



ENERGY FUTURES  
— INITIATIVE —

# The Green Real Deal

A FRAMEWORK FOR ACHIEVING A DEEPLY DECARBONIZED ECONOMY

  
**August 2019**

# THE CLIMATE CRISIS: TURNING AMBITION INTO ACTION

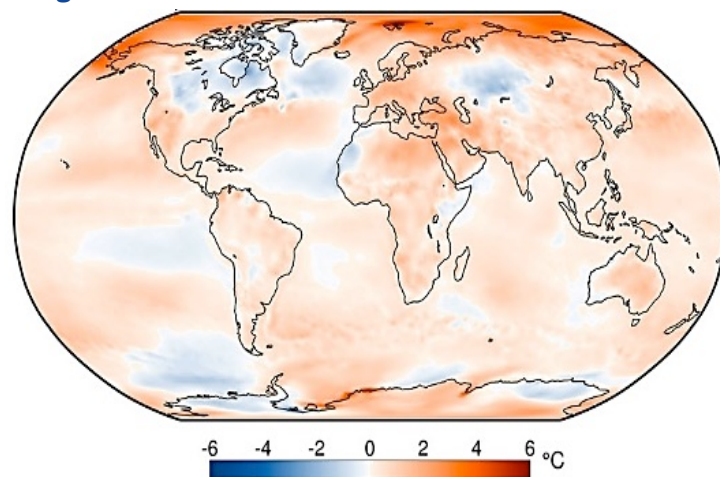
The threats posed by climate change to the world, our nation, and our way of life present an unprecedented and urgent challenge. Subnational entities have adopted aggressive carbon reduction targets and public support is mounting for climate action in the United States. In this context, a coalition-building and pragmatic strategy is needed—one that minimizes costs, maximizes economic opportunities, accelerates solutions, and promotes social equity—to translate climate mitigation ambitions into action. This is *The Green Real Deal—A Framework for Achieving a Deeply Decarbonized Economy*.

## The Climate Crisis—and Support for Action—is Growing

We are becoming increasingly aligned on the moral, social, environmental, and economic imperatives of addressing climate change. A Gallup poll earlier this year showed that 44 percent of U.S. adults said they care “a great deal” about climate change, up from 25 percent in 2011.<sup>1</sup> Sixty-nine percent are “somewhat worried” according to a 2019 Yale/George Mason survey. A recent poll by Luntz Global Partners showed that young people are overwhelmingly committed to climate action across political divisions and are calling for political accountability.<sup>2</sup>

It is not surprising that support for action on climate change is growing: its impacts are becoming increasingly visible, as seen in the record temperatures in Paris (108.7°F), London (101°F), and Anchorage (90°F) in July 2019; temperatures in Anchorage this July were 15 to 20 degrees above average.<sup>3</sup> The UN’s 2019 Climate Action Summit brief noted that “The last four years were the four hottest on record, and winter temperatures in the Arctic have risen by 3°C since 1990” (Figure 1). Arctic sea ice volumes in September 2018 compared to 1979 have declined by 75 percent.<sup>4</sup> Climate scientists have also expressed growing concerns about climate “tipping points”—irreversible changes in the climate system with uncertain triggers—after record-high global emissions in 2018.

**Figure 1**  
Temperature Differences Between 2018 and 1980-2010 Average



2015-2018 were the four hottest years on record. Orange shaded locations were above average overall in 2018 and blue shaded areas were below average. Source: The Weather Channel, 2018

The growing intensity and frequency of floods, hurricanes, and droughts across the country and the world have underscored both the ferocity and costs of a changing climate. The recent wildfires in California offer a case in point: 12 of the state's 15 largest wildfires have occurred since 2000 and estimates of costs of a single fire—the 2018 Camp Fire—are as high as \$16.5 billion.<sup>5</sup> While Earth has seen major climate variation over its history, the pace of change today is well beyond that attributable to natural phenomena and is driven by human activity, especially from energy. These trends are consistent with decades of forecasts and predictions.

A warning on the costs of prolonged inaction is found in the Fourth National Climate Assessment, whose contributors include representatives from eleven Cabinet-level agencies, NASA, USAID and the National Science Foundation. This Assessment highlights extremely high costs of inaction on climate change to the U.S. economy:<sup>6</sup>

*[R]ising temperatures, sea level rise, and changes in extreme events are expected to increasingly disrupt and damage critical infrastructure and property, labor productivity, and the vitality of our communities. Regional economies and industries that depend on natural resources and favorable climate conditions, such as agriculture, tourism, and fisheries, are vulnerable to the growing impacts of climate change...continued warming...without substantial and sustained reductions in global greenhouse gas emissions is expected to cause substantial net damage to the U.S. economy throughout this century...annual losses in some economic sectors are projected to reach hundreds of billions of dollars by the end of the century—more than the current gross domestic product (GDP) of many U.S. states.*

The Assessment indirectly underscores the social equity dimension of climate change: the high costs of inaction are disproportionately borne by those who can least afford them. These costs should be considered in the context of the Paris Agreement's targets of a 2°C increase in global temperatures by 2050, as well as its more desirable target of 1.5°C increase. The difference between the two targets comes with very significant consequences. According to the European Geosciences Union, "the additional 0.5°C would mean a 10-cm-higher global sea-level rise by 2100, longer heat waves, and would result in virtually all tropical coral reefs being at risk."<sup>7</sup>

In short, every *tenth of a degree matters* in the fight against global warming, no matter where we are in our progress to limit the rise of global temperatures. Concerns about tipping points also reinforce the need for an additional focus on the "tenth of a degree" solutions and contributions: any and all incremental carbon reductions, whether above or below the multinational targets, reduce the risks of the most catastrophic impacts from global warming caused by Earth's feedback loops.<sup>8</sup> *Clearly, we are in a climate crisis.*

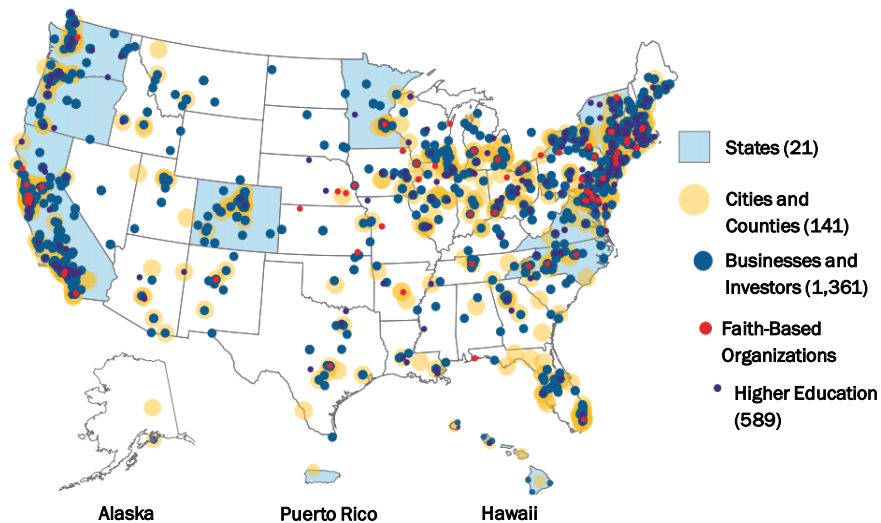
### **Global Efforts are Falling Short**

The post-Paris policies of the world's largest carbon emitters—the United States, China and the European Union—are not aligned with the Agreement's target of limiting temperature increases to 2°C by midcentury. In fact, after declines in the previous three years, U.S. greenhouse gas (GHG) emissions rose in 2018 at a historically high rate.<sup>9</sup> The UN Secretary General Antonio Guterres was quoted as saying in December of last year, "We are in deep trouble with climate change."<sup>10</sup> Concerned about these trends, he

recently sent a letter to all heads of state asking them to provide details at the UN's climate action summit this September on how they can increase the ambition of their emissions reductions targets for 2030 and achieve net zero emissions by 2050.

It is now both clear and urgent: stronger commitments and more effective responses are needed by the U.S. at a time when the current administration is rolling back existing policies and actively undermining efforts by subnational entities to address climate change. Fortunately, in the absence of constructive federal action—and in many cases in the face of significant federal obstructionism—a range of subnational entities including states, counties, cities, faith-based organizations, businesses, and academic institutions have committed to doing their part to help meet the U.S. commitments under the Paris Climate Agreement (Figure 2). These entities however all have different goals, measures, timelines, and policy drivers underscoring the difficulty of achieving ambitious economywide targets absent a coherent and inclusive strategy. Such a strategy is needed to harness and align state, regional, and local solutions.

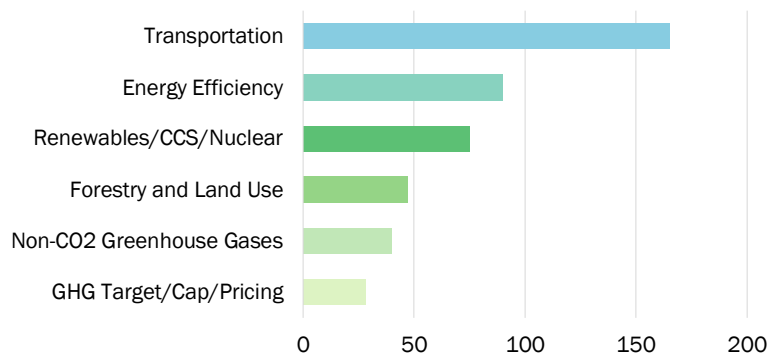
**Figure 2**  
**Subnational Entities Committed to the Paris Climate Agreement**



*Subnational entities that have committed to upholding the Paris Agreement targets through the “We Are Still In” pledge. Source: Fulfilling America’s Pledge, 2018*

Figure 3 highlights the number and types of state activities focused on climate change mitigation. In addition to sector-specific policies, several states have recently passed notable legislation that increase economywide climate targets from 80 percent reductions in GHG emissions by midcentury to “net zero” emissions—levels that are unlikely to be affordably met without technology, policy, and business model innovation breakthroughs. Without an innovation agenda focused on driving down the costs of mitigating climate change, significant increases in energy costs could disproportionately impact the poor, especially in the absence of progressive policies that advance social justice goals.

**Figure 3**  
**Total State-Level Mitigation-Related Activities by Type**



States (and other subnational governments) have been increasing their activities aimed at tackling climate change, including increasingly aggressive greenhouse gas reduction targets. Source: Fourth National Climate Assessment, 2018.

Many private sector players are also engaged in efforts to address climate change. Over 2,100 companies have signed the “We Are Still In” pledge (up from 1,361 when Figure 2 was produced), indicating that they are committed to meeting U.S. climate commitments after the Administration’s announcement on leaving the Paris

Agreement.<sup>11</sup> According to the Corporate Climate Tracker, produced by David Gardiner and Associates, 45 Fortune 100 companies have made climate commitments.<sup>12</sup> Earlier work by the National Association of State Energy Officials found that even more companies have set other kinds of goals, including to increase energy efficiency or renewable energy, and that over 120 major companies have “independently-verified, science-based” (i.e., 80 by 50) greenhouse gas reduction targets.<sup>13</sup>

A 2019 report from the Transition Pathway Initiative, however, assessed 274 of the world’s highest emitting publicly listed companies and concluded that only about half (54 percent) of those companies have begun integrating climate change into operational decision-making.<sup>14</sup> Of the 148 companies evaluated with the Initiative’s “Carbon Performance” benchmarking metric, only 18 percent are on track to meeting a 2°C target. Seventy percent of those companies are not aligned with any Paris goals at all (or do not disclose their emissions trajectory).

### The Green New Deal: An Aspirational Call to Action

In the context of an urgent need for action and insufficient progress to date, the Green New Deal resolution was introduced in Congress. It calls for, among other things:<sup>15</sup>

*[M]eeting 100 percent of the power demand in the United States through clean, renewable, and zero-emission energy sources...by dramatically expanding and upgrading renewable power sources...building or upgrading to energy-efficient, distributed, and ‘smart’ power grids, and ensuring affordable access to electricity...upgrading all existing buildings in the United States and building new buildings to achieve maximum energy efficiency, water efficiency, safety, affordability, comfort, and durability, including through electrification.*

The Green New Deal is aspirational, shining an important spotlight on the climate crisis. It has jump-started a critical national conversation on the imperatives of addressing

climate change risks to the economy, environment, and national security. In addition, it highlights the significant and growing need to address social equity issues for disadvantaged communities, who are least able to afford the costs of climate change and its mitigation options.

The Green New Deal also addresses social policies across a broad spectrum of issues beyond energy. Consistent with the purpose of a Congressional resolution—an articulation of ambitions, not a statutory plan for action—it does not offer detailed energy sector-specific technology or policy solutions for achieving its ambitious agenda.

### Turning Climate Ambitions into Meaningful Actions

The urgency of the climate crisis, the range and variability of subnational activities, and the ambition articulated in the Green New Deal resolution underscore a critical need: broad coalitions enabled by pragmatic, regional solutions and an emphasis on technology optionality and flexibility across all sectors of the economy. These coalition building blocks are essential for translating ambition into action.

The lack of focus on coalition-building in the past has hamstrung coherent and comprehensive climate mitigation efforts, hampering our ability to rapidly move forward with effective responses. Siloed approaches have spurred unrealistic “magical thinking” on both sides of the issue. High-impact coalitions must be committed to deep decarbonization, as well as recognize that their members will have a range of interests and be impacted very differently by different mitigation pathways. Such coalitions are also critical for acknowledging and effectively addressing the issues of stranded assets, economically dislocated communities, and displaced workers that could come with an accelerated clean energy transition.

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There is an existing foundation for expanding coalition-centric solutions, starting with a number of entities that have been focused on the need to bridge climate divides for many years. These include, among many others, the Bipartisan Policy Center, the BlueGreen Alliance, the Breakthrough Energy Coalition, C2ES’s Business Environmental Leadership Council, and ClearPath.

Recently, the Chamber of Commerce, which represents three million U.S. businesses at home and abroad, issued a statement in March 2019 saying that concrete steps are needed to address climate change and that there is common ground on which “all sides of this discussion could craft real solutions.”<sup>16</sup> The AFL-CIO stated: “America’s labor unions agree that climate change must be addressed...it is critical that the voices of American workers be included in the discussion, especially those who are most at risk of job disruptions and economic dislocation as a result of those actions.”<sup>17</sup> U.S. manufacturers are also engaging. The National Association of Manufacturers launched a

new initiative, the Energy Advance Center, that seeks to build partnerships with industry groups that are committed to carbon management policies.<sup>18</sup>

In public statements from this year's Vatican climate summit, leaders from the global energy sector and financial and investment communities agreed that governments should set reliable and economically meaningful carbon pricing regimes; that decarbonization policies should be designed in a way that delivers innovations and investment while assisting those who are least able to pay; and that greater transparency, advocacy and engagement of the energy sector, the investment community, political leaders, energy consumers, and civil society is needed.

On the conventional energy side: ten oil and gas companies launched the Oil and Gas Climate Initiative (OGCI) and in 2016 (three more have since joined), announcing a billion-dollar vehicle to “invest in innovative startups to lower the carbon footprints of the energy and industrial sectors and their value chains and use our OGCI network to help them achieve commercial success.”<sup>19</sup> It is critical that these ambitions translate to actions.

This confluence of a growing political consensus, imminent economic impacts, the value of incremental actions, bold political aspirations, and growing coalitions of disparate interests has created an opportunity and need for a robust coalition-building strategy. This strategy must offer pragmatic, science-based, accelerated, and durable solutions to energy-related climate challenges.

To underscore the importance of such actions, in March of this year, former Secretary of Energy Ernest Moniz and Andrew Karsner, appointees of the Barack Obama and George W. Bush administrations, respectively, published an op-ed that made an urgent call for action, noting that “Today we face the ‘slow motion train wreck’ of climate change, but without the presidential leadership of the original New Deal. This only elevates the importance of acting now in Congress, in states and cities and in civil society to develop a practical **Green Real Deal...**”

# WHAT IS THE GREEN REAL DEAL?

The Green Real Deal (GRD) is an actionable framework for meeting deep decarbonization of energy and associated systems by midcentury in ways that minimize costs, maximize economic opportunities, accelerate solutions, and promote social equity. This framework (Figure 4)—starting from five broad-based principles and organized around eight high-level key elements—is designed to provide policymakers, stakeholders, and industry with the context and building blocks for prioritizing, selecting and implementing energy policy, technology and business model innovations to effectively accelerate economywide decarbonization.

**Figure 4**  
**A Framework for Achieving a Deeply Decarbonized Economy**



*The Green Real Deal Principles are represented in the inner blue ring. Its Elements are represented by the outer ring. Source: EFI, 2019.*

In a recent article, the New York Times highlighted the solution space the Green Real Deal is designed to fill, noting that in the climate change discussion, “The question is whether any policy is both big enough to matter and popular enough to happen.”<sup>20</sup> For the GRD,



“big enough to matter” equates to those policy and technology options that meet both near-term and midcentury decarbonization goals, as well as the more specific needs and requirements of countries, regions, states, communities and workers.

“Popular” translates into building coalitions around practical but high-impact solutions for both mitigating and adapting to climate change, as well as ensuring that the range of social equity issues are fully addressed.

The GRD builds on the Paris Agreement and the commitments of the range of subnational players dedicated to deep decarbonization. Paris targets roughly translate to an 80 percent reduction by midcentury and typically a 30 percent reduction by 2030 (from a 1990 level). Advances in science and observed environmental changes in the short time since Paris have, however, caused a reevaluation of the stringency of the targets. A 40 percent economywide emissions reduction target by 2030 and net zero greenhouse gas emissions by 2050 are increasingly seen as the needed objectives. Operationally, this means that multiple pathways to economywide decarbonization must all be implemented while breakthrough innovation success will be needed at scale by midcentury. The GRD is designed with the emphasis on innovation and optionality and flexibility to respond to new and better understanding of the science.

This discussion of the GRD will focus on:

- The fundamental principles that support its mission, elements, and programs;
- Key trends, boundary conditions, and analytical findings that inform the GRD’s structure, the challenges it is designed to address, and the analysis and projects that are needed to support the overall framework; and
- Elements and sub-elements that, if supported by additional analytical work, would inform a comprehensive framework of technology, policy, and business model options for deep decarbonization of energy and associated systems in the United States.

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## Principles of the Green Real Deal

The Green Real Deal rests on five fundamental principles: a strong, ongoing commitment to and reliance on innovation; the need to attract and build strong and inclusive coalitions; a commitment to social equity in all deep decarbonization policies; economywide solutions to the climate challenge that are both sector specific and crosscutting; and technology and regional innovation options and flexibility supported by policies that enable each.

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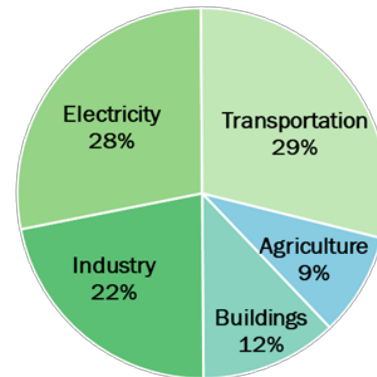
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- ✓ **Technology, Business Model, and Policy Innovations Are Essential.** Innovations in technology, business models, and policy are essential for meeting deep decarbonization targets by midcentury. Incremental and breakthrough innovations must be developed to meet the challenges of deep decarbonization, including the rising marginal costs of GHG abatement.
- ✓ **Broad and Inclusive Coalitions Must Be Built.** Solutions for addressing the climate challenge cut across all portions of the economy and require participation of businesses, consumers, governments, and advocacy groups. Finding common cause, proactively addressing conflict, and ensuring all members of society benefit from a transformation to a low-carbon economy will put wind in the sails of meaningful action.
- ✓ **Social Equity Is Essential for Success.** The transformation of energy and associated systems must also improve lives, grow public acceptance of the widespread change required to address climate change, and provide meaningful, well-paying jobs. The GRD subscribes to the National Academy of Public Administration’s definition of social equity: “The fair, just and equitable management of all institutions serving the public directly or by contract, and the fair, just and equitable distribution of public services, and implementation of public policy, and the commitment to promote fairness, justice, and equity in the formation of public policy.”
- ✓ **All GHG Emitting Sectors Must be Addressed in Climate Solutions.** Much of the academic and policy carbon abatement work to-date has focused on the electricity sector. Electricity is, however, only 28 percent of U.S. emissions (Figure 5) and is arguably the easiest to decarbonize. Sectoral analyses—electricity, transportation, industry, buildings and agriculture—will be central to identifying solutions and advancing innovation and net zero emissions targets. The recently published Energy Futures Initiative (EFI) analysis of California pathways to meeting climate policy goals,

“Optionality, Flexibility, and Innovation: Pathways for Deep Decarbonization in California,” is indicative of the bottom-up sectoral approach. Reaching economywide emissions reductions targets will require progress in every sector of the economy, including those that are difficult to decarbonize due technical, cost, and performance barriers.

**Figure 5**  
**2017 U.S. GHG Emissions by Sector**



*The largest GHG emitting sectors in the United States. Source: EFI, 2019. Compiled using data from EPA Greenhouse Gas Inventory 2017.*

✓ **Optionality and Flexibility are Needed for**

**Technologies, Policies, and Investments.** There are no clear “silver bullet” solutions to decarbonization at the present time. Multiple clean energy technology options are needed for each sector of the economy and region of the country—this requires technology and policy options and flexibility. Optionality in the energy space is best described as “thinking through the various scenarios that might follow a decision, not just Plan A, and placing appropriate value on possibilities opened-up or shut down by each path...Optionality allows a company to embrace new opportunities first at the margin, but eventually at the heart of operations.”<sup>21</sup>

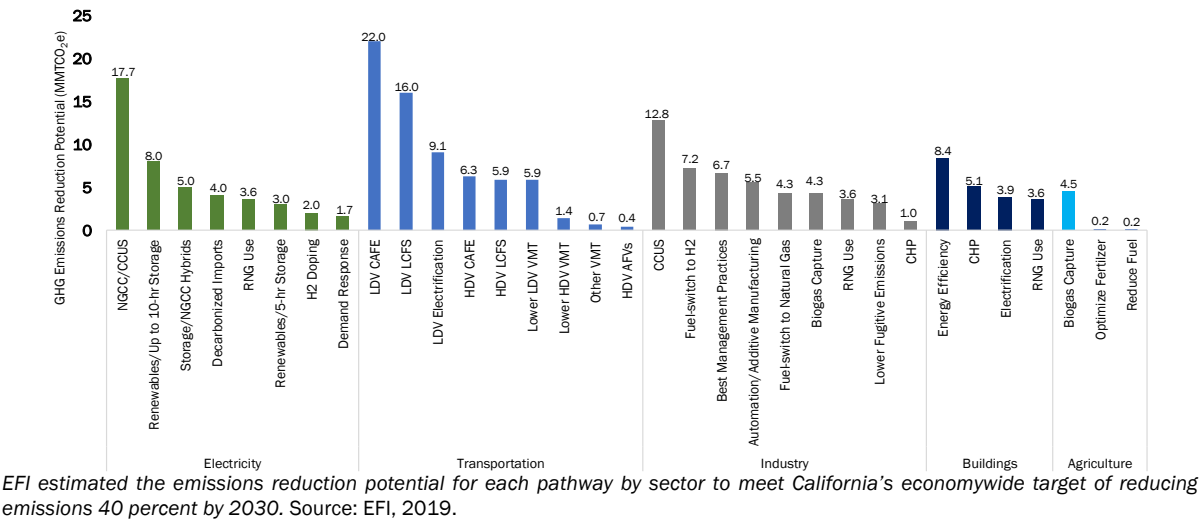
Text Box 1 offers an example of the range of technology options, and their potential for emissions reductions that are specific to California. Policymakers, state, cities, and communities need to be able to choose from a range of pathways for deep decarbonization by midcentury. They must also avoid prescriptive policies that could lock in suboptimal technologies and lock out opportunities. Economywide low-carbon goals are simply too challenging to permit a narrowing of options.

**Text Box 1**  
**Optionality, Flexibility, and Innovation for Deep Decarbonization**

In June 2019, EFI published a study, “Optionality, Flexibility, and Innovation: Pathways for Deep Decarbonization in California.” Guided by the principles of the Green Real Deal, this study was designed to help shape California’s near- and long-term decarbonization strategy. It offers insights on decarbonization pathways, energy system operational needs, costs, and areas that need innovation. The study concluded that California can indeed meet its 2030 and midcentury targets. Doing so will require success across all economic sectors, with multiple technologies contributing in each. Meeting the state’s carbon reduction goals and managing the costs will require a strong commitment to technology optionality, flexibility, and innovation.

For the 2030 targets, a comprehensive, sectoral analysis was performed that identified a portfolio of 33 clean energy technology pathways, covering all economic sectors (Text Box Figure 1), demonstrating the important role of optionality and flexibility for investors, policymakers, and innovators. Certain pathways, such as carbon capture, utilization, and storage (CCUS) offer tremendous emissions reduction potential in difficult to decarbonize applications (i.e. electricity load following and industry processes) but are not sufficiently supported in California to be deployed at scale. With this type of uncertainty, all pathways that offer measurable GHG emission reductions will be needed to ensure California reaches its near-term decarbonization goals.

**Text Box Figure 1**  
**Identified Emissions Reduction Potential of Pathways for Meeting the 2030 Targets**

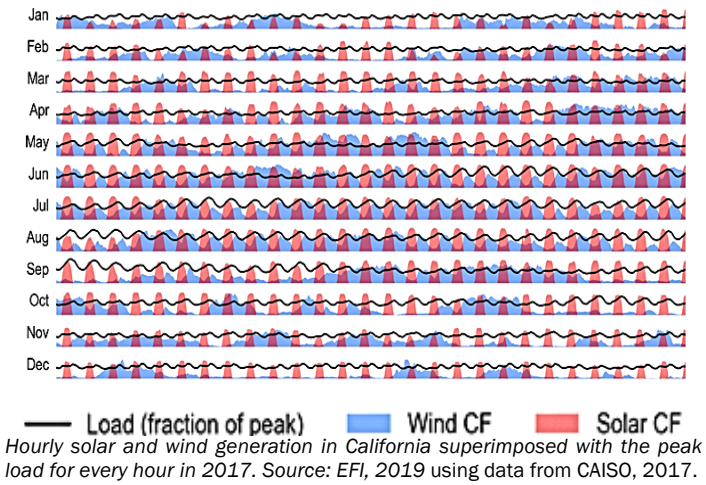


The Green Real Deal principles emphasize the need to effectively navigate the technical, economic, regional and social realities of decarbonizing the energy system: the energy system must provide essential services reliably at all times; energy delivery infrastructure must be available, reliable, and secure as the system transforms; affordable negative emissions technologies will be important at large-scale for deep decarbonization; and success will require aligning the interests and commitment of a range of key stakeholders. These boundary conditions shaped each clean energy pathway, revealing both opportunities and gaps for future efforts.

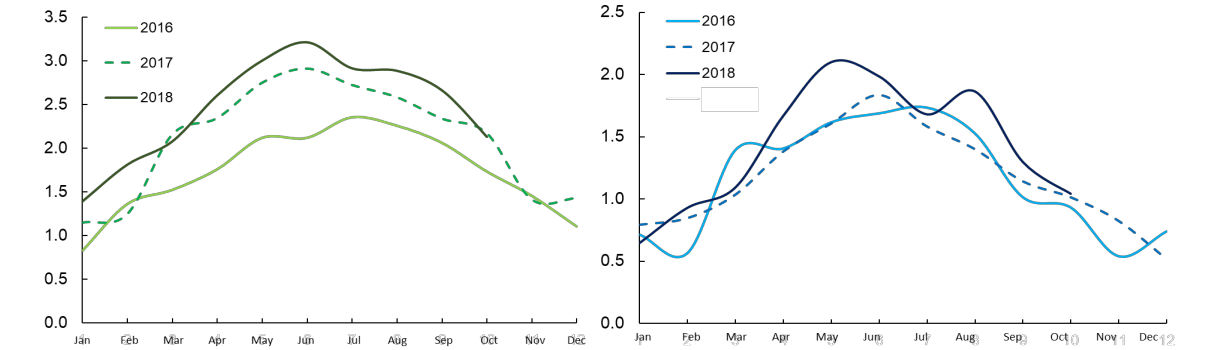
Meeting California’s long-term decarbonization targets, including an 80 percent GHG reduction (or more) by 2050 and carbon-free electricity by 2045—is impossible without breakthrough innovations. Also, managing and operating a deeply decarbonized energy system over a long duration has never been done and is technically very difficult.

A detailed review of the state’s regional attributes found that managing California’s electric grid even at current levels of intermittent renewables is challenging. In 2017, there were long stretches (between 5-10 days) of little to no wind generation (Text Box Figure 2). Solar production averaged 1.7 TWh in January but reached 3.2 TWh in June, reflecting significant seasonal variation (Text Box Figure 3). Wind follows the same seasonal variation. Current energy storage technologies are inadequate to address these weather-related phenomena and cost-effective long-duration storage does not currently exist.

**Text Box Figure 2**  
**California Hourly Trends in Solar and Wind Generation Normalized to Total Capacity, 2017**



**Text Box Figure 3**  
**California Metered Solar (Left) and Wind (Right) Generation, 2016-2018**



Metered solar (left) and wind (right) varies significantly on a seasonal basis throughout the year. Source: EFI, 2019. Compiled using data from CAISO, 2018.

The study identified eleven potential breakthrough technologies based on a review of the state’s existing policies, energy system and market needs, and other distinct regional features that help position California as a technological first mover and global leader. The technology priorities identified for California (these will vary by state or region) include hydrogen production from electrolysis, advanced nuclear, green cement, floating offshore wind, smart cities, and direct air capture, among others. These technologies, and many others with breakthrough potential, must be developed and deployed at scale by midcentury, with investments in innovation that must start today.

**These are all key lessons that inform the mission, principles and elements of the Green Real Deal.**

**Key Energy Trends and Boundary Conditions That Inform the Green Real Deal**

Achieving 80 or more percent carbon reductions by 2050 is an enormous societal challenge; many dynamic conditions contribute to the difficulties of the transition to clean energy systems. The GRD’s principles establish its foundation. These dynamic conditions, defined by the energy system’s boundary conditions and trends (Figure 6), inform its structure and mission.

**Figure 6**  
**Trends & Boundary Conditions Affecting the Pathways and Pace of Energy System Transformation**

Overarching Trends in—and Affecting—Energy Systems	Boundary Conditions of Energy Systems
<ul style="list-style-type: none"> <li>▪ The U.S. is now the number one producer of oil and gas in the world, costs of renewables and battery storage have dramatically declined, natural gas is the number one fuel for power generation, displacing coal, and there have been significant cost overruns for new GW-scale nuclear power plant builds</li> <li>▪ The energy system is moving from resource-based (e.g. reliance on fuel combustion) to technology-based (e.g. reliance on precision electric power delivery)</li> <li>▪ Digitalization, big data analytics, and smart systems continue to proliferate across energy subsectors</li> <li>▪ Demographic trends are moving towards global urbanization, cities and their infrastructure are becoming smarter, and commerce is increasingly digitalized</li> </ul>	<ul style="list-style-type: none"> <li>▪ Technology deployment timescales are unpredictable and technology cost curves are constantly evolving</li> <li>▪ Policy, regulatory, and investment environments can shift, constrain, or shape technology choices</li> <li>▪ The energy industry is multi-trillion dollar per year, highly capitalized, commodity business with exquisite supply chains, established customer bases, and providing essential services at all levels of society</li> <li>▪ The energy system has considerable inertia, aversion to risk, extensive regulation, and complex politics</li> </ul>

*Adapted from “Advancing the Landscape of Clean Energy Innovation.” Source: EFI & IHS Markit, 2019*

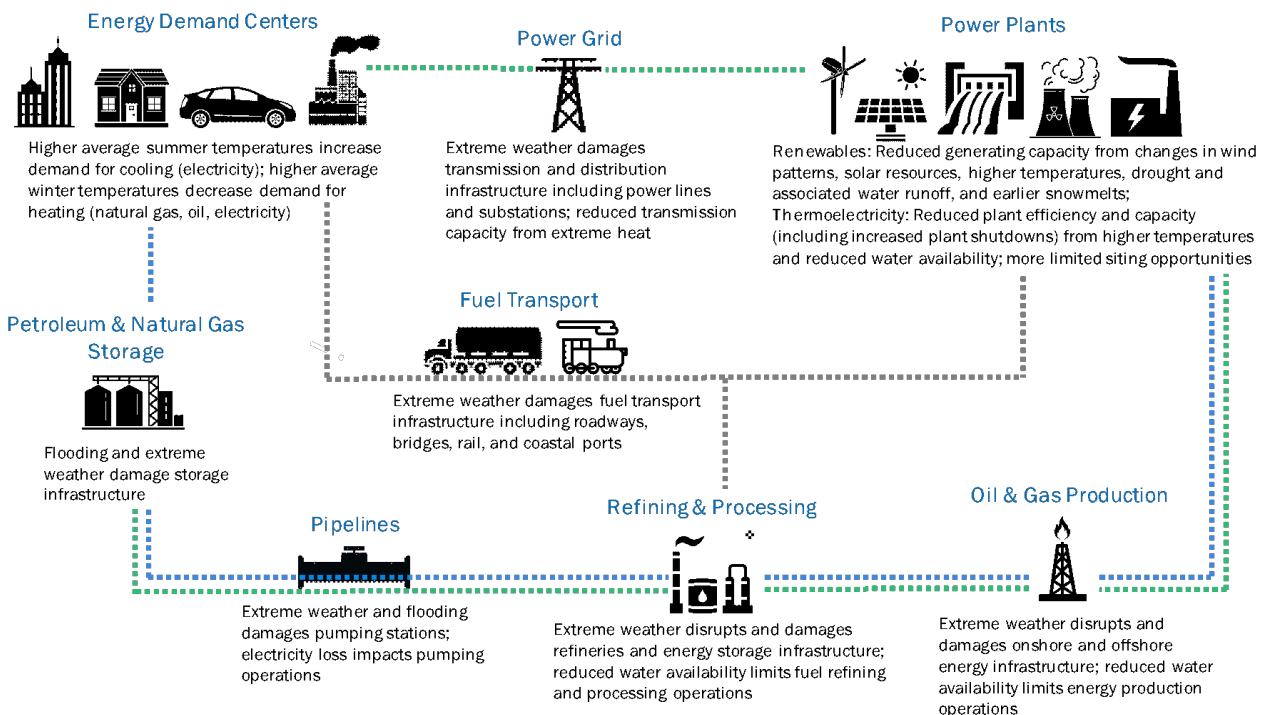
There are also significant analytic findings that draw from these trends and boundary conditions and contribute to the specific elements of the Green Real Deal, as well as the focus of its sub-elements:

- Today’s available technologies are insufficient to reach deep decarbonization across all sectors in the long term. Decarbonization policy must support innovation on dual tracks: incremental improvements in existing technologies to meet 2030 targets, and technology innovations with breakthrough potential needed to meet midcentury goals.
- The impacts and costs of climate solutions have uneven impacts and, absent proactive policy effort, could be costly for those who are least able to afford them.
- Public acceptance issues may slow progress when acceleration is needed.

- Climate impacts are regional, mitigation costs will vary by region, and regional solutions are essential. Energy sector infrastructures also vary dramatically by region; impacts of climate change on discrete systems, and cross-cutting, and interregional systems—must also be considered (Figure 7) when developing technologies, policies and business models for mitigating climate change.

Figure 7

### Impacts of Climate Change on Energy Systems, Infrastructure, and Use



Climate change impacts—including rising temperatures, sea level rise, extreme weather, etc.—will be felt in every part of the economy, including in the energy sector; the energy system will require adaptation-oriented solutions in addition to mitigation-oriented ones. Source: EFI, 2019. Adapted from the Fourth National Climate Assessment, 2018.

- The reduced reliance on carbon-intensive energy sources could strand assets—economically dislocate communities and displace workers—on the trillion-dollar scale. Supporting infrastructure must be modernized, resilient, and supported. Repurposing existing energy infrastructure could play a key role in enabling a clean energy future by reducing the overall costs of the transition to clean energy, as well as mitigate likely opposition to the needed transition by reducing the potential for stranded workers and investments.
- Energy efficiency, defined broadly, is likely to be the most cost-efficient approach to decarbonization, and one of the most effective options across all economic sectors.

- Electricity plays a critical role in decarbonization as both a source of emissions (that is relatively easy to decarbonize) and for supporting decarbonization of other sectors.
- Clean fuels (e.g., renewable natural gas, hydrogen, biofuels) are critical clean energy pathways due to the enormous value of fuels in providing flexibility for energy systems. Policymakers will have to manage the significant operational issues that arise from a high penetration of variable renewable electricity to ensure reliability, manage costs, and minimize emissions.
- Different policies in different sectors, or within the same sector, will have dynamic effects on each other. Changes in how one sector uses certain types of energy (especially electricity or natural gas) can create price volatility, reduced resource availability, and higher infrastructure costs for other sectors; and data collection for current greenhouse gas emissions, as well as on mitigation strategies, needs to improve and be standardized to facilitate better analysis, planning, policymaking, and research.

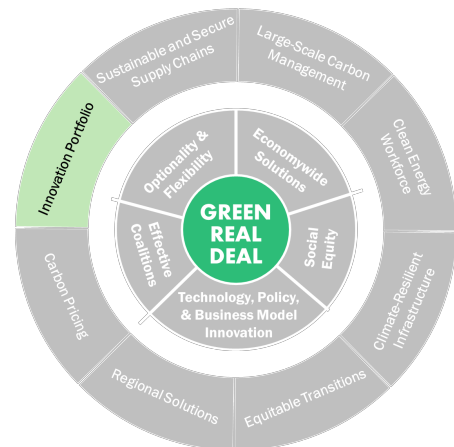
## Elements of the Green Real Deal

The GRD principles are designed to guide efforts to make deep decarbonization a reality. The principles form the basis for eight key elements (see Figure 4 above): areas of focus that, if supported by analyses and actions, will help forge broadly acceptable, equitable, and practical solutions to help mitigate the impacts of climate change by transforming our energy systems. These elements could support a range of efforts that offer stakeholders analytically sound and operationally focused strategies—essential building blocks for deeply decarbonizing the U.S. economy as rapidly as is technologically and politically feasible. They are also capable of garnering coalition support. The eight elements, with sub-elements that elaborate on major supporting analyses and actions, are discussed below.

### National Technology, Policy, and Business Model Innovation Program Portfolios

Innovation is at the core of the Green Real Deal. Technology innovation opens new doors to new cost-effective decarbonization options, enabling greater ambition and creativity in policymaking. Meeting the decarbonization goals of the GRD requires acceleration of current public and private sector energy innovation programs. The focus of these efforts should be to further reduce the cost of current technologies as well as to pursue aggressive programs focused on technology areas with breakthrough potential to transform the nation's energy systems.

This element will require strong support from the federal government. The Department of Energy (DOE), for example, is the largest single funder of energy R&D and viewed as the steward of the nation's energy technology innovation portfolio. Other federal agencies





also play important roles in advancing innovation within their mission areas—transportation, housing, and environment, among others.

Innovation strategies also need to encourage more robust public private partnerships and enable the growth of regional energy innovation ecosystems. The EFI/IHS Markit report “Advancing the Landscape of Clean Energy Innovation” provided a comprehensive survey of the current innovation landscape and developed a framework for a national energy technology innovation portfolio and identified an initial list of technologies with breakthrough potential warranting increased investment. Building on this report, EFI’s study “Optionality, Flexibility, and Innovation: Pathways for Deep Decarbonization in California” documented the importance of breakthrough innovation at the state level, providing the optionality and flexibility needed to move beyond near-term targets to achieve deep decarbonization goals by midcentury. Other studies have provided corroborating results. The next steps in pursuing the innovation agenda include five major sub-elements.

#### **Develop a National Energy Technology Innovation Program Portfolio**

A national energy innovation program would provide the opportunity to garner broad-based input and support for an accelerated RD&D effort combining the efforts of the public and private sectors. Such a program portfolio would draw upon the previous studies to define a comprehensive innovation portfolio of energy technology areas with breakthrough potential. It should identify technology goals, research building blocks and implementation plans including costs and schedules. The portfolio must be comprehensive and reflect broad engagement of the nation’s science and technology experts. Technology areas with breakthrough potential must be emphasized, such as long-duration energy storage technologies, advanced nuclear fission and fusion power, hydrogen at scale, advanced carbon capture technologies and carbon removal technologies, and gigatonne-scale CO<sub>2</sub> utilization. The portfolio should allow for flexible, regionally focused innovation programs.

#### **Analyze Alternative Funding Mechanisms for the National Technology Innovation Portfolio**

Accelerating the pace of innovation requires increased levels of investment. Several studies have recommended that funding for the DOE energy innovation portfolio, currently at about \$5 billion, needs to be doubled or tripled. In 2015, the U.S. joined with over 20 other nations and the E.U. to form Mission Innovation and pledged to double the level of government investment in clean energy R&D over five years. Congress has been supportive of increased investment in energy R&D but at a slower pace. Congressional appropriations for the total DOE science and energy R&D program portfolio have increased by 30 percent over the past 5 years, putting the DOE budget on a track to nearly double over 10 years. Achieving the larger step-change in funding to support an accelerated energy innovation program would require augmentation of the current federal annual appropriations process with dedicated funding from new funding sources. This analysis would identify and assess the feasibility of such dedicated, alternative funding sources to support the accelerated doubling of public investment.

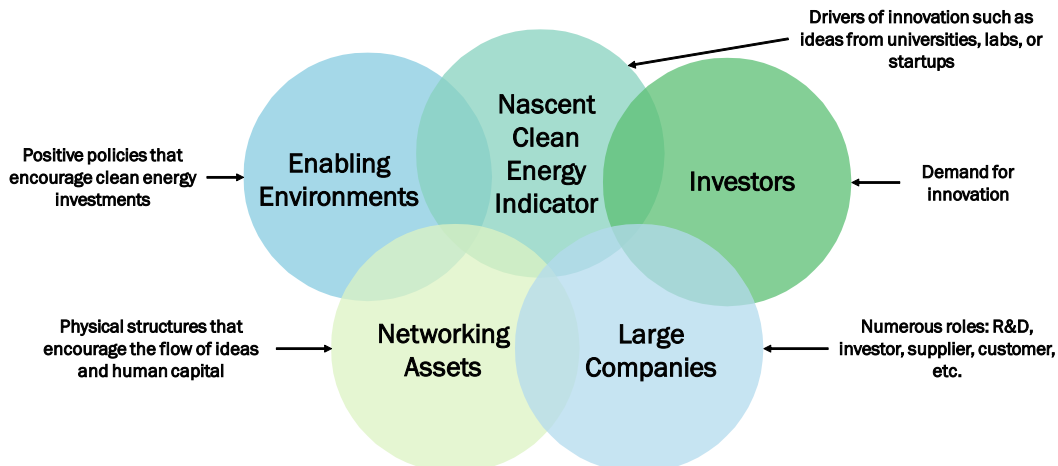
### **Advance New Flexible Business Models to Improve the Effectiveness of the Energy Innovation Process**

The private sector has implemented new approaches to increase investment in energy innovation. These include collaborative efforts such as the Oil and Gas Climate Initiative (OGCI) and the formation of the Breakthrough Energy Ventures, the private sector counterpart to Mission Innovation. Many companies are looking at opportunities to allocate increased resources to capital investment in energy innovation as part of their sustainability commitments, taking advantage of the increased resources made available by the 2017 Tax Cut and Jobs Act. Efforts to develop new and innovative public sector business models are needed to take advantage of the opportunities for increasing public private partnerships. Such an effort should review the current DOE organization—a fuels-based structure that has been largely unchanged for 40 years—to assess what changes may be needed to improve stewardship of the innovation agenda, including more effective public-private partnerships. This effort would also assess opportunities for improving DOE cost sharing, demonstration project management and intellectual property provisions.

### **Foster Regional Innovation Ecosystems**

There are significant differences among regions in energy resources, energy markets, and energy innovation capabilities. Federal policies and funding should be sensitive to regional variation and support stronger linkages at the regional level among innovation funders, performers and customers. Evidence suggests that regional innovation ecosystems can deliver faster and better solutions for regional needs. Stronger regional innovation ecosystems also can provide the foundation for subnational decarbonization implementation strategies. The principal components of a regional innovation systems are generally known, as depicted in Figure 8, but additional analyses are needed of the factors that drive the formation and implementation of successful regional innovation ecosystems, as well as policies to leverage financial support and measure performance. EFI is currently conducting an analysis of the attributes and measures of innovation by state, with deep dive case studies of several states. Future analysis should build on these efforts. Analysis should also be conducted to design federal funding mechanisms to encourage formation and growth of regional innovation ecosystems.

**Figure 8**  
**Components of a Regional Clean Energy Innovation Ecosystem**



*The five principal elements of a clean energy innovation ecosystem involve the interaction among investors, large companies, networking assets, enabling environments, and nascent clean energy indicators. Source: EFI, 2018. Compiled using Lin, 2016.*

### Accelerate Market Deployment through Transformative Regulatory and Financial Policies

Meeting deep decarbonization goals will not only require the acceleration of the pace of clean energy technology innovation but also accelerating the pace of clean energy technology deployment. Both need public policy and private sector business model innovation to occur in parallel. This element would include a series of analyses of policy measures to promote commercial deployment of low-carbon solutions for electric power generation, liquid and gaseous fuels and energy efficient end use applications.

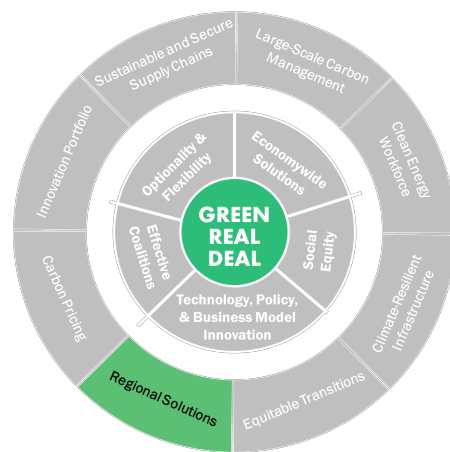
While carbon pricing in theory could provide a market signal to encourage deployment, in practice, the level of carbon pricing policy for the foreseeable future may not provide sufficient incentives for technology transformation across all sectors of the energy economy; this points to the need for companion regulatory policies and financial incentives.

New regulatory policy initiatives could be designed on a sector-specific basis. For example, a national clean energy standard for electricity generation could provide the market-based incentive to accelerate deployment of innovative clean energy technologies emerging from the RD&D process. A national clean fuels standard could encourage reductions in lifecycle carbon emissions from fuels production including use of non-fossil fuel resources (e.g., advanced biofuels). Expanded energy efficiency standards that push the envelope for energy use in residential, commercial and industrial applications could have enormous cumulative impact; for example the efficiency standards effected during the Obama administration will save over a half trillion dollars in consumer energy bills and avoid three billion tonnes of CO<sub>2</sub> emissions cumulatively to 2030.

New financial incentives to be assessed should include options to expand the scope of the existing DOE and other federal loan and loan guarantee programs to provide greater flexibility in technology eligibility and more flexibility in the types of credit support allowed (including co-lending and secondary credit support to state and local financial assistance programs such as Green Banks). Existing federal tax incentives also should be further analyzed with a view toward greater focus on technology-neutral innovation.

### Subnational and Corporate Decarbonization Strategies

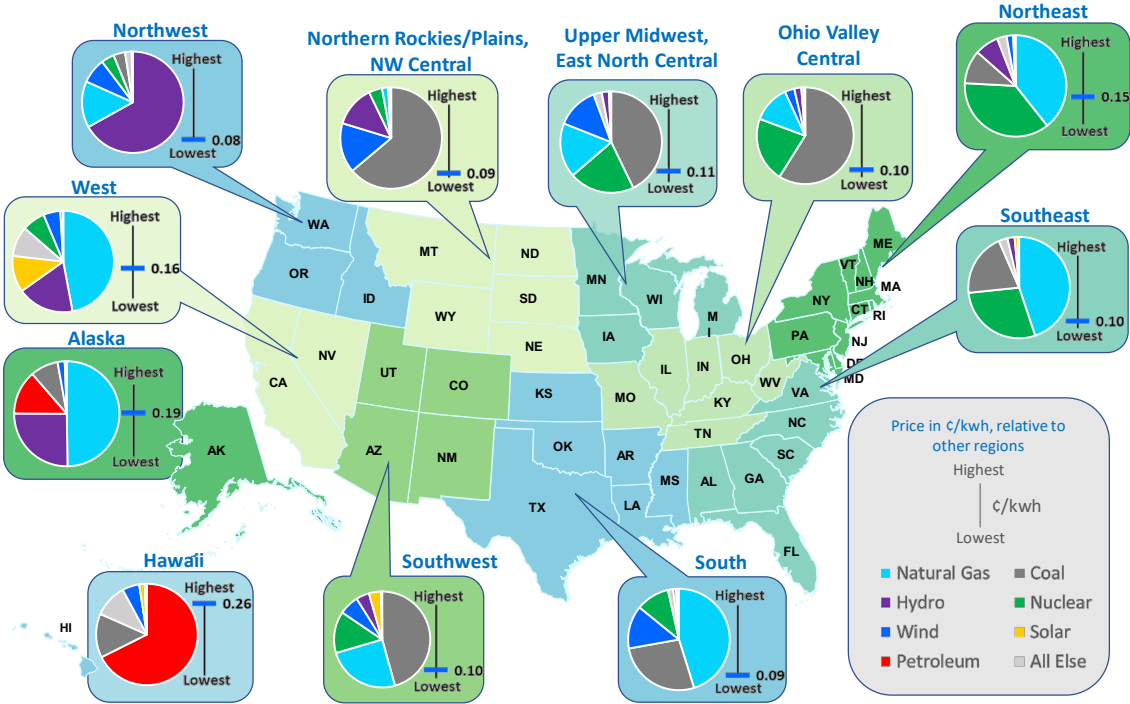
As noted, many states and cities are developing strategies and action plans to implement their “We are still in” commitments. These efforts could benefit from information-sharing on common issues, such as baseline definition and best practices, as well as external expert reviews to help identify new and creative approaches. This element focuses on techno-economic and policy assessments of the bottom-up multi-sectoral pathways need to meet challenging decarbonization objectives in the 2030 to 2040 timeframe. This approach builds upon the previous work conducted by EFI on the California Decarbonization study as well as current on-going work by the Drexel-ICF-EFI team to develop specific strategies to meet New York City’s “80 by 50” goals. This element should include three sub-elements.



### Develop Techno-economic Case Studies of Subnational Decarbonization Strategies

Additional case study assessments should be undertaken to provide further insights, gaps and best practices to assist regions and states in consideration of deep decarbonization strategies. Other states and cities have adopted or are in the process of adopting midcentury decarbonization strategies, and additional case studies reflecting regional variations would be instructive in identifying optimal strategies at the national level. Figure 9 shows regional variation in power generation and prices, suggesting that the costs of, and technologies and strategies for, deep decarbonization will be very different for different regions of the country; further analysis is needed to identify potential areas of variation in regional technology and policy options.

**Figure 9**  
**Power Generation Mix (%) and Price (¢/kWh) by Region**



The high degree of variability among states and regions in terms of current generation resources, energy costs, economic activity, local climate, demographics, etc. means that there is no one-size-fits-all solution for decarbonization. Instead, a regionally tailored approach is needed. Source: EFI, 2019. Compiled using data from EIA, 2017.

**Conduct Deep-Dive Policy Options Analyses**

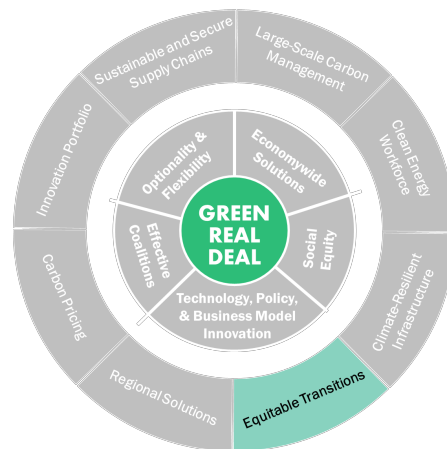
Many subnational decarbonization strategy and road-map reports contain insufficient detail for establishing effective and efficient implementation policies and programs. This sub-element could provide a deep dive analysis of the policy options—including their legal, economic and socio-economic impacts—needed to implement specific decarbonization pathways. A number of resources are available for some of the policy pathways, such as *Designing Climate Solutions: A Policy Guide for Low-Carbon Energy* (Harvey et al, 2018), but adaption of these and other novel policy solutions to regional needs is important. For example, one such analysis could address the policy measures needed to implement the decarbonization options identified in the California Decarbonization study.

### Improve Corporate Climate Disclosures

As noted earlier, major corporations are increasingly setting climate goals, but industry is having difficulty meeting and internalizing climate policies into results. This sub-element should, through analytically supported policy recommendations, assist businesses in meeting climate goals, including US commitments to the Paris agreement. This analysis should provide a significant boost to current corporate efforts to develop sustainability plans and increase climate disclosures in their shareholder reporting.

### Social Equity in the Distribution of the Costs and Benefits of Deep Decarbonization

Transformation of the energy economy will incur cost, but these costs can be minimized through innovation combined with effective policy measures that enhance social equity. Families at lower income levels pay a higher proportion of their household budgets on energy than those at higher levels. Innovation in wind and solar energy have led to significant cost reductions, and many energy efficiency measures reduce consumer costs, but many decarbonization measures currently have higher costs, exacerbating the regressive impacts of energy costs. Environmental justice issues also arise in the consideration of the location of new energy infrastructures or the repurposing of existing assets. Three potential areas for follow-on analysis have been identified.



### Assess the Effectiveness of Programs that Address Social Equity Needs

This analysis should provide a comprehensive review of existing federal and state policies and programs to promote social equity, including an assessment of the effectiveness of these policies and programs, and identification of needed enhancements to address the transition to a low-carbon economy. There are, for example, a number of federal programs that provide various forms of technical and financial assistance to lower income households, or provide technical and policy analysis in support of environmental justice objectives. Some combination of refocusing and augmentation of these programs could ease the burden of clean energy transformation and help to gain public acceptance for decarbonization programs.

### Assess Equity Issues Embedded in Utility Rate Structures

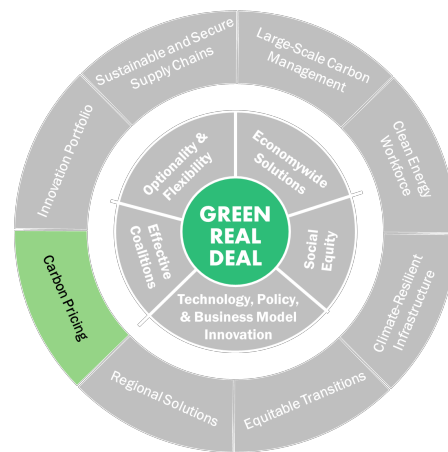
This analysis should assess the equity impacts of regulated distribution utilities' pricing policy. This includes pricing structures (e.g. fixed versus volumetric charges) and allocation of costs among customer classes. The analysis should identify principles and practices to ensure that local electricity, natural gas, telecommunications and water and wastewater utilities are allocated on an equitable basis. This is especially important as "new" services, such as storage, are integrated into rate structures.

### Promote Social Equity in Carbon Pricing Policies

The issue of social equity is particularly important to address as part of any policy to impose an economywide carbon charge. Proposals have been advanced to establish economywide carbon taxes with mechanisms to rebate proceeds in a manner that is progressive by income class. These deserve further study, perhaps through one or more regional-scale case studies.

### Fair and Effective Carbon Pricing

Economywide carbon charges have been advocated by economists as the most cost-effective approach for achieving deep decarbonization. An economy wide charge will mobilize market forces to pursue least cost solutions, and also will motivate innovators to develop and provide new solutions. In the near term, it is unlikely that policy makers will support carbon pricing regimes at levels that will induce technology-shifting across all sectors of the economy. This means other policy measures, such as CAFE and low-carbon fuel standards, industrial decarbonization, and CO<sub>2</sub> sequestration tax credits will need to be continued as companion policies.



Carbon pricing can work in concert with other policy measures. For example, some states currently have carbon cap-and-trade programs (a form of shadow carbon pricing) in addition to sector specific mandates and incentives. Also, many private sector entities already have included carbon shadow prices in their analysis of long-term investments. While there have been a number of modeling studies on the impact of carbon pricing on decarbonization, several important elements require further examination.

### Perform Case Studies of Cumulative Economic Impacts of Carbon Pricing

A case study should be undertaken of how a carbon tax would flow through the various sectors of the economy with an assessment of the cumulative impact on consumers. Focusing the case study on a geographic area with well-defined boundaries, such as Hawaii, would provide a good example.

### Develop Carbon Price Border Adjustment Methodology

This analysis should address the need for and functioning of border adjustments to ensure that domestic industry is not placed at a competitive disadvantage in global markets under a U.S. carbon pricing regime. While the concept of border adjustments is often cited as an element of a carbon pricing policy, the mechanics of how it would be implemented and the integration of carbon border adjustments into trade policy have not been studied in any depth. This analysis should focus on one or more energy intensive trade exposed (EITE) industry sub-sectors, identify how the level of a border adjustment

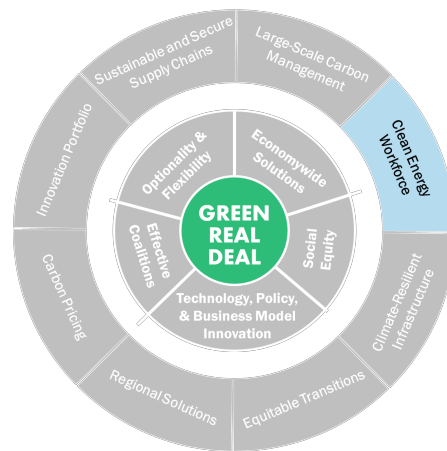
would be determined, and analyze the mechanics of how it would be implemented within the framework of current trade policy

### Assess the Socio-economic Effects of Economywide Carbon Charges

Deeper analysis should be undertaken of the cumulative impacts of carbon pricing on socio-economic classes, and development of strategies to address social inequities. This issue also was addressed as an integral part of the social equity analysis described above.

### Workforce for a Clean Energy Future

Clean energy innovation, including deployment, has also been important for the creation of U.S. jobs. The U.S. Energy and Employment (USEER) report from January 2019, produced by EFI in partnership with NASEO and BW Research, indicated that in 2018 there were nearly two million workers directly employed in Electric Power Generation and Fuels technologies; 800,000 of them were working in low-carbon emission generation technologies, including renewables, nuclear, and advanced/low-emission natural gas.<sup>22</sup> The greatest increases in this category were in advanced/low-emissions natural gas, wind, and CHP generation jobs, which grew by 7 percent, 3.5 percent, and 7.4 percent, respectively.<sup>23</sup> Energy efficiency jobs, which include design, installation and manufacture of energy efficiency products and services, increased 3.4 percent from 2017 to 2018 with over 2.35 million total jobs in 2018.



The transformation of the energy economy will require new workforce skills. To ensure policymakers are doing everything possible and the *right* things, these trends in job growth need to be understood and analyzed from the perspective of needs, requirements, and the necessary innovation infrastructure to support jobs. Further analyses should address the workforce in three key dimensions.

### Perform Regional Energy Workforce Analyses

A more detailed assessment of regional workforce needs and supporting infrastructures should be undertaken. This analysis should address the connection between policy initiatives at the federal, state and local level and the resultant impacts on job creation. For example, previous work by EFI identified that state RPS policies not only resulted in additional clean energy jobs in wind and solar power generation, but also fostered job growth in supply chain industries in those states.

### Conduct Deep-Dive Socio-economic and Demographic Analyses of the Energy Workforce

Further in-depth analysis of the socio-economic and demographic analysis of the changing energy workforce is needed. The EFI-NASEO USEER provides the only comprehensive and



robust baseline on energy jobs in the U.S. and can serve as the starting point to assess potential changes in the workforce needed to support a future low-carbon economy. This analysis should address whether and how energy job growth can also lead to greater diversity in the energy workforce.

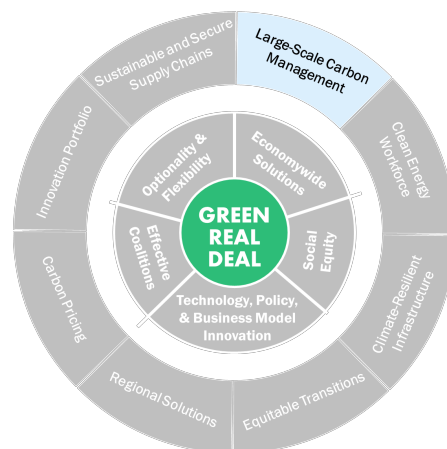
### Assess Energy Workforce Development Programs

Further analysis should be undertaken to assess the effectiveness of current federally sponsored workforce training programs, including post K-12 training programs, traineeships, apprenticeships, and other delivery mechanisms. The analysis should examine the relationship among changing energy demand, energy technology innovation and workforce training and resultant linkages to job creation.

### Large-Scale Carbon Management Systems

The transition to a deeply decarbonized economy may not necessarily require the elimination of fossil fuels. Natural gas, in particular, will continue to play an important role in providing dispatchable electric power generation and high-temperature industrial process heat—applications that are not readily amenable to non-fossil fuel options.

Carbon capture, utilization and storage (CCUS) opportunities will be needed to enable continued use of natural gas and for high efficiency coal-fired power generation. CCUS technology solutions are available today, but implementation is limited due to constrained financial incentives under the current 45Q tax credit and long-term uncertainty of compliance with regulatory requirements for carbon sequestration.



Climate science is providing increasing evidence for the need to achieve carbon neutrality, which will require measures with negative CO<sub>2</sub> emissions. These pathways for carbon dioxide removal (CDR) will involve new technological approaches to remove carbon already in the atmosphere and oceans. There have been several recent studies identifying research needs for CDR, including large scale biological sequestration, and these need to be translated into functional RD&D programs that will be an important element of the technology innovation agenda. Specific analyses to address these issues are currently underway at EFI in two areas.

### Develop a CDR RD&D Initiative

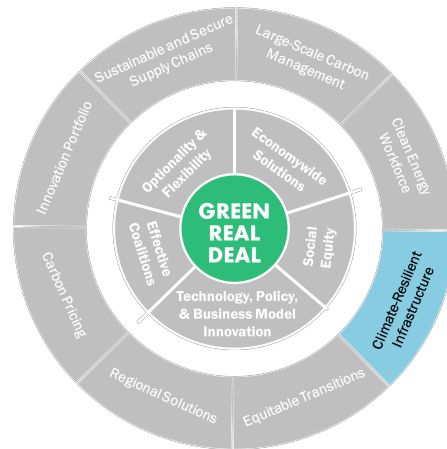
This effort should develop the program portfolio design and implementation of an RD&D initiative to develop the technical approaches for carbon dioxide removal from the environment (atmosphere and oceans) at gigatonne scale. This analysis, currently underway at EFI, will address a whole-of-government approach to carbon dioxide removal, spanning RD&D program design, funding, management and interagency coordination.

### Design a Carbon Sequestration Liability Risk Management Program

This analysis should focus on the development of a framework to manage long-term liability risk associated with gigatonne scale carbon sequestration activities. A national program for managing long term liability risk should include a management framework, funding and ability to implement offsets to address CO<sub>2</sub> leakage issues. The analysis also should address the design of regulatory oversight, including long-term monitoring requirements.

### Modernized, Innovative and Climate-Resilient Energy Infrastructures

Numerous studies have documented the significant investment needs for modernization of energy and energy-related publicly and privately-owned infrastructures. These estimates primarily focus on the need to replace aging infrastructure while managing the influx of “smart” and connected devices. These requirements are compounded by the need to make energy infrastructure more reliable and more climate resilient. Deployment of new clean energy technologies, such as battery and fuel cell zero-emission vehicles, will require entirely new energy infrastructures for charging and fueling. Widespread deployment of smart and distributed electricity generation and storage systems also will require new infrastructure investment in transactive transmission and distribution systems enabled by digital control systems, and sophisticated energy management systems supported by broadband communication capabilities. Finally, the impact of climate change will require that new infrastructures have enhanced resiliency. Meeting these needs will require substantial increases in investment as well as innovation in the architecture of infrastructure systems. Further analyses should address three specific areas.



### Develop Expanded Investment Programs

This analysis should address policies and strategies needed to mobilize increased investment from both the public and private sectors, with an emphasis on incentivizing adoption of innovative infrastructure technologies. This should include analysis of options to expand federal co-funding, credit support and tax incentives.

### Develop Strategies to Support Transformation of Physical and Human Infrastructures

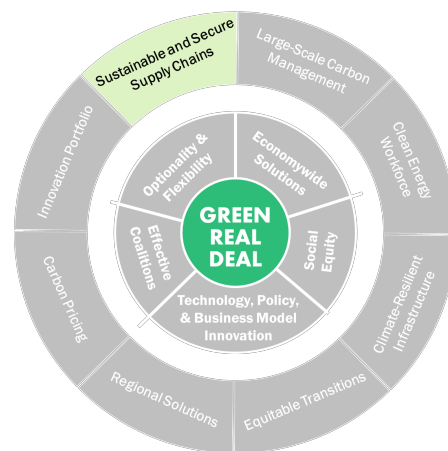
This effort should assess an emerging need to repurpose existing energy infrastructures that will be diminished in demand due to the changing character of a low-carbon economy. This analysis should include consideration of new policy, regulatory and financial incentives to minimize stranded assets and stranded workforces and ease the transformation to a future clean energy economy.

### Develop and Implement a Strategy for Universal Broadband Deployment

An analysis of technology and funding strategies needed to achieve universal broadband implementation should be undertaken, as the integration of broadband communications and modern, digital grids provides the essential foundation for smart, decarbonized communities. This analysis should consider strategies for expansion and better leveraging of existing rural broadband programs in the Department of Agriculture and the Federal Communications Commission. The potential for innovative technologies and approaches to help close the gap also should be considered.

### Sustainable and Secure Clean Energy Technology Supply Chains

Widespread deployment of clean energy technology solutions will require that those technologies be supported by sustainable and secure supply chains. Critical materials supply chains for new clean energy technologies are emerging as the energy security challenge of the coming decades. Many clean energy technologies, for example, rely upon new or critical materials that may not be readily sourced domestically. According to the World Bank, “Global demand for strategic minerals” such as lithium, graphite and nickel will skyrocket by 965 percent, 383 percent, and 108 percent respectively by 2050.”<sup>24</sup> A 2017 World Bank study of the mineral and metals needed for wind, solar, and battery technologies concluded that: “Simply put, a green technology future is [materials] intensive and, if not properly managed, could bely the efforts and policies of supplying countries to meet their objectives of meeting climate and related Sustainable Development Goals.”<sup>25</sup> This element would address these issues through four key sub-elements.



### Conduct Case Studies of the Supply Chain for a Clean Energy Technology

Supply chain analysis is a critical need for clean energy technologies to ensure long term stability and affordability for clean energy. For example, the nascent offshore wind industry is planning to deploy technologies that require large quantities of neodymium. They also will require specialty steels that currently have limited domestic production capability. A deep dive case study could identify key elements of the supply chain and issues for further action.

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*A 2017 World Bank study of the mineral and metals needed for wind, solar, and battery technologies concluded that: “Simply put, a green technology future is [materials] intensive and, if not properly managed, could bely the efforts and policies of supplying countries to meet their objectives of meeting climate and related Sustainable Development Goals.”*

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### **Develop Environmentally Sound and Sustainable Mining Practices for Critical Materials**

Energy security considerations likely will dictate that the increased demand for critical materials for clean energy technologies be met in part through increased domestic supply. This sub-element will focus on the development of policies and practices to ensure that new domestic mining activity will be

undertaken in an environmentally responsible and sustainable manner. These practices should reflect broad input from both the mining companies, miners and their representative unions, states and other stakeholders. This effort also would consider trade policy and other strategies to ensure that sustainable mining practices are implemented globally. Populations in other countries should have access to comparable environmental and safety protections while domestic sustainable mining activities should not be placed at a global competitive disadvantage.

### **Assess Opportunities for Recycling Critical Materials**

Efforts have recently been initiated to explore opportunities for recycling of lithium. Additional analyses are needed to assess the techno-economic feasibility of recycling and identify needed federal policies and programs to promote recycling.

### **Develop a Focused Critical Materials R&D Portfolio**

DOE historically has supported a broad portfolio of materials R&D including materials substitution. An assessment of current DOE and other federally funding materials R&D, including the work of the DOE-sponsored Critical Materials Institute, is needed in order to determine if current federal R&D programs should be better focused to address emerging critical materials issues. Recommendations for new and additional research should become part of the broader national innovation portfolio.

## **Conclusion**

Each of the five principles and eight elements of the Green Real Deal is critical for translating climate mitigation ambitions into actions. Such an ambitious undertaking will require comprehensive analyses beyond those listed here and an across-the-board approach to aggressive decarbonization, while building broad coalitions from disparate parts of society. However, time is not on our side. Meaningful progress—that must be accountable to current and future generations—will require urgent, concerted efforts across policy and politics, business, science and technology, providers and consumers, and other stakeholders. In short, meaningful progress requires a Green Real Deal.

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