LWVNM Nuclear Issues Study Task 3 Report

# Meeting US Electricity Needs in 2050

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***Task 3. Consider the current U.S. energy situation and domestic nuclear plant status including closures with related impacts on states.***

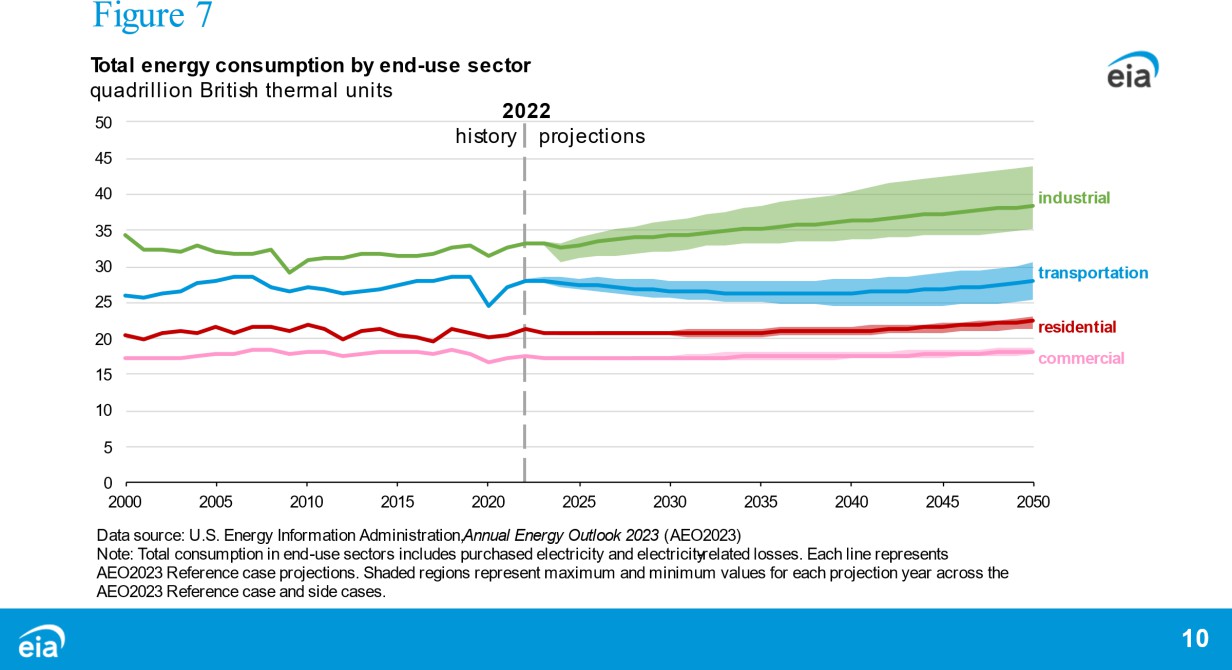
# Executive Summary

The Task 3 report analyzes how U.S. electricity needs can be met through 2050 while reducing greenhouse gas (GHG) emissions. DOE estimates of electricity supply and demand give evidence that renewable energy sources will provide well over half of needed supply, with the remainder primarily from declining amounts of natural gas, existing nuclear power plants, and much smaller uses of coal. Variations in current electricity sources among states and challenges to growth of renewable energy are identified. Technologies are becoming available with substantial investment to make renewables the “new baseload” energy source and to address end-of-useful-life waste issues of solar panels and wind turbines. The energy transition to renewable sources is moving ahead quickly enough that no new nuclear plants are needed to meet 2050 GHG reduction goals.

# Electricity Supply and Demand Estimates to 2050

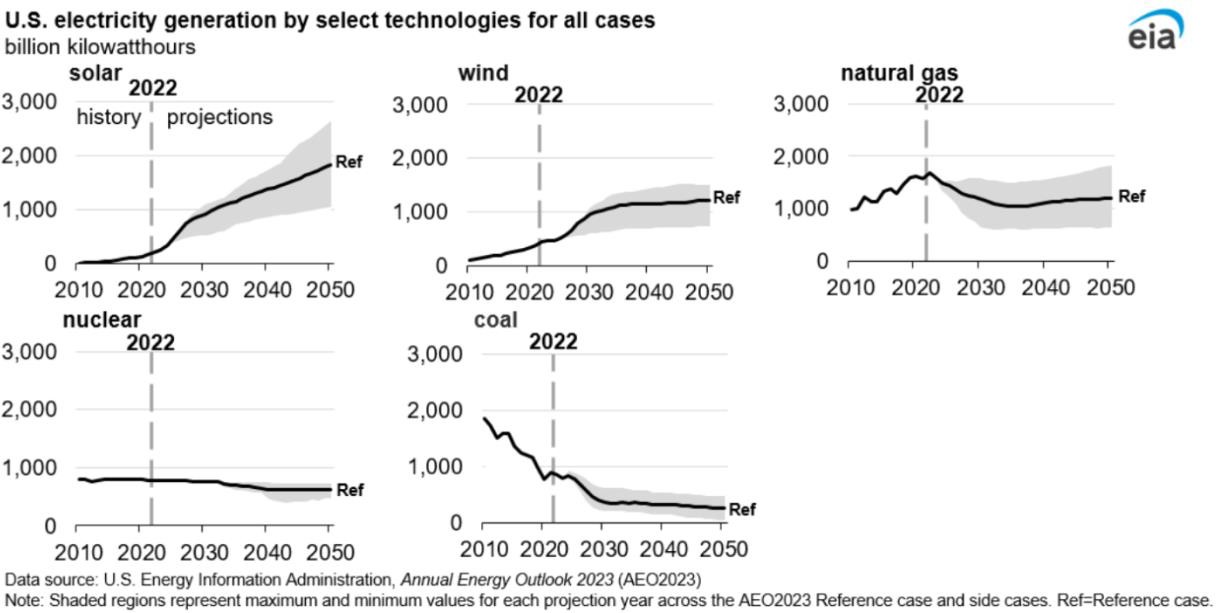
In order to meet climate goals of reducing reliance on fossil fuels for electricity generation by 2050, we need to analyze whether and how US electricity requirements can be met by other energy sources. A first step is to investigate the current and estimated demand for electricity and then identify various ways that this demand can be met. This brief report will focus on the energy mix of fossil fuels (coal and natural gas), nuclear energy, and renewable energy sources (solar and wind) in the US between now and 2050. Note that a number of assumptions must be made in all estimates of energy demand and supply, such as economic growth rates, technological advances, costs and prices, public policies, etc. Likewise, estimates of which investments in non-fossil fuel sources should be selected also depend upon a number of assumptions, which should be made transparent.

A particularly relevant, unbiased, and up-to-date source of data for estimating energy demand and supply is the US Energy Information Administration (EIA). Its *Annual Energy Outlook 2023* (AEO2023) provides estimates, using 2022 as the baseline and ending in 2050. First, regarding demand, the AEO2023 estimates that increases in total demand could be as low as zero by 2050 or as high as 15% above the 2022 level. The shaded “cone of uncertainty” in the figure below (from the EIA report) takes into account various assumptions about economic growth, energy costs and availability, energy efficiency, etc. The finding that US energy demand in the residential, commercial, and transportation sectors will remain virtually unchanged in 2050 in itself is a remarkable forecast. Growth is projected to occur in the industrial sector, which also has the greatest range of uncertainty.



The AEO2023 also provides estimates of where the supply of energy to meet the demand will come from. The figure below tracks estimates for individual energy sources in the context of pre-2020 growth from 2010 to 2050. The reference case (bold line) estimates energy sources under current US laws and regulations (such as the Inflation Reduction Act) as they are expected

to be implemented. Note that the use of solar energy is predicted to increase dramatically. Wind energy continues to increase until the mid-2030s and then stabilizes. Natural gas and nuclear energy each exhibit small declines. Coal continues its long-term decline.

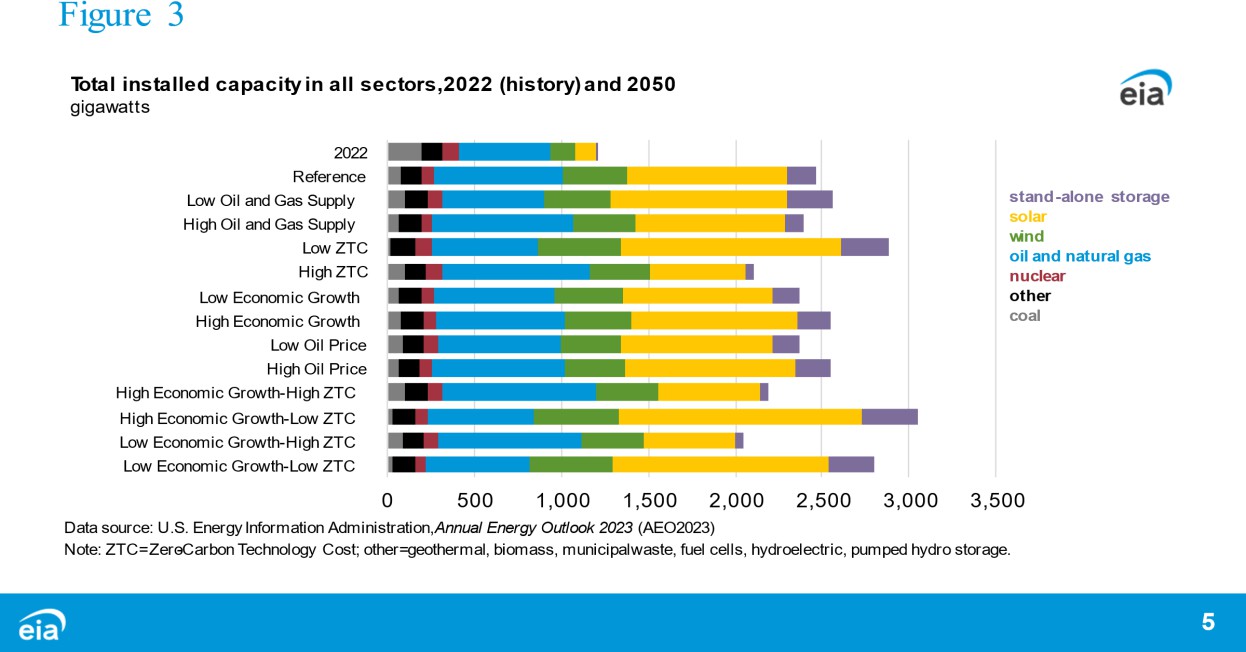


The chief reason why renewable energy sources are becoming dominant is because of declining costs relative to other sources. Between 2009 and 2021, the cost of solar dropped 90% and wind

during this period.

(See Appendix A for data on declining costs of renewables compared to traditional energy sources.)

Figure 3 below from the AEO2023 consolidates the individual estimates for each energy source into a single chart. It shows the 2022 sources of electricity in the top line and the “reference case” in the second line. The following twelve lines are the estimates of 2050 energy sources based upon various assumptions, such as low vs high oil and gas supply, low vs high renewable energy cost, low vs high economic growth, etc. In all cases, renewable sources, that is, solar and wind energy taken together, are the largest sources of energy, and coal is the lowest source by 2050. The percentage of oil and natural gas may increase or decline depending upon relative costs. Nuclear energy is declining over the period.



The EIA summarized its findings as follows: “In AEO2023, we see stable growth in U.S. electric power demand through 2050 in all cases we considered because of increasing electrification and ongoing economic growth. The combination of declining capital costs and government subsidies, including IRA initiatives, drive rising renewable technologies for electricity generation, such as solar and wind. **Once built and when the resource is available, wind and solar are the least cost resources to operate to meet electricity demand because they have zero fuel costs.** Over time, the combined investment and operating cost advantage increases the share of zero-carbon electricity generation. As a result, in AEO2023**, we see renewable**

**generating capacity growing in all regions of the United States in all cases.** Across all cases, compared with 2022, solar generating capacity grows by about 325% to 1019% by 2050, and wind generating capacity grows by about 138% to 235%. We see growth in installed battery capacity in all cases to support this growth in renewables.” 1 (Emphasis added.) EIA thus supports the position that a mix of energy sources, including significant growth in renewables, is sufficient to meet the demand for electricity in 2050.

1 Quote from US Energy Information Administration (EIA), “Annual Energy Outlook 2023,” March 2023. <https://www.eia.gov/outlooks/aeo/narrative/index.php#ExecutiveSummary>

# State Variability in Electricity Energy Sources

AEO2023 focuses on national estimates of energy demand and supply for electricity, but it is worthwhile to consider how the energy mix varies widely by state, due to differences in natural resource availability, relative costs and technologies when initial investment decisions were made, public policies, long-term contracts, impacts on communities, etc. Energy transitions are not smooth and automatically responsive to cost differences. Public utility investments in electricity generation are very large and long-term, and may be influenced by noneconomic considerations.

One example of how state variability might influence the pace at which fossil fuels are replaced by non-greenhouse gas energy sources relates to uses of coal. Appendix B lists the top 10 states that are currently using coal to generate electricity. Note that public utilities in West Virginia, Wyoming, and Kentucky are most dependent upon coal to generate electricity. Some state utilities on this list may choose to continue using coal because it is sourced within their state and benefits many state residents. Utilities in other states are more likely to switch to another energy source as long-term contracts expire and coal plants become obsolete if given incentives to do so or if it is otherwise less costly or preferred by citizens.

A somewhat different analysis might face the 28 states that currently have nuclear plants in operation. Appendix C lists the states with one or more reactors in the order of percentage of dependence on nuclear power in 2023. Note that Nuclear Regulatory Commission licenses to operate are initially for 40 years but may be extended in increments of 20 years if the reactor is operating safely and if requested by the state utility commission. Of the 92 US nuclear reactors operating in 2020, 88 have received an extension of 20 years on the initial 40-year license.

Appendix C shows that New Hampshire is most dependent upon nuclear energy. New Hampshire utilities generated a total of 1,520 MW-hr. of electricity, of which 59.1% came from its Seabrook nuclear plant. Seabrook has already received one extension to operate until 2050. The state’s public utility commission will have to decide in the 2040’s whether to request an additional 20-year license extension to 2070 or shift to another energy source. A possible alternative energy source might be hydroelectric energy that will be transmitted from Quebec by Avangrid’s New England Clean Energy Connect (NECEC) line.

In Appendix C Illinois has the second highest dependence on nuclear energy at 55.6%. After 11 reactors were built in the 1970s and 1980s, its legislature passed a very restrictive requirement in 1987 against building any new nuclear facilities, one of twelve states that have such bans or restrictions.2 However, conflicts have arisen in recent years in Illinois about whether to continue to rely on nuclear energy by lifting the restrictions. The state legislature passed a bill in 2023 that would have repealed the state’s law banning the construction of new nuclear facilities until a permanent site for nuclear waste disposal is selected. However, the Illinois governor vetoed the legislation. Meanwhile, its nuclear utility is applying to extend the licenses of two plants to operate into the 2040s.

While most states with nuclear facilities have opted to extend their licenses to operate for at least 20 years, ten states chose to permanently close 12 U.S. nuclear reactors between 2013 and 2021,

2 According to the National Conference of State Legislatures website, the 12 states with bans or strong restrictions on new nuclear power plants are: California, Connecticut, Hawaii, Illinois, Maine, Massachusetts, Minnesota, New Jersey, New York, Oregon, Rhode Island, and Vermont. [https://www.ncsl.org/environment-and-natural-resources/states-restrictions-on-new-](https://www.ncsl.org/environment-and-natural-resources/states-restrictions-on-new-nuclear-power-f) [nuclear-power-f](https://www.ncsl.org/environment-and-natural-resources/states-restrictions-on-new-nuclear-power-f)

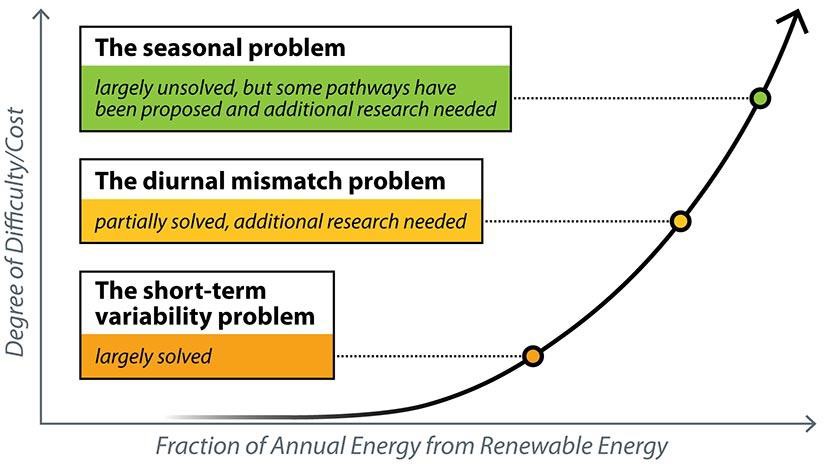
according to a Congressional Research Service (CRS) report in 2021. (See Appendix D for a list of these shutdowns.) Seven other reactor retirements were announced through 2025. However, the CRS report notes that announced retirements have not always occurred as planned because states may take actions to provide more revenues to keep a plant operating. Many other U.S. reactors have been identified by recent studies as being “at risk” of shutdown for economic reasons, although their closures have not been announced.3

It appears that growth in new nuclear power plants is unlikely at the present time. The strategy in most cases is to keep existing nuclear plants in operation when safe to do so and cost-effective compared to alternatives.

# Renewable Energy Challenges

Many scholars assert that the U.S. can become 100% reliant on renewable energy sources in the foreseeable future (e.g., Jacobson, et al., 2017; Jacobson, 2023), but acknowledge that a number of technical and non-technical challenges to renewable energy growth must be addressed. (See Breyer, et al., for a review of scholarly research on 100% renewable energy opportunities and challenges, beginning in the 1970s and growing substantially since 2014. This extensive analysis has 472 references.) Recently, academic and business research articles (e.g., Wouters, 2023; McKinsey & Company, 2022) have claimed that renewable energy is becoming the “new baseload,” refuting an argument against reliance on solar and wind energy. “The Baseload Fallacy” (Wouters, 2023) identifies ways that variability in solar and wind power generation can be managed to provide electricity 24/7, including interconnecting existing regional power grids; demand management; and energy storage.

The 2021 study by the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) and DOE's Office of Energy Efficiency and Renewable Energy (EERE) concluded that current technical knowledge was sufficient to achieve up to 80% reliance on renewable energy sources. This study (called the NREL-EERE study below) divided the technical problems in the transition to 100% renewable energy into 3 categories, as shown in NREL-EERE’s graphic below.



The short-term variability problem relates to the public utility balancing the supply of renewable energy and demand for electricity on a minute-by-minute basis. This problem is largely solved, according to the NREL-EERE study. Studies of the second problem, called the diurnal mismatch problem, focus on balancing supply and demand over a 24-hour period because peak demand occurs at night but supply of solar and wind energy is mostly generated during the day. Battery storage systems are key to solving this problem. The NREL-EERE study claims that battery

3 Quote from Congressional Research Service (CRS), “U.S. Nuclear Plant Shutdowns, State Interventions, and Policy Concerns,” June 10, 2021. https://crsreports.congress.gov R46820.

technology is currently sufficient to achieve up to 80% of electricity demand using renewable energy sources.

In the third zone, however, the seasonal mismatch problem needs research to “evaluate the suite of technologies that can help ensure renewable supply matches demand patterns across all time periods—and that we will need significant engineering and design to transition the grid from one that is dependent on synchronous machines to one that is based on inverters.”4

The non-technical problems in transitioning to renewable energy are economic, environmental, social, and political. They include the following issues:

1. Large investments necessary for electrical grid expansion and upgrades. (That is, more transmission lines to connect solar and wind sources to end users and to update existing transmission lines to integrate renewable sources).
2. Creation of recycling facilities for solar panels and wind turbines.
3. Local opposition to large solar and wind installations based upon land use and environmental issues, such as impacts on wildlife.
4. Very long permitting times for some renewable energy projects, which relate in part to the local opposition issue above. (For example, Pattern Energy’s SunZia transmission line in New Mexico, the largest wind energy project in the Western Hemisphere as of 2023, took 17 years to be approved.)
5. Worker and community exposures to hazardous amounts of lead, lithium, tin, and cadmium used in manufacturing solar and wind equipment.
6. Supply chain issues, including availability of critical but scarce minerals and materials. (See Breyer, et al., 2022, Section VI, Part D for a detailed analysis of this issue.)
7. Opposition by other energy interest groups.

Perhaps one of the easier issues to solve is modernizing the electrical power grid because we have been working on it since at least 2015. The DOE prepared a comprehensive multi-year plan to modernize the electrical power grid nation-wide in November 2015. The Pacific Northwest National Laboratory is taking responsibility for researching “renewable integration.” Much of the early work is on research to identify low-cost technical solutions that could be implemented at state and local levels.

Subsequently state-level actions to modernize the power grid have been extensive as reported by the National Council of State Legislatures. Its 2021 report stated: “Legislatures, public utility commissions and energy providers across the nation are discussing grid modernization, assessing needs, policies, costs and return on investment. While needs vary from state to state, the latest report from the American Society for Civil Engineers found that current grid investment trends will lead to funding gaps of $42 billion for transmission and $94 billion for distribution by 2025… Although many of these upgrades may require significant investment, many can result in operational savings while providing resiliency and other benefits. Technologies that increase knowledge of grid operations, for instance, can allow utilities to better balance fluctuating supply and demand, respond to outages, optimize resource use and increase efficiency.”5 At least $378 billion in federal grants, loans, and tax credits for grid modernization and wind energy projects

4 The “inverter problem” is described in the NREL-EERE study. An inverter converts direct current (DC) electricity, which is what a solar panel generates and battery systems produce, to alternating current (AC) electricity, which the electrical grid uses. With DC, electricity is maintained at constant voltage in one direction. With AC, electricity cycles in both directions in the circuit. See EERE’s website for a description of inverters. [https://www.energy.gov/eere/solar/solar-integration-inverters-and-grid-services-](https://www.energy.gov/eere/solar/solar-integration-inverters-and-grid-services-basics#%3A~%3Atext%3DTraditional%20%E2%80%9Cgrid%2Dfollowing%E2%80%9D%20inverters%2Cthe%20inverter%20tries%20to%20match) [basics#:~:text=Traditional%20%E2%80%9Cgrid%2Dfollowing%E2%80%9D%20inverters,the%20inverter%20tries%20to%20match](https://www.energy.gov/eere/solar/solar-integration-inverters-and-grid-services-basics#%3A~%3Atext%3DTraditional%20%E2%80%9Cgrid%2Dfollowing%E2%80%9D%20inverters%2Cthe%20inverter%20tries%20to%20match)

5 Source for quote: National Council of State Legislatures, “Modernizing the Electric Grid: State Role and Policy Options.” Updated September 22, 2021. <https://www.ncsl.org/energy/modernizing-the-electric-grid>

have been announced by the Department of Energy. Other federal agencies also have clean energy funding available.

The second problem relates to recycling the large amount of worn out solar panels and wind turbines, which have useful lives of about 20 to 30 years. While 28 recycling facilities already exist for solar panels, many more will be needed to process the 95% of solar panels that can be recycled with existing technology. The Environmental Protection Agency is funding studies to extract silver and lead and to refine silicon in order to design a “circular economy” for renewable energy materials. Progress to recycle wind turbines is also being made by DOE’s Wind Energy Technologies Office.

The other issues are challenges to be addressed on a case-by-case basis. Each state has particular circumstances that influence support for or opposition to renewable energy sources. Appendix E shows the percentage of renewable energy generated in each state in November 2023. The contrast between the top 10 states and the bottom 10 is stark. Seven states are already above 50% usage of renewable energy, while six states use 5% or less. The midpoint is only 14%.

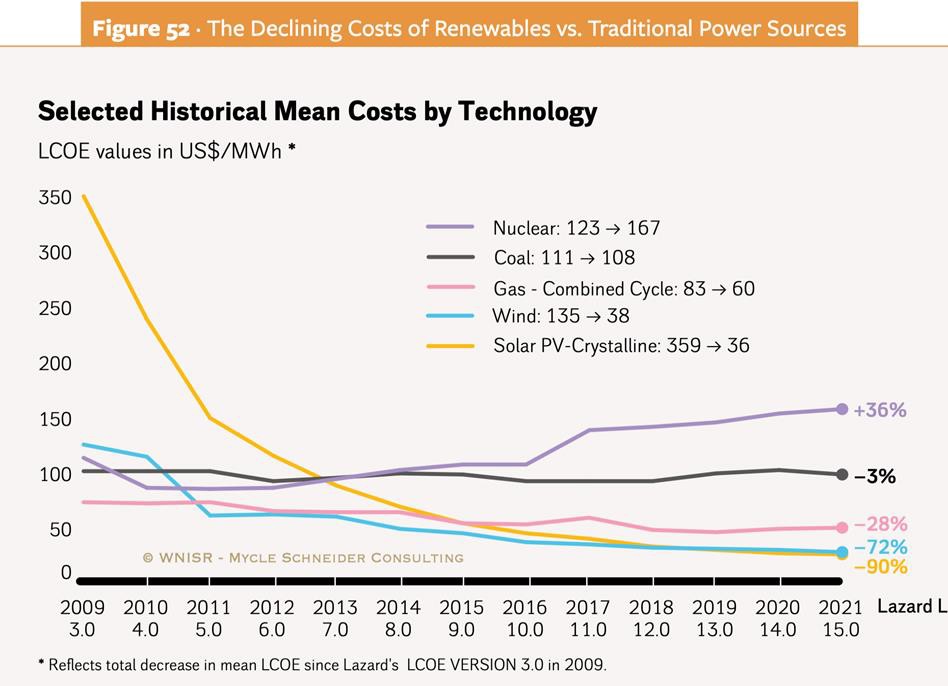
Clearly, there is much room to increase use of renewable sources, and funding is available to expedite this growth.

# Conclusions

The U.S. Energy Information Administration’s AEO2023 states that it is technically feasible to rely on a mix of energy sources to meet both the predicted demand for electricity in 2050 and also net-zero climate goals. Solar and wind energy sources will provide over 50% of supply with substantial funding at the federal and state levels. Existing nuclear energy will continue to provide electricity with plants in operation today whose useful lives have been extended 20 to 40 years beyond initial licenses. The balance of supply will come from natural gas to a large extent and from coal at a much lower extent than in the past.

Achieving the goal of 100% renewable energy requires overcoming a number of challenges. Leading states are showing the way in how to overcome these challenges. The general public is strongly in favor of developing solar and wind energy projects. (See Appendix F for a 2022 Pew survey question comparing public opinions about renewable vs. nuclear energy projects.) Many states are well on the way to investing in infrastructure to support solar and wind energy projects. In our view, the energy transition to renewables is moving ahead quickly enough that no new nuclear plants are needed to meet 2050 goals.

# Appendix A



Source: World Nuclear Industry Status Report 2022, page 280 <https://www.worldnuclearreport.org/IMG/pdf/wnisr2022-figure52_lazard_lcoe_2021.pdf>

# Appendix B

**Top 10 states using coal to generate electricity in 2023\*:**

|  |  |  |  |
| --- | --- | --- | --- |
| West Virginia | 83.9% | Nebraska | 50.7% |
| Wyoming | 75.1% | Utah | 44.7% |
| Kentucky | 69.0% | Indiana | 43.8% |
| Missouri | 64.7% | Montana | 39.8% |
| North Dakota | 60.0% | Iowa | 37.4% |

\*Data are extracted from <https://www.chooseenergy.com/data-center/electricity-sources-by-state/>. The website provides state-by-state data of energy sources as well as lists of the top 10 states using 5 energy sources.

# Appendix C

## Nuclear Energy Dependence by State, Generation, No. of Reactors, and Potential Lifespan\*

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\*Sources: Choose Energy, [https://www.chooseenergy.com/data-center/electricity-sources-by-](https://www.chooseenergy.com/data-center/electricity-sources-by-state/) [state/](https://www.chooseenergy.com/data-center/electricity-sources-by-state/);

US Energy Information Administration, [https://www.eia.gov](https://www.eia.gov/); Nuclear Regulatory Commission <https://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>; Office of Nuclear Energy, <https://www.energy.gov/ne/office-nuclear-energy>

# Appendix D

## U.S. Nuclear Reactor Shutdowns, 2013-2021\*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **State** | **Reactor** | **Start-up Year** | **Shutdown Date** | **Generating Capacity (Megawatts)** | **Major Factor(s) Contributing to Shutdown** |
| Florida | Crystal River 3 | 1977 | Feb. 2013 | 860 | Cost of major repairs to reactor containment |
| Wisconsin | Kewaunee | 1974 | May 2013 | 566 | Operating losses |
| California | San Onofre 2 | 1983 | June 2013 | 1,070 | Cost of replacing |
|  |  |  |  |  | defective steam |
|  |  |  |  |  | generators |
| California | San Onofre 3 | 1984 | June 2013 | 1,080 | Cost of replacing |
|  |  |  |  |  | defective steam |
|  |  |  |  |  | generators |
| Vermont | Vermont | 1972 | Dec. 2014 | 620 | Operating losses |
|  | Yankee |  |  |  |  |
| Nebraska | Fort Calhoun | 1973 | Oct. 2016 | 479 | Operating losses |
| New Jersey | Oyster Creek | 1969 | Sept. 2018 | 614 | Agreement with state |
|  |  |  |  |  | to avoid building |
|  |  |  |  |  | cooling towers |
| Massachusetts | Pilgrim | 1972 | May 2019 | 685 | Operating losses; rising |
|  |  |  |  |  | capital expenditures |
| Pennsylvania | Three Mile | 1974 | Oct. 2019 | 803 | Operating losses |
|  | Island I |  |  |  |  |
| New York | Indian Point 2 | 1974 | Apr. 2020 | 1,020 | Low electricity prices; |
|  |  |  |  |  | settlement with state |
| Iowa | Duane Arnold | 1975 | Aug. 2020 | 601 | Lower-cost alternative |
|  |  |  |  |  | power purchases |
| New York | Indian Point 3 | 1976 | Apr. 2021 | 1,038 | Low electricity prices; |
|  |  |  |  |  | settlement with state |

\*Source: Adapted from Table 1, Congressional Research Service. U.S. Nuclear Plant Shutdowns, State Interventions, and Policy Concerns. June 10, 2021. https://crsreports.congress.gov R46820.

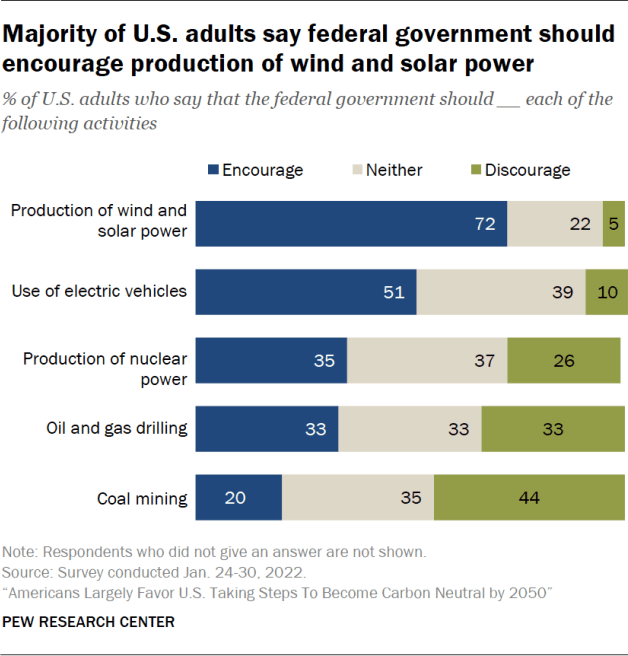
# Appendix E

## Renewable Energy Use by State, November 2023\*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **State** | **% Renewable**  **Sources (11/23**) |  | **% Solar** | **% Wind** | **Hydroelectric** |
| 1. Vermont | 95.3 |  | 25.0 | 16.0 | 54.3 |
| 2. Washington | 65.8 |  | 1.2 | 5.7 | 58.9 |
| 3. South Dakota | 64.1 |  | 0 | 44.6 | 19.5 |
| 4. Idaho | 59.9 |  | 9.1 | 10.5 | 40.3 |
| 5. Maine | 57.0 |  | 13.3 | 16.4 | 27.3 |
| 6. Oregon | 55.3 |  | 5.3 | 14.6 | 35.4 |
| 7. California | 50.5 |  | 31.4 | 5.0 | 14.1 |
| 8. Montana | 46.3 |  | 2.3 | 13.4 | 30.6 |
| 9. Iowa | 40.9 |  | 1.7 | 38.2 | 1.0 |
| 10. New Mexico | 38.9 |  | 10.2 | 28.7 | 0 |
| 11. Massachusetts | 38.1 |  | 33.1 | 0.8 | 4.2 |
| 12. Colorado | 35.1 |  | 11.1 | 22.0 | 2.0 |
| 13. Hawaii | 32.4 |  | 24.8 | 7.6 | 0 |
| 14. North Dakota | 31.8 |  | 0 | 28.1 | 3.7 |
| 15. Kansas | 30.7 |  | 0.4 | 30.3 | 0 |
| 16. Nevada | 30.3 |  | 27.3 | 0.5 | 2.5 |
| 17. New York | 28.9 |  | 5.9 | 2.9 | 20.1 |
| 18. Oklahoma | 28.4 |  | 0.3 | 26.5 | 1.6 |
| 19. Minnesota | 22.7 |  | 4.6 | 17.0 | 1.1 |
| 20. Nebraska | 22.7 |  | 0.4 | 20.4 | 1.9 |
| 21. Texas | 21.4 |  | 6.3 | 15.0 | 0.1 |
| 22. Alaska | 18.6 |  | 0 | 0 | 18.6 |
| 23. Wyoming | 14.7 |  | 0.5 | 13.0 | 1.2 |
| 24. Utah | 14.2 |  | 13.1 | 1.1 | 0 |
| 25. Rhode Island | 14.0 |  | 12.7 | 1.3 | 0 |
| 26. North Carolina | 12.4 |  | 9.2 | 0.2 | 3.0 |
| 27. Tennessee | 11.9 |  | 1.5 | 0 | 10.4 |
| 28. Maryland | 11.2 |  | 6.9 | 0.7 | 3.6 |
| 29. Illinois | 9.5 |  | 2.3 | 7.1 | 0.1 |
| 30. New Hampshire | 9.4 |  | 0 | 2.1 | 7.3 |
| 31. Indiana | 9.0 |  | 3.3 | 5.3 | 0.4 |
| 32. Missouri | 8.6 |  | 1.4 | 5.5 | 1.7 |
| 33. New Jersey | 8.1 |  | 8.1 | 0 | 0 |
| 34. Kentucky | 7.7 |  | 0.5 | 0 | 7.2 |
| 35. Virginia | 7.5 |  | 6.4 | 0 | 1.1 |
| 36. Michigan | 7.0 |  | 1.6 | 4.6 | 0.8 |
| 37. Arkansas | 6.3 |  | 1.8 | 0 | 4.5 |
| 38. Delaware | 6.2 |  | 6.2 | 0 | 0 |
| 39. Alabama | 6.1 |  | 0 | 0 | 6.1 |
| 40. Arizona | 6.1 |  | 0 | 1.4 | 4.7 |
| 41. Florida | 6.1 |  | 6.1 | 0 | 0 |
| 42. Georgia | 5.9 |  | 5.9 | 0 | 0 |
| 43. Wisconsin | 5.9 |  | 2.6 | 1.4 | 1.9 |
| 44. South Carolina | 5.6 |  | 3.6 | 0 | 2.0 |
| 45. Connecticut | 5.0 |  | 4.3 | 0 | 0.7 |
| 46. West Virginia | 5.0 |  | 0.1 | 2.2 | 2.7 |
| 47. Ohio | 3.1 |  | 1.7 | 1.1 | 0.3 |
| 48. Pennsylvania | 2.5 |  | 0.7 | 0.8 | 1.0 |
| 49. Louisiana | 1.3 |  | 0.5 | 0 | 0.8 |
| 50. Mississippi | 0.9 |  | 0.9 | 0 | 0 |

\*Source: Adapted from [https://www.chooseenergy.com/data-center/electricity-sources-by-state/,](https://www.chooseenergy.com/data-center/electricity-sources-by-state/) November 2023.

# Appendix F



**References**

*Works cited in Task 3 Report are noted with an asterisk (\*). Other references were consulted as background*.

bp. “bp Energy Outlook – 2023 Edition. [https://www.bp.com/content/dam/bp/business-](https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2023.pdf) [sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2023.pdf.](https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/energy-outlook/bp-energy-outlook-2023.pdf) BP’s research predictions for 2050. “The future of global energy is dominated by four trends: declining role for hydrocarbons, rapid expansion in renewables, increasing electrification, and growing use of low-carbon hydrogen.” No specific mention of nuclear.

\*Breyer, C., et al. "On the History and Future of 100% Renewable Energy Systems Research."

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