



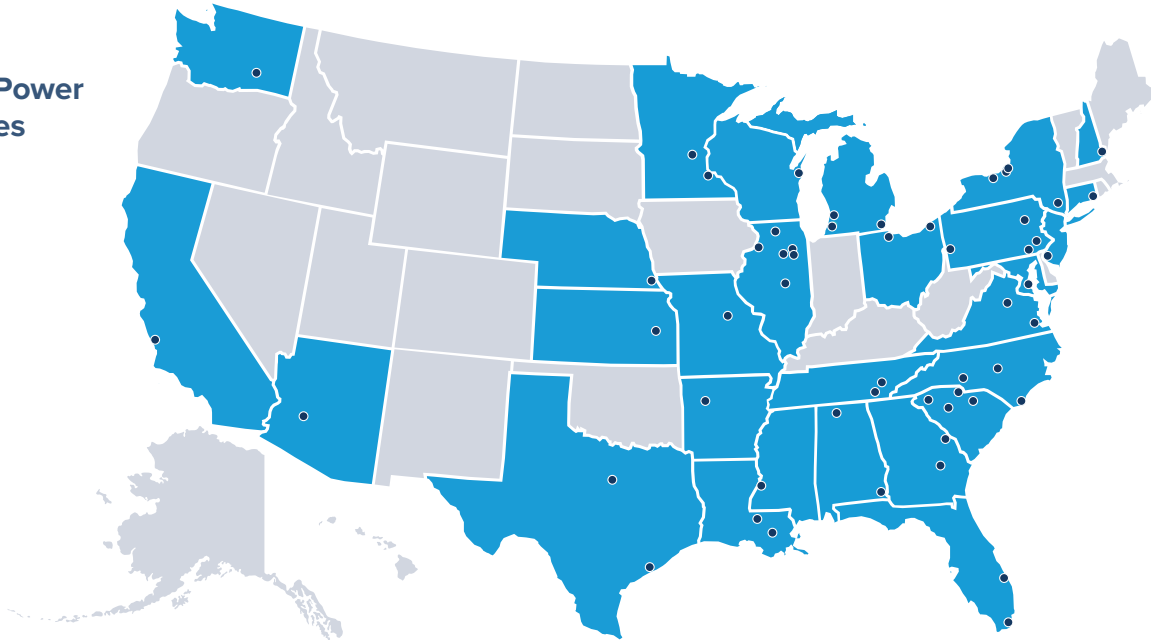
# NUCLEAR ENERGY IN A LOW-CARBON ENERGY FUTURE

## Challenges and Opportunities

## OVERVIEW

The nuclear energy sector is directly responsible for approximately 100,000 well-paying jobs, and the nuclear sector is the highest paying industry in the electric power generation sector.<sup>1</sup> Approximately 70% of these jobs, or 70,000 people, are directly employed in nuclear power generation and fuels production,<sup>2</sup> with the balance employed in fields such as construction, decommissioning, regulation, research and development. All told, the nuclear energy industry is responsible for nearly 500,000 direct, indirect and induced jobs across the United States' economy.<sup>3</sup>

### Nuclear Power Plant Sites



Each of the 94 nuclear power reactors operating across the country employ between 500 to 1,000 people full-time, with about 20 million additional union labor hours created nation-wide each year through regular refueling outages. These are long-term jobs that pay better than any other energy industry and can last for generations; most nuclear plants are licensed to operate out to 60 years, and may plan to operate for 80 years or more. These large, stable on-site workforces—and the large local tax base and economic activity that comes with them—help make nuclear energy a major contributor to employment and economic activity (and carbon-free electricity generation) in many states:

| State          | Percentage of carbon-free generation <sup>4</sup> | Jobs at Nuclear Plants | Salaries Paid at Plants (publicly available) | State & Local Taxes (aggregated from public sources) | Total Annual Economic Output (publicly available) |
|----------------|---|------------------------|--|--|---|
| Arizona        | 73%   | 2,500                  |  | \$55M  | \$2.0B  |
| Florida        | 88%   | 1,800                  | \$147M                                       | \$31M  |   |
| Illinois       | 88%   | 5,400                  | \$452M                                       | \$132M   | \$8.9B  |
| Minnesota      | 51%   | 1,500                  | \$237M                                       | \$33M  | \$1.0B  |
| New York       | 56%   | 3,350                  | \$320M                                       | \$75M  |   |
| North Carolina | 75%   | 2,600                  | \$203M                                       | \$14M  |   |
| Ohio           | 87%   | 1,500                  | \$230M                                       | \$23M  | \$811M  |
| Pennsylvania   | 92%   | 4,500                  | \$550M                                       | \$14M  | \$3.1B  |

<sup>1</sup> "Nuclear Power Pays: Assessing the Trends in Electric Power Generation Employment and Wages," Oxford Economics, April 2019. <https://www.oxfordeconomics.com/recent-releases/nuclear-power-pays-assessing-the-trends-in-electric-power-generation-employment-and-wages>

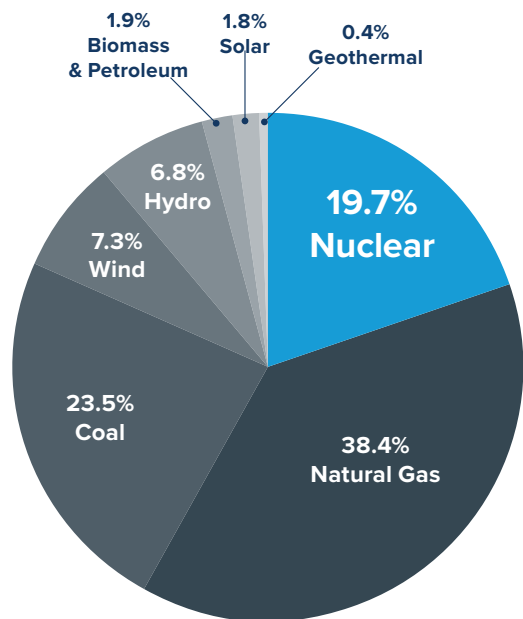
<sup>2</sup> "2020 U.S. Energy & Employment Report," National Association of State Energy Officials and the Energy Futures Initiative. <https://www.usenergyjobs.org/>

<sup>3</sup> "Jobs," Nuclear Energy Institute. <https://www.nei.org/advantages/jobs>

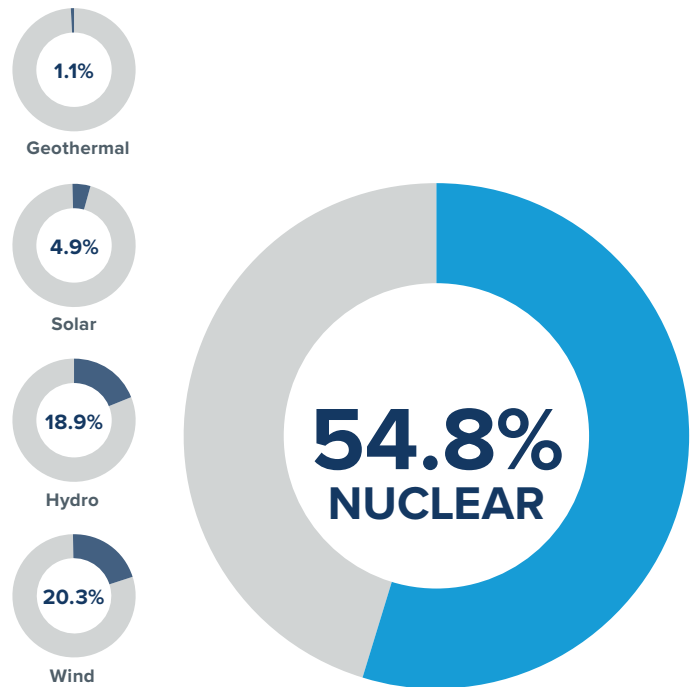
<sup>4</sup> "Map of U.S. Nuclear Plants," Nuclear Energy Institute. <https://www.nei.org/resources/map-of-us-nuclear-plants>

Nuclear reactors produce about 20 percent of U.S. electricity and are the largest source of carbon-free electricity in the U.S.—by far. More than half of all carbon-free electricity in the U.S. comes from nuclear power.<sup>5</sup> These reactors produce power around the clock, for 18 to 24 months between refueling outages, and in 2019 achieved a record 93.4 percent capacity factor. This makes nuclear power reactors the ideal carbon-free, 24/7 partner to wind turbines and solar panels in a decarbonized electricity system; in fact, utilities that have pledged to decarbonize are now investing in license renewals for their nuclear plants to keep these zero-carbon generators online to 2050 and beyond.<sup>6</sup> Nuclear energy is a pathway for the U.S. to achieve environmental and economic goals, both at home and around the world.

### Sources of Electricity in the U.S.



### Sources of Carbon-Free Electricity in the U.S.



The construction of new reactors in the U.S. and abroad provides a tremendous opportunity to create even more American jobs while enjoying the other benefits of global nuclear energy leadership. For example, the construction workforce at the Vogtle 3 and 4 nuclear reactors in Georgia recently reached 9,000 people.<sup>7</sup> Over the life of the project, an estimated 12,000 union craft members have been employed at the site, with many more union members employed in the manufacturing supply chains for the Vogtle project.

As states, cities, and major electricity consumers and producers pledge to deeply or completely decarbonize their electricity supply, energy decision-makers are coming to appreciate the full value of all that nuclear energy delivers to the U.S. energy system. As a result, nuclear plant operators are committing to continued operation of existing reactors out to mid-century and are looking at adding new nuclear generation to complement significant additions of wind and solar generation. Energy companies and energy end-users are developing next-generation nuclear energy systems that can go beyond electricity production to provide a broad range of energy products and services—including production of hydrogen, process heat for industrial applications and desalination of drinking water—to help decarbonize non-electric sectors of the energy system. All told, a revitalized U.S. nuclear energy sector can play a valuable role in creating jobs, decarbonizing energy systems and ensuring continued U.S. leadership in global nuclear energy issues.

<sup>5</sup> "Frequently Asked Questions (FAQs)," U.S. Energy Information Administration, March 2020. <https://www.eia.gov/tools/faqs/faq.php?id=427&t=3>  
<sup>6</sup> For example, see "Duke Energy will seek to renew nuclear plant licenses to support its carbon reduction goals," Duke Energy, Sept. 19, 2019. <https://news.duke-energy.com/releases/duke-energy-will-seek-to-renew-nuclear-plant-licenses-to-support-its-carbon-reduction-goals>  
<sup>7</sup> "Plant Vogtle Expansion Workforce Hits 9,000," Demarest. Aiken Standard, Feb. 18, 2020. [https://www.postandcourier.com/aikenstandard/news/plant-vogtle-expansion-workforce-hits-9-000/article\\_eaaa3a84-b017-529c-844f-829ddabfd014.html](https://www.postandcourier.com/aikenstandard/news/plant-vogtle-expansion-workforce-hits-9-000/article_eaaa3a84-b017-529c-844f-829ddabfd014.html)

## KEY POLICY NEEDS FOR THE U.S. NUCLEAR ENERGY SECTOR

### Properly Value All Sources of Carbon-Free Generation

Building a carbon-neutral economy will require a balanced mix of all carbon-free energy technologies including solar, wind and 24/7 nuclear energy. Policy frameworks should be technology-neutral to create a complementary portfolio of clean technologies.

### Invest in the Workforce of the Future

Operating today's reactors and building the next generation requires a well-trained workforce. The U.S. should maintain support for university nuclear engineering education programs and ensure support is available for apprenticeships and other training programs to help meet present and future workforce needs.

### Use Federal and State Policy to Create Demand for Firm, Carbon-Free Generation

Comprehensive policies to reduce emissions from electricity production, such as clean energy standards, are being pursued by states and can inform a federal approach. Targeted, near-term, convertible tax credits can help retain the tens of thousands of well-paying jobs at the operating fleet of reactors while advancing the next generation of nuclear plants so that nuclear energy remains a foundation for our clean energy system.

### Invest in Next-Generation Technology Demonstration

New nuclear energy technologies—both to support today's reactors and to form the basis for a next generation of nuclear plants—are under development by dozens of U.S. firms. Public-private partnerships to demonstrate new technologies, along with investments in R&D infrastructure at national labs and universities, can help America's innovators deliver world-leading technologies to market. Ensuring the availability of uranium and advanced nuclear fuels can help improve the economics of today's reactors and support the next generation.

### Prioritize U.S. Leadership in Global Nuclear Energy Markets

Nuclear energy projects can result in a century-long strategic relationship between the supplier and recipient nations, and help spread U.S. standards on nuclear safety and nonproliferation. The U.S. should work to reclaim U.S. leadership in global nuclear energy markets by ensuring competitive export financing, restoring the nuclear energy policy director position on the National Security Council staff, making the export review process more efficient and continuing to aggressively support U.S. companies in global markets.

### Resolve the Stalemate over the Nuclear Waste Policy Act

The nuclear waste stalemate stands in the way of fully realizing the potential of nuclear energy. Despite collecting fees from nuclear power users for almost 40 years and amassing more than \$45 billion in funds, the federal program to develop a management system for spent nuclear fuel is woefully behind schedule and has been stalled for nearly a decade. It is long past time for the government to establish a sustainable national program to permanently dispose of this fuel. The industry stands ready to work with the government to identify solutions.

## CHALLENGES AND OPPORTUNITIES

The promise of nuclear energy in a low-carbon energy future is driving a wave of nuclear energy innovation unlike anything seen in almost forty years. Dozens of startups, as well as more established nuclear companies, have invested well over a billion dollars in the development of a broad range of new nuclear energy technologies.<sup>8</sup> We can help to both preserve today's nuclear generation and accelerate the commercialization of new technologies by addressing some longstanding challenges and taking the opportunity to learn from the success of the wind and solar industries to unlock nuclear energy's full potential.

There are huge benefits to be gained from a strong nuclear energy industry. Today's nuclear energy sector is directly responsible for approximately 100,000 well-paying jobs. According to a 2018 study by Oxford Economics, the nuclear sector is the highest paying industry in the electric power generation sector,<sup>9</sup> and typical nuclear power reactor employs 500 to 1,000 workers.<sup>10</sup> Nuclear power plants have become the economic engines for the rural areas where they are often located, offering a large number of high paying jobs and the large local tax base and economic activity that comes with them.

Approximately 70,000 of these jobs are employed in nuclear power generation and fuels production, with the balance employed in fields such as construction, decommissioning, regulation, research and development. This number has fallen slightly in recent years as about six percent of U.S. nuclear energy capacity has been shuttered, but could be poised for a rebound as new nuclear plants are constructed. This would be great news for our next generation of nuclear energy workers; the average mid-wage worker in the nuclear industry earns 22% more per hour than the average mid-wage worker in the coal industry and 25% more than a worker in the natural gas industry.<sup>11</sup> The pay differential with solar installers is even more dramatic; the average solar panel installer earns less than half per hour than the average mid-wage worker in the nuclear industry.<sup>12</sup> To help ensure a sufficient, skilled workforce is available to meet both current and future needs, the U.S. nuclear industry has partnered with other organizations to form the Center for Energy Workforce Development (CEWD). CEWD is the first partnership between utilities, their associations, contractors, and unions to focus on the need to build a skilled workforce pipeline that will meet future industry needs.<sup>13</sup>

“ Yes, jobs are at stake, good jobs, high-paying jobs, union jobs. The labor movement is proud to provide the highest quality labor at nuclear facilities, trained and educated through private funds negotiated in our collective bargaining agreements. And why not? The nuclear industry supplies high quality, long-term, steady work that usually pays one-third more than the average job surrounding a plant. These are the type of family- sustaining careers the American people are demanding more of. ”

LIZ SHULER, SECRETARY-TREASURER  
AFL- CIO, FEB. 21, 2017

<sup>8</sup> “The Advanced Nuclear Energy Industry,” Third Way, June 15, 2015. <https://www.thirdway.org/report/the-advanced-nuclear-industry>

<sup>9</sup> “Nuclear Power Pays: Assessing the Trends in Electric Power Generation Employment and Wages,” Oxford Economics, April 2019 <https://www.oxfordeconomics.com/recent-releases/nuclear-power-pays-assessing-the-trends-in-electric-power-generation-employment-and-wages>

<sup>10</sup> “Jobs,” Nuclear Energy Institute. <https://www.nei.org/advantages/jobs>

<sup>11</sup> p. 108, 113 and 119, “2020 U.S. Energy & Employment Report,” National Association of State Energy Officials and the Energy Futures Initiative. <https://www.usenergyjobs.org/>

<sup>12</sup> “Solar Energy System Installer Hourly Pay,” Payscale. [https://www.payscale.com/research/US/Job=Solar\\_Energy\\_System\\_Installer/Hourly\\_Rate](https://www.payscale.com/research/US/Job=Solar_Energy_System_Installer/Hourly_Rate)

<sup>13</sup> “About,” Center for Energy Workforce Development. <https://cewd.org/about/>

America's labor unions deserve a special mention. They are a crucial component of what makes the U.S. nuclear energy industry the best in the world, and unionization rates at U.S. nuclear power plants are twice the national average.<sup>14</sup> Thousands of the 9,000 person construction workforce at the Vogtle 3 and 4 nuclear reactors in Georgia are union members, and over the life of the project, an estimated 12,000 union craft members have been employed at the site. The International Brotherhood of Electrical Workers (IBEW), United Association, Carpenters, Iron Workers, Laborers International, Roofers, Insulators, Bricklayers, Sheet Metal Workers, Boilermakers, Cement Masons, Operating Engineers, Teamsters and Painters have all had members working at the Vogtle site. Many more union members—from organizations including the IBEW, Boilermakers, United Association and Steelworkers—have been employed in making the large quantities of equipment and materials used in Vogtle construction. That's part of the reason why the AFL-CIO, the IBEW, the United Association, the Utility Workers, the Boilermakers and the Steelworkers have all voiced strong support for nuclear energy to be at the forefront of any clean energy strategy, and have stated their readiness to supply the best labor, updated educational programs, and new tools and techniques to ensure we are in the best position to maintain a plentiful, productive nuclear workforce.<sup>15</sup>

### Filling the employment pipeline

The U.S. can help ensure the availability of the necessary workforce by increasing its investment in engineers as well as in trained craft and skill tradespeople. University nuclear engineering programs have enjoyed strong support from the U.S. Department of Energy over the past decade, and this support has the university community well positioned to meet future workforce needs. Regarding skilled craft and tradespeople, funding is needed to ensure apprenticeships and other training programs are available.

## Getting the most out of today's reactors

The first step to building a carbon-free electricity system is to build upon the pieces that are already in place. Even though the U.S. nuclear fleet is operating at the highest levels of efficiency and safety in history, the policy environment in which it operates has not valued its role in providing clean energy. Eleven reactors have closed and eight are heading down this path. Each closure results in the loss of hundreds of well-paying jobs at the plant with crushing economic impacts on the surrounding communities. Policies that value nuclear energy's carbon-free electricity can ensure that these plants will continue to be part of the energy portfolio of the future.

### Comprehensive Clean Energy Policy

A comprehensive energy policy to dramatically reduce carbon emissions will provide a meaningful incentive to continue operating nuclear plants unless the policy is specifically designed to discriminate against nuclear energy's use. Any technology-neutral framework—including a clean energy standard, a carbon price or a cap-and-trade system—will value the carbon-free nature of nuclear's electricity production equally with other sources. Nuclear will complement solar and wind as part of a portfolio that remakes our electricity system to tackle the challenge of our age.

### Investment Tax Credit

The legislative process to enact a comprehensive policy to reduce carbon emissions in the long-term can itself be a lengthy process. Those plants facing immediate economic challenges may be unable to wait to see if the journey is successful. A short-term investment tax credit (ITC) has received bipartisan support in Congress to incentivize the ongoing capital investments that will enable these nuclear plants to remain in operation for years to come. In the midst of a recession, these tax credits can be most effective when they are allowed to be converted into direct payments. The 2009 American Recovery and Reinvestment Act included this provision for solar and wind development during the previous recession. Renewing this option will make tax credits much more valuable as a means to encourage continued nuclear plant investments.

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<sup>14</sup> p. 96, "2020 U.S. Energy & Employment Report," National Association of State Energy Officials and the Energy Futures Initiative. <https://www.usenergyjobs.org/>

<sup>15</sup> "Shuler at Third Way: Nuclear Power is Good for the Labor Movement," AFL-CIO, Feb. 17, 2017. <https://aflcio.org/speeches/shuler-third-way-nuclear-power-good-labor-movement>

## Complementing state clean energy policies

In the absence of federal action to address the need to preserve and promote carbon-free electricity, many state governments have stepped forward to ensure they are on a path to build the energy system of the future. Federal policies can frustrate these efforts and indeed have recently done so. The Federal Energy Regulatory Commission oversees many aspects of this state-federal interface and can impose actions that effectively undercut state efforts to create low-carbon energy systems. Appointments to FERC should be given priority and prospective commissioners should be vetted to ensure that state policies to promote carbon-free technology deployments are accommodated, not undermined.

## Regulatory transformation

Safe operation is a prerequisite for nuclear plants to be part of the energy future. The independent Nuclear Regulatory Commission plays a vital role in ensuring public and worker safety. Appointments to the NRC should encourage the continuing modernization of how the NRC performs its role. Regulatory and management attention should be focused on areas that really impact safety, not distract from it. The NRC benefits from decades of accumulated knowledge working with an industry that has made significant technological advancements, all of which serve to advance the safety focus. Commissioners need to convey the importance of the core mission of public safety and resist viewing effective regulation in terms of political reaction.

## Ensuring sufficient supply of uranium and advanced nuclear fuel

Most of the uranium used in U.S. nuclear power plants comes from outside the U.S. While most of the suppliers on the world market are reliable allies, the potential does exist for market disruption. As a result, establishment of a U.S.-origin uranium reserve can help ensure stability of supply while helping to restore the U.S. uranium industry.

Because advances in nuclear fuel can have such beneficial impacts on nuclear cost and performance, DOE has been investing in the development of a next-generation of nuclear fuel called accident tolerant fuel (ATF), so named because it can endure accident conditions for much longer than current fuel. Several ATF designs are

under development and are being demonstrated in U.S. commercial reactors. Coupling these ATF designs with more powerful uranium fuel (so-called high-enriched low-assay uranium, or HALEU fuels) can support improvements in both today's reactors and a wide variety of advanced reactor designs. DOE should continue its efforts to qualify and provide HALEU for ATF and other advanced fuel concepts.

## Creating a path to new nuclear construction

Energy analysts have demonstrated that an affordable, reliable, decarbonized electric grid will require significant build-out of three classes of carbon-free energy resource: “fuel saving” resources like wind and solar; “fast burst” resources like batteries that can respond to short-term fluctuations on the grid; and “firm low-carbon” generation like nuclear energy, geothermal energy, or fossil fuels with carbon capture.<sup>16</sup> A recent study of a 100% decarbonized electric grid in the Pacific Northwest proves the point; it found that more than \$8 billion per year could be saved by both retaining the existing nuclear-powered Columbia Generation Station (CGS) and by adding new Small Modular Reactors (SMRs) to complement existing and new hydro, wind and solar resources (see figure 1).<sup>17</sup> Continued investment in technology development and demonstration—coupled with smart federal and state clean energy policies—is needed to ensure all three classes of resource are available in the quantities and on the timelines required.

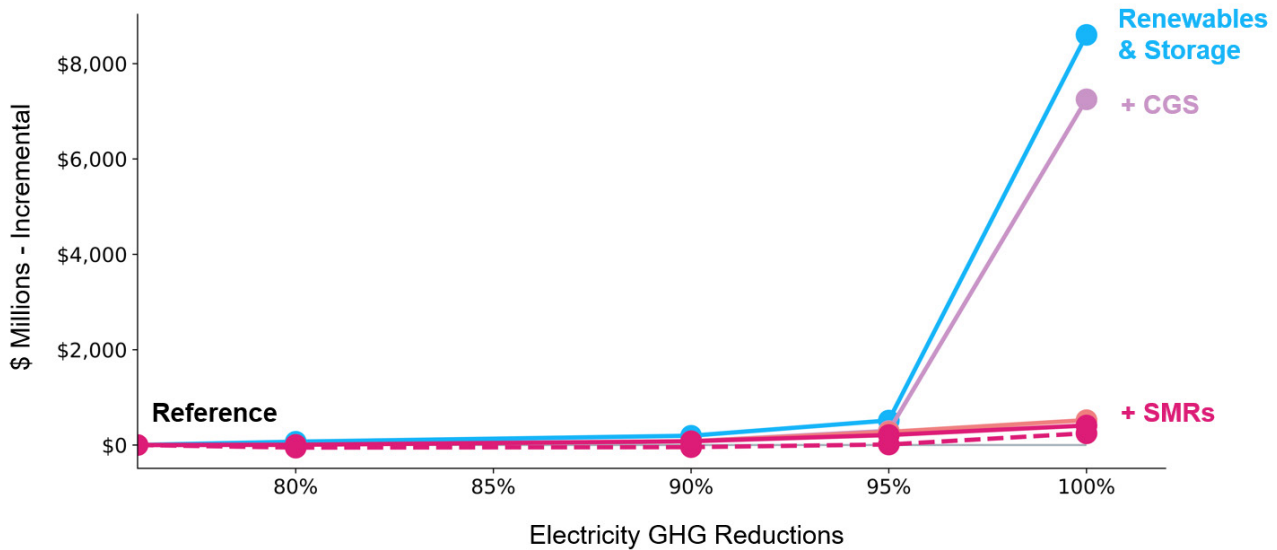
Looking specifically at nuclear energy, there are dozens of advanced reactor and nuclear technology developers in the U.S. working on new and innovative reactor designs ranging in size from a few megawatts to more than 1,000 megawatts. These designs specifically address the economic and safety concerns that have held nuclear energy back as a clean energy resource. And this new generation of designs will enable more than just electricity production at large central facilities. It will help provide carbon-free, resilient and reliable energy to remote locations that are currently using diesel; it will also enable the replacement of retiring coal facilities utilizing the existing infrastructure (and in doing so, preserve or possibly increase the jobs in the local community).

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<sup>16</sup> “The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation,” Sepulveda, Jenkins, de Sisternes and Lester. Joule 2, no. 11, Nov. 21, 2018. [https://www.cell.com/joule/pdf/S2542-4351\(18\)30386-6.pdf](https://www.cell.com/joule/pdf/S2542-4351(18)30386-6.pdf)

<sup>17</sup> “Pacific Northwest Zero-Emitting Resources Study, Executive Summary,” Energy & Environmental Economics, Jan. 29, 2020. <https://www.energy-northwest.com/Documents/E3%20Study%20Executive%20Summary%20final.pdf>

**Figure 1:**  
**Annual system-wide cost savings**  
**including existing and new nuclear on the**  
**Pacific Northwest grid under decarbonization scenarios**



Source: Energy and Environmental Economics, Inc. (E3).

### Advanced reactor demonstrations

The FY 2020 Congressional appropriations legislation directed DOE to conduct demonstrations of multiple advanced reactor technologies through private-public partnerships. Two advanced reactor designs by TerraPower and GE Hitachi Nuclear Energy joint venture and X-energy. Demonstrating advanced nuclear technologies will open other market possibilities including hydrogen production and process heat generation with carbon-free energy. As discussed below, introducing nuclear power into these sectors will be instrumental in achieving decarbonization of the broader energy sector in the U.S. and worldwide. Lastly, these demonstrations will spur international sales of U.S. reactors by building confidence in the technical and financial viability of new concepts. Smart investments in near-term technology demonstrations will help ensure that the U.S. captures the lion's share of the new jobs and other economic and security benefits of leading in next-generation nuclear energy.

### Market-stimulating policies

To ensure deployment extends beyond initial demonstrations, it will be important for both Congress and state governments to enact market-stimulating policies for the full range of carbon-free energy resources. A recent study from MIT demonstrated the role that such market-stimulating policies—including federal tax credits and state renewable portfolio and clean energy standards—have played in attracting the private-sector investment needed to drive down costs and achieve widespread commercialization of solar power.<sup>18</sup> In the case of nuclear energy, the existing (but limited) Nuclear Production Tax Credit (PTC) should be reformed to include features that have facilitated the expansion of wind generation. The value of the PTC should be indexed to inflation, bringing its value to \$25/MWh, and there should be an option to convert the PTC to an ITC. In addition, the per-reactor cap should be removed and the national program cap should be raised from the current 6,000 MW up to 25,000 MW. A stronger incentive for investment in new nuclear, alongside existing means of federal clean energy support such as loan guarantees and power purchase agreements, can help bridge the gap between technology demonstration and widespread commercialization.

<sup>18</sup> "Evaluating the Causes of Cost Reduction in Photovoltaic Modules," Kavlak, McNerney and Trancik. Energy Policy 123, Aug. 5, 2018. <https://www.sciencedirect.com/science/article/pii/S0301421518305196?via%3Dihub>

## Regulatory transformation

If we are to realize the full benefit of advanced reactor technology, the regulatory system must keep pace. One of the challenges facing today's NRC "is to adapt its regulations and oversight practices to a generation of technologies that didn't exist when today's regulatory framework was developed."<sup>19</sup> A commitment to regulatory transformation must remain high on the NRC agenda.

## Investments in R&D infrastructure

All healthy technology sectors are backed by robust research infrastructures at universities, national labs, and private industry. The Nuclear Energy Innovation and Capabilities Act, signed into law in 2018, recognized this and authorized the establishment of a much-needed versatile fast neutron test reactor (VTR) user facility to be built in the U.S. Currently the only accessible fast neutron facility is in Russia. The VTR project, conceived under the Obama Administration and supported by the current administration and Congress, will enable the continued innovation of new fuels, instrumentation, equipment, to support further innovation in the advanced nuclear industry. Congress must provide sufficient funding for the VTR project and continued robust funding to support and enhance the one-of-a-kind research infrastructure at the U.S. national laboratories and universities.

## Decarbonizing other energy sectors

Even if nuclear, solar and wind successfully partner to create a carbon-free electricity system, the U.S. will still have work to do. Driving emissions out of the power sector is the first big step to a carbon-neutral economy, but it needs to be complemented by dramatically reducing emissions from transportation and industrial use; these sectors account for about half of the greenhouse gas emissions from U.S. energy use.<sup>20</sup> There are two strong options to do this. The first would be to rely on this carbon-free electricity to provide more of the energy to move people and produce goods. The second is to produce carbon-free substitutes that can take the place of fossil fuels. We will need thoughtful policies encourage the economic innovation that will transform how energy is used to drive economic growth and create jobs for the future.

## Decarbonizing the transportation sector

Decarbonizing the transportation sector require moving away from fossil fuels—including gasoline, diesel and natural gas—and increasing the use of low-carbon fuels. The greatest potential for decarbonizing the transportation sector comes from using electricity or hydrogen generated from zero-carbon sources like nuclear reactors, wind turbines and solar panels.

Nuclear energy can play a significant role in providing the carbon-free electricity needed to power a growing fleet of electric vehicles. To ensure maximum benefit from the increased electrification of passenger cars and other vehicles, the U.S. should adopt policies that incentivize the use of zero-carbon generation to power electric vehicle charging infrastructure. The DOE should also consider development of a low-carbon standard for electric vehicle charging infrastructure, to ensure consumers have accurate information regarding the carbon-intensity of the electricity provided at charging stations.

In a similar vein, the U.S. should fund large-scale demonstrations and enact policies that incentivize the use of zero-carbon resources to produce the growing amounts of hydrogen and ammonia that will be needed to decarbonize modes of transportation that are not readily electrified. Small-scale demonstrations are already underway. For example, DOE's H2@Scale program<sup>21</sup> recently awarded a grant to demonstrate hydrogen production at a commercial nuclear power plant in the Midwest, and DOE's Office of Nuclear Energy is working with operators of three commercial nuclear power plants to demonstrate hydrogen production in nuclear power plants in different regions of the U.S.<sup>22</sup> Projects such as these should be continued and expanded to ensure we have a broad range of carbon-free technologies from which to produce the necessary quantities of hydrogen to decarbonize heavy transport modes.

DOE's R&D programs should be expanded to specifically include ammonia in the clean transport fuel R&D agenda. Ammonia is generating considerable interest as a potential clean marine transport fuel due to its volumetric energy density and production cost.<sup>23</sup> Advanced nuclear energy systems could be an important source of hydrogen and process heat for the production of ammonia as well as for other decarbonized transport fuels such as aviation fuels.

<sup>19</sup> "Nuclear Technology Innovation and Regulatory Transformation Are Essential to Meeting Climate Goals," Miller, Lyons and Kotek. Utility Dive, Sept. 3, 2019. <https://www.utilitydive.com/news/nuclear-technology-innovation-and-regulatory-transformation-are-essential-t/561995/>

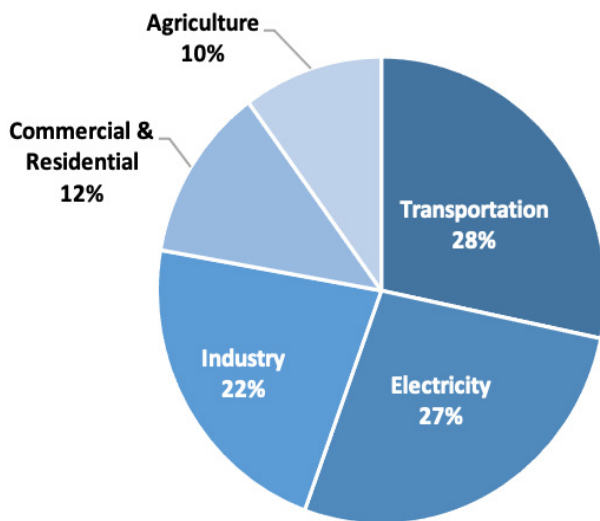
<sup>20</sup> "Sources of Greenhouse Gas Emissions," U.S. Environmental Protection Agency. <https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>

<sup>21</sup> "H2@Scale," U.S. Department of Energy. <https://www.energy.gov/eere/fuelcells/h2scale>

<sup>22</sup> "U.S. DOE Awards Funds to Support Innovation," World Nuclear News, Sept. 12, 2019. <http://world-nuclear-news.org/Articles/US-DOE-awards-funds-to-support-industry-innovation>

<sup>23</sup> "Safe and Effective Application of Ammonia as a Marine Fuel," De Vries, June 12, 2019. <http://resolver.tudelft.nl/uuid:be8cbe0a-28ec-4bd9-8ad0-648de04649b8>

## Total U.S. Greenhouse Gas Emissions by Economic Sector in 2018



Total emissions in 2018 were 6,677 million metric tons of CO<sub>2</sub> equivalent. Percentages may not add up to 100% due to independent rounding.

\* Land Use, Land Use Change, and Forestry in the United States is a net sink and offsets approximately 12% of greenhouse gas emissions. This emissions offset is not included in the total above.

Source: U.S. Environmental Protection Agency,  
[Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018.](#)

## Decarbonizing the industrial and construction material sectors

Major industrial facilities that are already located near the nation's 94 nuclear reactors have lower carbon profiles than other facilities. New nuclear technologies will provide the opportunity to further reduce the carbon intensity of the industrial sector. A 2016 report by the Joint Institute for Strategic Energy Analysis at the National Renewable Energy Laboratory<sup>24</sup> examined the possibility of replacing fossil-fuel combustion in industry with nuclear (specifically SMRs), solar thermal and geothermal energy sources. The report found that SMRs are an option to supply both process heat as well as hydrogen production for feedstock use.

Nuclear energy can also help achieve the construction material decarbonization goals of the House Energy and Commerce Committee's CLEAN Future Act.<sup>25</sup> The Act would "establish a Buy Clean Program that sets performance targets to steadily reduce emissions from construction materials and products used in projects that receive federal funding." Hydrogen and process heat from carbon-free nuclear power generation can play a major role in meeting these goals.

The U.S. can create the necessary pathway to decarbonize industrial and construction material energy uses by following the recommendations of a recent study out of Columbia University's Center on Global Energy Policy,<sup>26</sup> which encouraged policymakers to "Tailor tax incentives to critical applications. Decarbonizing the power sector will require commercializing an array of technologies to perform a range of functions, most notably to provide enhanced flexibility to the power system to accommodate the rise of cheap but intermittent renewable energy ... Policy makers can harness market competition to support the most promising technologies for each different function by designing tax incentive schemes tailored for each application." The application of incentives for the decarbonization of non-electric energy uses could unleash nuclear's potential to green difficult-to-decarbonize parts of the energy economy.

## Creating American Jobs and Influence through Nuclear Technology Exports

Of course, it's not enough to develop new technologies that will only be deployed in the U.S. To help deeply decarbonize the global economy while realizing maximum benefit to U.S. workers and families from the clean energy transition, the U.S. must compete and win in the global marketplace. In the case of nuclear energy, at present more than 95 percent of the world's nuclear construction projects are being built outside of the United States, and the vast majority are being built using nuclear technology supplied by Russia or China. We are trailing in an industry we once led.

Aside from the obvious economic impacts, efforts by Russia and China to displace the U.S. as the nuclear energy technology partner of choice have serious implications for our national security. The export of a broad range of civil nuclear technologies ensures U.S. influence to protect against misuse. Through exports we can ensure U.S. standards of safety and security become commonplace throughout the world.<sup>27</sup>

<sup>24</sup> "Generation and Use of Thermal Energy in the U.S. Industrial Sector and Opportunities to Reduce its Carbon Emissions," McMillan et al., December 2016.  
<https://www.nrel.gov/docs/fy17osti/66763.pdf>

<sup>25</sup> "The CLEAN Future Act Memo," House Committee on Energy & Commerce.  
<https://energycommerce.house.gov/sites/democrats.energycommerce.house.gov/files/documents/CLEAN%20Future%20Act%20Memo.pdf>

<sup>26</sup> "The Next Generation of Federal Clean Electricity Tax Credits," Sivaram and Kaufman. Center on Global Energy Policy at Columbia University SIPA, June 3, 2019.  
<https://www.energypolicy.columbia.edu/research/commentary/next-generation-federal-clean-electricity-tax-credits>

<sup>27</sup> "Don't Squander America's Leadership in Nuclear Energy," Miller, Lyons and Kotek. The Hill, July 26, 2017.  
<https://thehill.com/blogs/pundits-blog/energy-environment/343895-dont-squander-americas-leadership-in-nuclear-energy>

## Ensuring competitive export financing

To compete in this international landscape, U.S. suppliers must be able to offer competitive financing to potential customers. International energy infrastructure contracts almost always require the bidder (in this case, a U.S. supplier) to offer export credit financing for the high capital cost of building the infrastructure. Russian and Chinese nuclear energy suppliers are state-owned and are backed directly by their governments. We must ensure competitive export financing tools are available to U.S. nuclear firms including adequate resources and products through Ex-Im Bank. We must also fully implement the U.S. International Development Finance Corporation's modernized nuclear energy policy and make additional products available to support U.S. exporters during the early project development phase if we hope to win our fair share of this trillion-dollar global market.

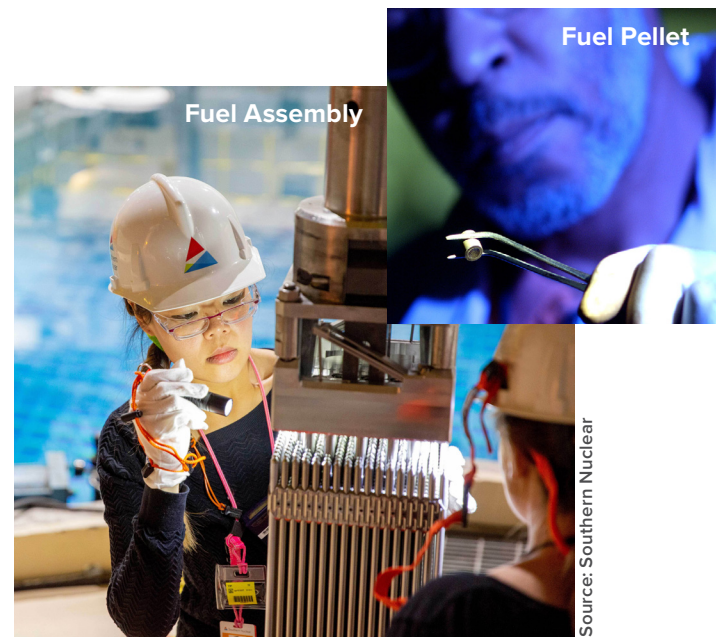
## Increasing advocacy and market access

Because nuclear energy projects are large-scale and can result in a century-long relationship between the supplier and recipient nations, U.S. nuclear energy exports are strategic endeavors that both require and deserve high-level government involvement. The U.S. should restore the nuclear energy policy director position on the National Security Council staff, open more markets to U.S. firms, make the export review process more efficient and continue to aggressively support U.S. companies in global markets.

## Management of Spent Nuclear Fuel

In 1987, Congress amended the Nuclear Waste Policy Act and named the Yucca Mountain site in Nevada as the only site to be examined as a potential location for the nation's first deep geologic repository for spent commercial and government-origin nuclear fuel and other high-level radioactive wastes. After having spent over \$10 billion dollars and more than twenty years characterizing the site and developing an application for a repository at Yucca Mountain, on March 3, 2010 the DOE filed a motion with the NRC to withdraw the license application. In its funding request for fiscal year 2011, DOE proposed to de-fund the Yucca Mountain project. Congress agreed to this proposal, and no funding has been provided to move forward with

Yucca Mountain—or with an alternative waste management program—for the past decade. While the industry and the nation wait for the government to fulfill its responsibility, the NRC has concluded that dry casks can be used to store spent fuel at reactor sites for at least a century. But this is not a long-term solution, and taxpayers are assessed between \$500 million and \$1 billion annually to pay for the costs of at-reactor storage because of the federal government's failure to meet its obligation to dispose of used fuel.



Nuclear fuel has a very high energy density, which allows nuclear fuel assemblies to power a reactor for about five years. After removal from the reactor, radioactive byproducts in the “spent” fuel cause the fuel to be both thermally hot and highly radioactive, so it must be stored in a way that keeps the fuel cool and protects workers from the radiation. Initially, the spent fuel is placed into an isolated water-filled pool adjacent to the nuclear reactor. After a couple of years or more, the fuel has cooled to the point where it can be moved into a dry, air-cooled storage container called a spent fuel cask. There are more than 80,000 metric tons of spent commercial nuclear fuel stored in 36 states across the U.S. This might sound like a lot, but it really isn't. For example, if you got all of your electricity from nuclear energy for your entire lifetime, the spent fuel from your electricity use would fit a soda can. Put another way, one solid nuclear fuel pellet provides as much energy as one ton of coal or 149 gallons of oil.

The following picture shows the dry spent fuel storage facility at the former Connecticut Yankee nuclear power plant. The storage facility is a fenced, guarded and monitored concrete pad about the size of a hockey rink. The facility hosts 40 spent fuel casks (plus 3 more holding radioactive wastes from the reactor structure) containing the spent fuel from nearly 30 years of reactor operation. Visitors to these facilities are often surprised by the small area needed to store all the fuel ever used by the plant.



Source: [Connyankee.com](http://Connyankee.com)

For comparison, if the electricity supplied over Connecticut Yankee's operating life were instead supplied by a modern natural gas plant, the resulting carbon dioxide emissions would fill the Superdome in New Orleans—more than 3,000 times.

The bottom line is that solving the spent fuel issue is not a technical challenge, it is a sociopolitical challenge. Other nations have identified and licensed sites for spent fuel disposal and plan to begin operating those facilities in the 2020s. But if we want to realize a bright future for nuclear in the U.S., the administration and Congress need to break the current stalemate. The nuclear industry has continued to explore solutions and innovations for managing spent fuel, and stands ready to work with the government on a path forward. Until this happens and the U.S. resumes a program to develop a durable solution for long-term spent fuel management, spent nuclear fuel can be safely stored at existing and new nuclear power plant sites as the U.S. increasingly relies on nuclear energy to provide the firm, dispatchable zero-carbon generation needed to realize an affordable, reliable, low-carbon energy system.



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**CONTACT**  
Harsh Desai at [hsd@nei.org](mailto:hsd@nei.org)  
for additional information.