis facility could supply half of ports' drayage fleet (5,000 trucks), the entire ports' electricity requirement (50MW/h), 80% of SCGs petroleum refiner demand, 10% of SCG's petroleum refiner demand , 10% of SCG's residential gas demand (as blend), and CO_2 sequestration equivalent to half an average coal plant emissions. Source: EFI 2020.

its entire value chain, the natural gas sector directly employs over 636,000 Americans.[17] The utility sector is the largest industry sector for natural gas, which employs almost 184,000 people, followed by mining and extraction, and construction with 166,000 and 110,000, respectively.

According to the Energy Information Administration (EIA) during the period from 2005 to 2018, the largest source of GHG emission reductions in the U.S. electricity sector came from the substitution of natural gas for coal within that system, roughly 580MMmt.[18] Current limitations on the reliability of wind and solar generation due to their inherent variability, underscore the role of natural gas in both our energy transition to a low carbon economy and in meeting our energy requirements in the post-2050 period.

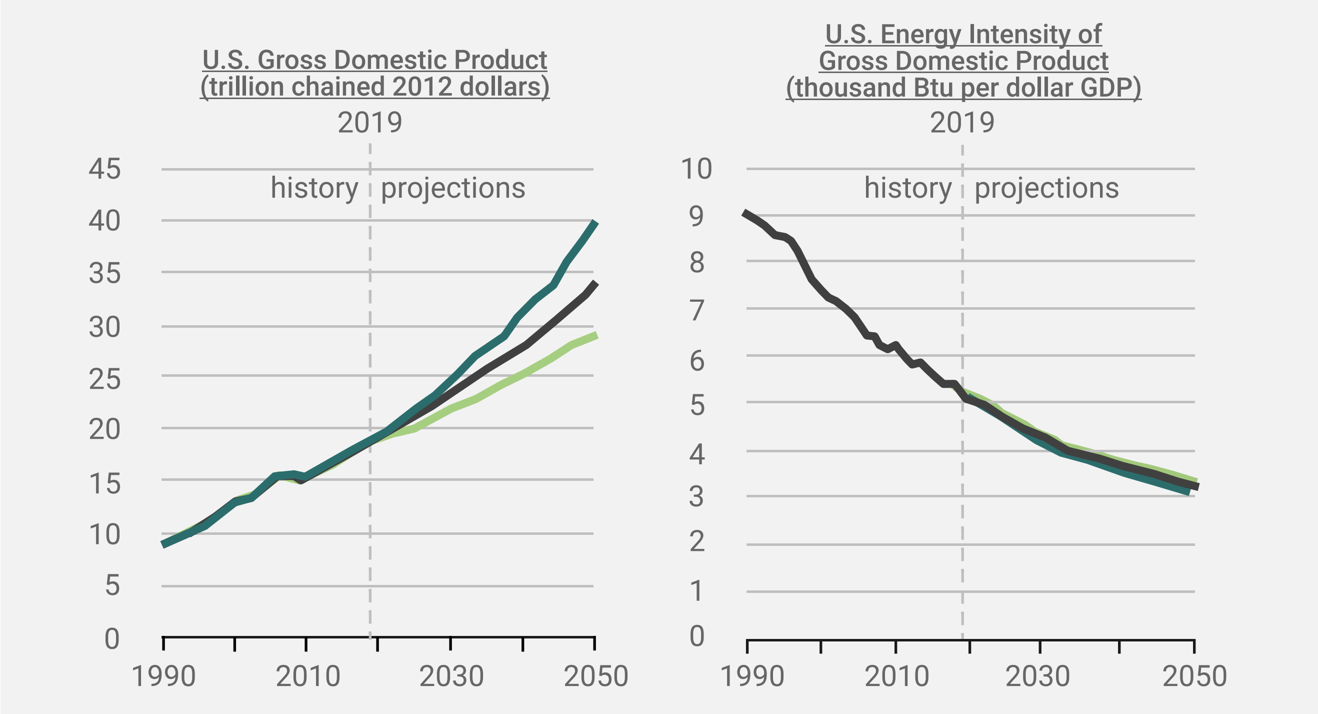
The LEP will examine natural gas use in a future low carbon economy, including:

1. The utilization of natural gas with CCUS technology both in the power sector and the industrial sector. We will examine whether this is an economical approach to reducing emissions in either or both sectors.

2. The role of natural gas as a feed stock in the chemicals industry. The LEP analysis will assess options for reducing the carbon footprint associated with the use of natural gas as a feedstock in this important industry.

3. The transition of natural gas to a hydrogen fuels' economy. One of the significant technological challenges to emissions' reductions is the creation of low carbon fuels for heavy duty transportation and industrial process heat. Natural gas conversion to hydrogen, combined with CCUS, offers

Figure 8 | Gross Domestic Product Increases, Energy Intensity of GDP Increases



Source: Adapted from EIA, 2019. EFI, 2020.

a potentially economical, large scale source of hydrogen fuels for peak electricity generation, industrial process heat as well as transportation fuel.

It is also important to note that the natural gas transmission and distribution system, currently employing over 236,000 people, could also play an important role in a repurposed infrastructure used for both hydrogen and CO_2 transportation in a low carbon economy. The LEP analysis will review options for infrastructure reuse.

Element No. 6

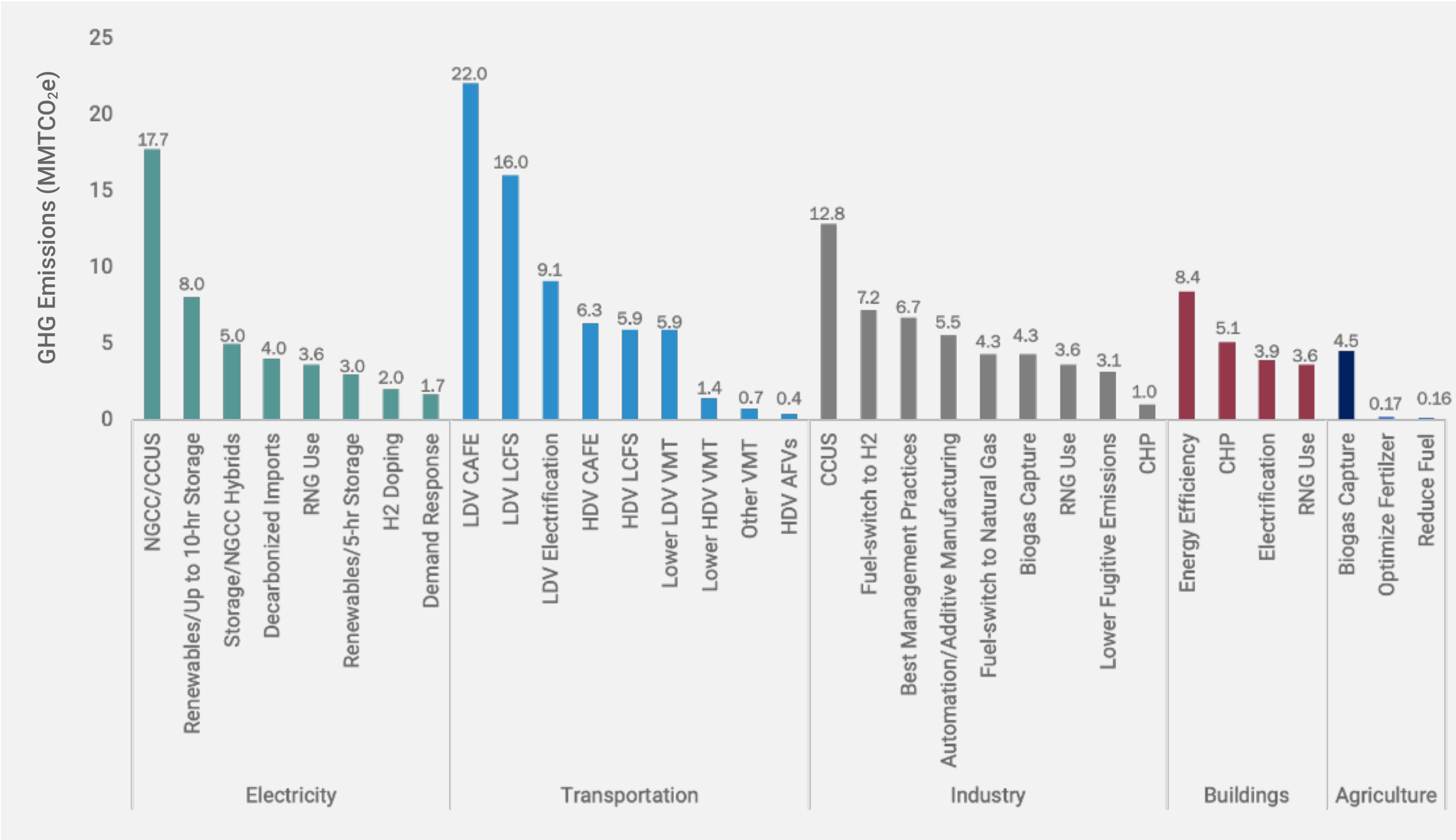
An analysis of the economic challenges and cost benefits of the development of hydrogen fuels' alternatives for the transportation, power and industrial sectors.

High-grade industrial process heat and transportation fuels for heavy duty trucks are two of the challenges to electrification of the economy. One solution to both issues would be the development of a hydrogen fuels system in which hydrogen was produced, stored and transmitted cheaply enough to be used as an industrial and heavy-duty transportation fuel. Hydrogen also has the potential to become economically viable for electricity generation, including co-use with natural gas and to store energy from renewables that would otherwise be curtailed.

The hydrogen industry is already a $122 billion industry, producing hydrogen largely for consumption in the petrochemical and other industries where it is used to refine petroleum, produce fertilizers, and treat metals.

Current challenges to the wide-scale deployment of hydrogen as an industrial and transportation fuel include its relatively high cost of production either from electrolysis or methane reforming and its safe and efficient storage and distribution. One possible pathway to more wide-spread utilization of hydrogen to reduce GHG emissions would be the creation of "hydrogen hubs" where geographically concentrated end users such

Figure 9 | Identified Emissions Reduction Potential for Sector-Specific Pathways for Meeting California's 2030 Targets



Source: EFI, 2019.

as ports with warehousing and manufacturing assets could easily benefit from hydrogen usage without significant transmission requirements (see Figure 7). A recent study on the jobs' impact of a robust transition to the use of hydrogen as a zero-carbon fuel for industry and transportation found that the industry would support from 700,000 to 1,000,000 employees in the United States.[19]

The LEP will develop strategies to accelerate the market deployment of a hydrogen economy, such as hydrogen hubs, with a focus on policies and business models to foster hydrogen use at scale in power generation and industrial markets.

Element No. 7

The expansion of energy efficiency finance mechanisms and policy recommendations to enable the full utilization of energy efficient technologies in commercial and residential buildings, industrial processes, and transportation.

For most of the 20th century economic growth required additional production and consumption of energy. However, in the late 1970's, a decoupling of energy consumption and economic growth began in the U.S. and, with one exception during the 2006-7 period, has continued unabated. Today, most economic forecasts prepared by EIA, anticipate a continued decline in energy consumption per unit of GDP (Figure 8).

As a result of the wide-scale adoption of energy efficiency technologies across the economy, "energy efficiency jobs" have become an important component of economic development strategies. 75% of all utilities in the United States today operate or finance energy efficiency programs. Over 30 states have set energy efficiency standards or targets. According to the 2020 USEER, in 2019, over 2.3 million Americans now work in energy efficiency with almost 55% in the construction sector. Another 13% work in the manufacture of energy efficient products such as HVAC or lighting systems, appliances, electric motors, and insulation products. Energy efficiency jobs are also more heavily unionized than the U.S. workforce as whole with over 11% belonging to unions, almost double the national average.[20]

Only a small fraction of the commercial, residential, industrial, and government buildings that could benefit from energy efficiency retrofits are, however, renovated in a single year. There are over four million public government building alone in the U.S. According to one analysis by the University of Massachusetts' Political Economy Research Institute, every $1 million invested by the government in energy efficiency retrofits creates 9.8 jobs.[21] Other estimates have been even higher.

One of the major obstacles to the wide-scale adoption of energy efficiency products and processes has been the difficulty of monetizing the benefits of energy efficiency. As with many new technologies, until financial markets become comfortable with predictable rates of return, investments tend to be sporadic and concentrate on higher return technologies such as lighting and HVAC systems. Additionally, there is often a mismatch between those who would make the necessary investment in energy efficiency and the entity that benefits from energy savings. Addressing these risks in the market and setting the right incentives will be necessary to increase adoption of energy efficiency products and processes.

A recent study on decarbonization in California noted the importance of energy efficiency in the electricity, transportation, industrial, and building sectors over the next decade (Figure 9) .

> ***Meeting the Clean Energy Ministerial's target of 30 million electric vehicle sales by 2030 would require 314kt/yr. of cobalt, almost three times the 2017 level for all uses. At those rates, reserves would last 23 years.***[22]

Stabilizing markets for the wide-spread deployment of new technologies has frequently been managed through regulations or mandates. Sometimes this has been accomplished through public-private partnerships between states and energy savings companies. In other cases, utilities have partnered directly with private sector building owners or manufacturing companies. However, the rate of adoption of energy efficiency technologies has been painfully slow, resulting in lost opportunities for both job creation, cost savings, and GHG reductions.

The LEP will examine current methods of financing end use efficiency and demand management programs and practices, and develop additional policy options and financing mechanisms that would accelerate the adoption of state-of-the-art energy efficiency measures and provide universal access economically to all consumers.

Two primary goals of the LEP analysis will be to issue a best practices' guide to existing financing mechanisms for energy efficiency in America along with a roadmap for wide-scale adoption of these technologies and how they will benefit every major economic sector.

Element No. 8

An assessment of the domestic capacity of the United States to sustainably mine, process, and manufacture the critical minerals and materials necessary for the domestic production of low-carbon technologies.

One of the most complex problems facing the transition to a low carbon economy are the daunting requirements for minerals across a wide range of new technologies. In 2017, the World Bank estimated the demand for critical

Figure 10 | Global Lithium, Cobalt, Nickel Production/Reserves

Lithium Production/Reserves (metric tons)

Country	Mine Production		Reserves
	2017	2018	
United States	W	W	35,000
Argentina	5,700	6,200	2,000,000
Australia	40,000	51,000	2,700,000
Brazil	200	600	54,000
Chile	14,200	16,000	8,000,000
China	6,800	8,000	1,000,000
Portugal	800	800	60,000
Namibia	---	500	NA
Zimbabwe	800	1,600	70,000
World Total (Rounded)	69,000	85,000	14,000,000

Cobalt Production/Reserves (metric tons)

Country	Mine Production		Reserves
	2017	2018	
United States	640	500	38,000
Australia	5,030	4,700	1,200,000
Canada	3,870	3,800	250,000
China	3,100	3,100	80,000
Congo (Kinshasa)	73,000	90,000	3,400,000
Cuba	5,000	4,900	500,000
Madagascar	3,500	3,500	140,000
Morocco	2,200	2,300	17,000
Papua New Guinea	3,310	3,200	56,000
Philippines	4,600	4,600	280,000
Russia	5,900	5,900	250,000
South Africa	2,300	2,200	24,000
Other Countries	7,650	7,000	640,000
World Total (Rounded)	120,000	85,000	14,000,000

Nickel Production/Reserves (metric tons)

Country	Mine Production		Reserves
	2017	2018	
United States	22,100	19,000	110,000
Australia	179,000	170,000	19,000,000
Brazil	78,600	80,000	11,000,000
Canada	214,000	160,000	2,700,000
China	103,000	110,000	2,800,000
Columbia	45,500	43,000	440,000
Cuba	52,800	53,000	5,500,000
Finland	34,600	46,000	NA
Guatemala	53,700	49,000	1,800,000
Indonesia	345,000	560,000	21,000,000
Madagascar	41,700	39,000	1,600,000
New Caledonia	215,000	210,000	---
Philippines	366,000	340,000	4,800,000
Russia	214,000	210,000	7,600,000
South Africa	48,400	44,000	3,700,000
Other Countries	146,000	180,000	6,500,000
World Total (Rounded)	2,160,000	2,300,000	89,000,000

Source: USGS, 2019.

Figure 11 | Options for Managing Issues Associated with Increased Use of Metals and Minerals for Clean Energy Technologies

The U.S. should consider:

- Increasing its diplomatic and investment focus on Western Hemisphere and Africa
- Protecting supply chains for metals/minerals needed for wind, solar, and batteries
- Supporting innovation in mining efficiency and in earth abundant materials for wind, solar and batteries
- Using renewable energy for electricity need in mining operations
- Promoting humane mining conditions around the world
- Starting metals and minerals recycling programs

Source: EFI, 2020.

minerals in the solar, wind, and electric vehicle technologies if the global economy were to meet the emission reduction requirements of the Paris Agreement. That study found significant increases would be required in the production of rare earths, lithium, cobalt, copper, nickel, and palladium. Even more common minerals such as iron ore would also be needed in significantly increased volumes for the expansion products such as wind turbine towers. According to a May 2020 World Bank study, "the production of minerals, such as graphite, lithium and cobalt, could increase by nearly 500% by 2050, to meet the growing demand for clean energy technologies. It estimates that over 3 billion tons of minerals and metals will be needed to deploy wind, solar and geothermal power, as well as energy storage, required for achieving a below 2°C future." [23]

Assessments of the availability of recycled materials found them to be inadequate to meet growing demand. For instance, lithium requirements for vehicle electrification were predicted to rise by 500% by the World Bank. Current rates of lithium recycling are virtually zero. Even if the recycling rates of some of the most critical minerals such as bauxite (aluminum), cobalt, nickel and copper are assumed to rise to 100%, significant new resources will be needed. Another significant barrier in some parts of the world is that recycling is more expensive than new mineral production.[24]

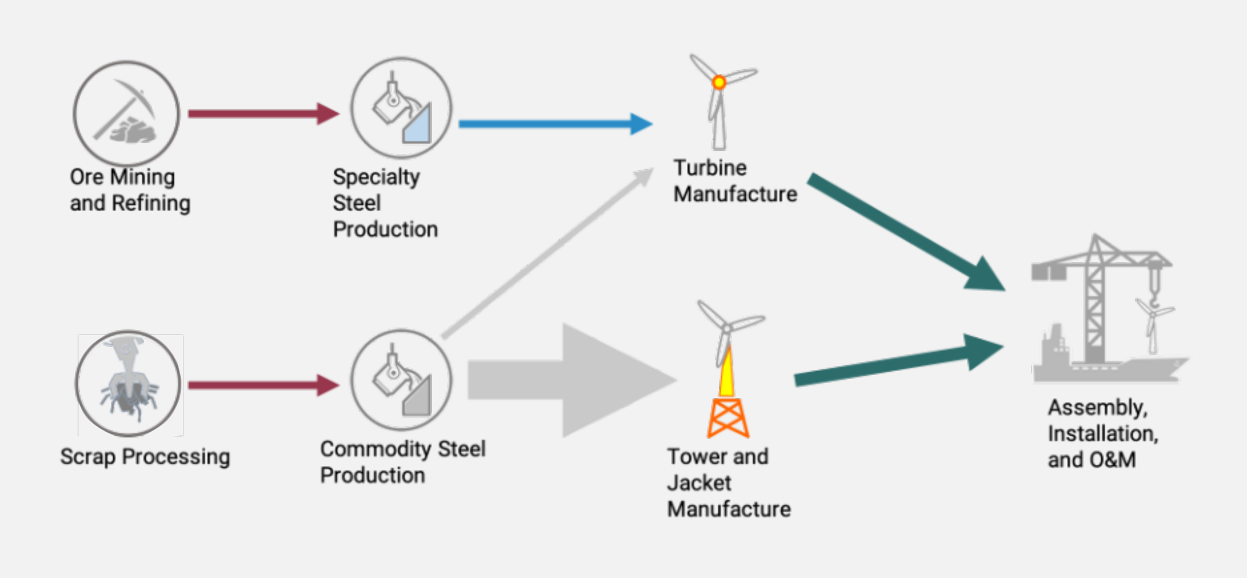
In addition, the recent global experience with supply chain vulnerability for personal protective equipment, during the COVID-19 pandemic, has underscored that the U.S. cannot allow its energy system to be overly dependent on minerals that we no longer mine in the U.S. (see Figure 10). Today, China has a virtual monopoly on the production of rare earth minerals, necessary for the production of renewable generation, smart grid technologies, and data management systems. China has also taken a dominant position in the world's supply chain of cobalt.

Energy security in a low carbon economy will require both increased domestic production of critical minerals and the development of stable, strategic international supply chains.

The LEP will address this issue through multiple approaches:

1. The LEP will collaborate with the mining industry and various stakeholders to develop policies for sustainable mining, where mining can be accomplished domestically. In so doing, the U.S. can become the global leader in responsible mining, with industry leading environmental and labor standards. The LEP also will develop strategies to ensure that domestic production of these critical minerals is safeguarded with environmental and labor standard border adjustments to prevent the erosion of sustainable domestic

Figure 12 | Offshore Wind Industry Steel-Related Supply Chains



Source: EFI, 2020.

supply chains with imports from countries that do not follow similar practices.

2. The LEP will assess opportunities for expanding domestic production of strategic materials from rehabilitation of closed or abandoned mines. Returning these sites to productive use will enable re-establishment of local economies as well as afford the opportunity to clean up residual waste. As a first step, the LEP could promote efforts to update domestic surveys of U.S. strategic minerals by the U.S. Geological Survey (USGS), including a review of closed or abandoned mines to assess the value of waste rock for secondary mineral recovery, such as the rare earths found in some coal waste material.

3. The LEP will work with the federal government to identify opportunities to improve the integration of various federal responsibilities for domestic development of strategic materials currently dispersed among the Departments of Labor, Energy and Interior. The focus of this effort will be to foster the development of a comprehensive sustainable and responsible mining initiative with appropriate standards for the health of the miners, their communities, and the overall environment as we meet our domestic and global requirements for critical minerals.

Other options that need to be analyzed are highlighted in Figure 11.

Element No. 9

An analysis of the offshore wind supply chain, including its raw material requirements, manufacturing technologies, and geographical differences between the East Coast, West Coast, and Great Lakes.

The pipeline for offshore wind power contracts in the Northeastern United States through 2030 implies up to 20 GW of capacity and $68 billion capital investment in the major components of wind turbines, not including necessary investments in supporting infrastructure, shipping and port capacity, or workforce development.[25] The total economic potential of the Northeast and beyond is up to five times that amount.[26] A study from 2017

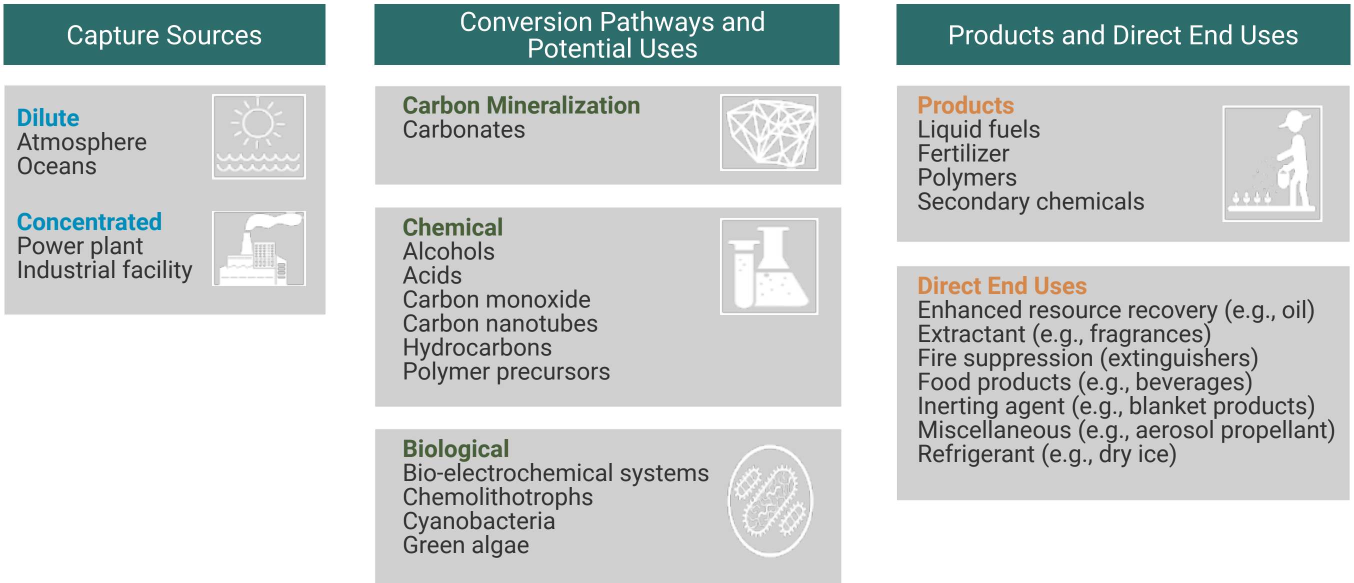


Figure 13 | CO_2 Utilization: Sources, Conversion Pathways, Potential Uses and Products

Source: EFI, 2019.

found that just an 8 GW buildout by 2030 would generate a peak 16,000 annual jobs, and that number could be up to twice as much with higher proportions of domestic manufacturing than included in the study.[27] The offshore wind industry has the potential to generate vast economic activity for the U.S. economy.

The creation of a new offshore wind sector in the Northeast and followed, potentially, by similar industry developments in the Southeast, Great Lakes, and Pacific Coast provide the U.S. with the opportunity to create robust and competitive global supply chains for this new industry. However, as with other new technologies, supply chains will not grow themselves without the conscious involvement of local, state, regional, and federal players from both the public and private sectors.

The LEP will undertake a detailed analysis is needed on all aspects of the supply chain, from the raw materials—including critical minerals—needed for the offshore wind industry, to its generation equipment and components, transmission technologies, and the ports and boats needed for staging and installation. As other countries—predominantly European—have taken the lead in developing this sector, the U.S. and its stakeholders need a policy-guided strategy to build up the domestic supply chains (Figure 12).

Already, a labor union-led coalition, Climate Jobs New York, is engaged with the permitting process, developers, and European companies to guide this process. The LEP will build upon this process by undertaking an extensive mapping of existing domestic companies, potential technology clusters, timelines, and appropriate incentives need to be catalogued to ensure that the public investments in offshore wind result in maximizing domestic, high-quality job creation throughout the resulting supply chains.

Finally, the LEP supply chain analysis will address the workforce skills' requirement of this new industry and document the opportunities to expand access to new jobs to disadvantaged communities.

Element No. 10

A roadmap for implementing carbon dioxide removal at scale.

Most scientific reviews of climate policy acknowledge that some level of direct carbon dioxide removal will be necessary to achieve the most aggressive goals of emission reductions, such as net zero by 2050. Current technologies, however, are too expensive to provide a viable path for large-scale carbon dioxide capture and sequestration or reuse.

An executable plan is needed for a multi-prong approach for research, development, and deployment for perfecting technologies, developing pilot plants, and creating viable strategies for the cost reduction that comes with mass deployment (Figure 13). This kind of strategic investment in new technologies requires multiple partners led by the federal government, subject to rigorous review, and with clear, long-term economic incentives.

In this manner, a number of utility-scale solar technologies were tested in the national laboratory system, funded by the DOE Loan Program Office between 2009-15 and opened the door for their wide-scale commercial deployment by private sector developers and utility companies in the years that followed. The Investment Tax Credit (ITC) played a critical role in attracting capital once the technology was proven and cost reductions had been achieved.

A recent workforce assessment of direct capture technologies performed for the Carbon Capture Coalition by the Rhodium Group estimated that, when brought to scale, these new technologies could create between 100,000 and 140,000 jobs in construction and operations.[28]

The most pressing need today is the development of a clear roadmap that integrates the necessary policy supports with the RD&D funding, timeline, and implementation architecture.

Conclusion

Creating Quality Jobs and an Inclusive Workforce

The LEP initiatives delineated above will enable the U.S. to move forward in a manner that creates new, quality jobs and an inclusive workforce. At the core of each of these initiatives is a set of key social policies that should be linked to the regulations and economic incentives that will encourage that transition. Some of these are currently in law, covering some government procurement policies, while others represent best practices in the private sector. All of them should be expanded to provide maximum opportunity for quality job creation and ease of access to those jobs by all demographic groups. They include:

- **Davis-Bacon Prevailing Wage Standards.** Davis-Bacon requires that prevailing wages be paid for federal government-funded projects, thus diminishing labor rates from the competitive bidding process.

- **Project Labor Agreements.** Project labor agreements promote pre-hire agreements between union contractors and labor unions to ensure appropriate skills, labor availability, adequate training, and labor peace during project construction.

- **Labor Standards Requirements for Energy Tax Credits.** Federal tax incentives have been critical for the growth of clean energy technologies. In 2020, the House of Representatives passed HR2, which included the GREEN Act, which for the first time requires the Department of Labor to certify that bonus tax credits for renewable energy tax credits only go to employers who comply with labor and civil rights laws.

- **Buy America Provisions.** Buy America provisions require that public funds use American-made products on government-funded projects, thus ensuring the development of domestic supply chains for new technologies. Currently, Buy America provisions only apply to the Departments of Transportation and Defense.

- **Buy Clean Standards.** Pioneered by the State of California, Buy Clean standards require carbon accounting of the products used in government contracts, thus encouraging the purchase of the least carbon intensive products, almost always domestically produced.

- **Border Adjustments for Energy Intensive Industries.** Energy-intensive industries produce 70% of industrial GHG emissions in the U.S. Border adjustment tariffs on imported energy intensive products such as steel, aluminum, pulp and paper will prevent carbon leakage and reward American companies for their high environmental performance.

- **Community Benefits Agreements.** Community Benefits Agreements provide insurance that government funded projects will support minority-owned businesses, provide training and hiring guarantees to disadvantaged communities, and lead to greater social equity as a result of climate-related projects.

- **Good Neighbor Agreements.** Good Neighbor Agreements are legally enforceable agreements in labor- and environmentally-sensitive industries and projects necessary for the low-carbon transition, such as mining or multi-state high voltage direct transmission lines. GNA's provide community input and social buy-in for environmentally sensitive projects.

The late Senator Paul Wellstone used to say, “There’s no social problem in America that we can’t solve with a good job, good health care, and a good education.” His infectious optimism guides our approach to the contribution that climate solutions can make to our greater challenge of social equity in America in 2020.

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