Transcending Renewables' Limits: Why Innovation Is Essential and How Federal Investments Can Unlock It

LINH NGUYEN | DECEMBER 2021

Renewables are far from being affordable, available, or reliable enough to meet growing demand for zero-carbon electricity. Scientists have developed promising solutions to these limitations, but it will require sustained, expanded federal investments to grow them to a transformative scale.

KEY TAKEAWAYS

- The current scale of federal investment is too small to accelerate renewables innovation with the urgency the climate challenge demands, especially given the time it takes to bring new technologies into widespread use.
- Federal investment in renewables research, development, and demonstration (RD&D) should focus on technologies that are higher performing, more efficient, viable in broader geographies, and better integrated with the grid.
- Researchers are exploring several promising alternatives to crystalline silicon photovoltaic (PV) cells. Perovskite—a class of hybrid organic-inorganic PV material—is worthy of special attention.
- Floating wind farms will be necessary to transcend the geographical limits of offshore wind power. But other countries are far outspending the United States in demonstrating floating offshore wind technologies.
- Enhanced geothermal systems (EGS) projects require significant upfront investments to cover drilling costs and mitigate geological risk during exploration. Despite the scale of investment required, federal funding for EGS RD&D dropped in FY 2021.

INTRODUCTION

Renewables will be essential pillars of a cleaned-up power system in a carbon-constrained world. Many studies find that global renewable power capacity must double, or even triple, by 2050 to limit global temperature increases.[1] Record-cheap solar photovoltaic (PV) and wind power have given the power sector an early edge in the race to net zero greenhouse gas emissions by mid-century. However, despite impressive improvements over recent decades, renewables are far from being affordable, available, or reliable enough to meet the world's growing demand for zero carbon electricity. The good news is scientists have developed promising solutions that may overcome renewables' current limits. Sustained and expanded federal investments will be essential if these solutions are to grow to a transformative scale.

The renewables that power the grid today are harnessed by certain dominant technologies. Globally, over 90 percent of solar panels are made with crystalline silicon (c-Si) PV cells, 99 percent of offshore wind turbines have fixed bottoms, and 99 percent of geothermal resources come from natural reservoirs.[2] There is no doubt that reaching net zero will require the further deployment of these mature technologies.

But it would be dangerous to assume—as too many do—that these weapons will win the battle. Every technology has limits, and one purpose of innovation is to overcome those limits.[3] Variability, for instance, is the biggest challenge facing solar PV and wind power. Innovation can address it by enhancing these technologies' ability to provide reliable power throughout the day. In parts of the world with dense cities and limited land, innovation is important to overcome renewables' siting issues and land-use conflicts. Innovation can also increase the efficiency of generating equipment to produce more power using fewer resources.

Market formation and demand-pull policies are equally critical to foster early, rapid, and widespread adoption of truly transformative innovations.

This briefing complements the Information Technology and Innovation Foundation's (ITIF's) 2021 "Climate Technologies to Watch" series and the 2020 report "An Innovation Agenda for Advanced Renewables."[4] It provides a deeper dive into federal investments in certain emerging renewable technologies that should be on federal policymakers' priority list.

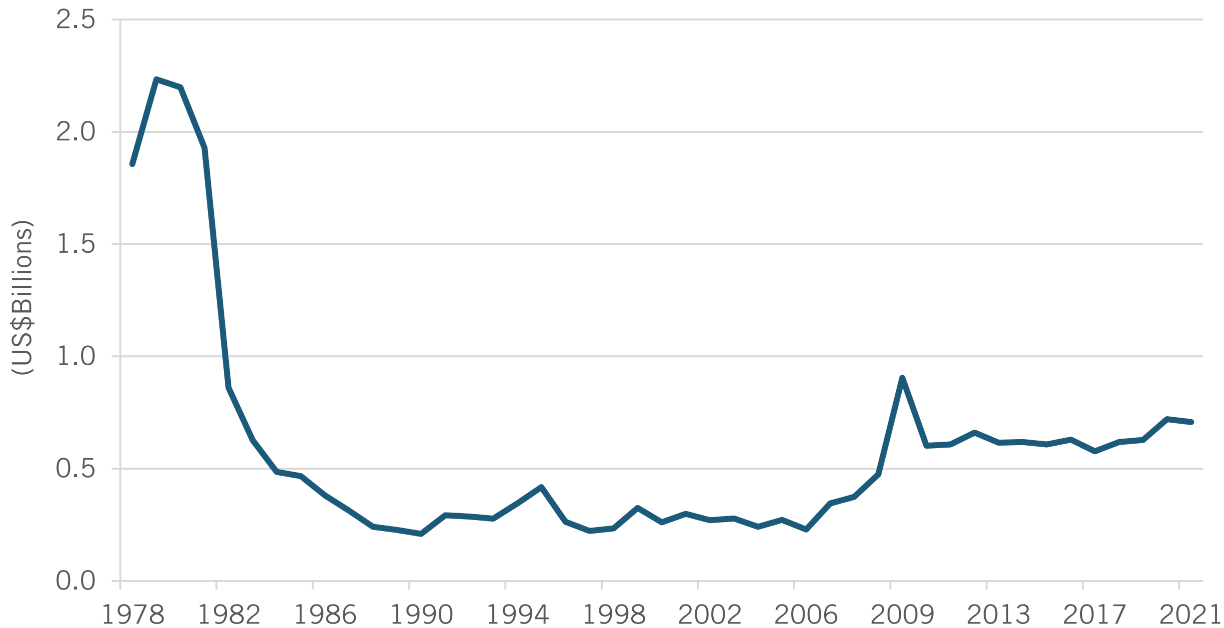
GOVERNMENT SPENDING ON RENEWABLES INNOVATION HAS STAGNATED

The federal government is uniquely suited to spur further innovation in renewables to decarbonize the power grid and address the climate crisis. The private sector cannot afford to invest in high-risk, high-capital-cost research, development, and demonstration (RD&D) that often sets the stage for truly transformative innovations. Market formation and demand-pull policies are equally critical to foster early, rapid, and widespread adoption.

For instance, federally funded nuclear power RD&D and supportive regulatory policies led to large-scale private investment in commercial power plants in the 1960s and 1970s. These plants now account for 20 percent of U.S. electricity generation and 54 percent of low-carbon generation.[5] Similarly, federal support for shale gas resource characterization and directional drilling—in tandem with industry-matched applied research and a federal production tax credit—

led to the dramatic rise of shale gas production from less than 1 percent of the domestic total in 2000 to nearly 80 percent in 2020.[6]

Figure 1: U.S. Department of Energy spending on renewables RD&D, FY 1978–2021[7]



Even though climate change poses a more severe threat than the energy crises of the late 1970s did, the U.S. government is investing far less in renewables innovation than it did then. As figure 1 shows, even when the investment surge provided by the 2009 American Recovery and Reinvestment Act is taken into consideration, real federal funding remains less than half of 1978 levels.

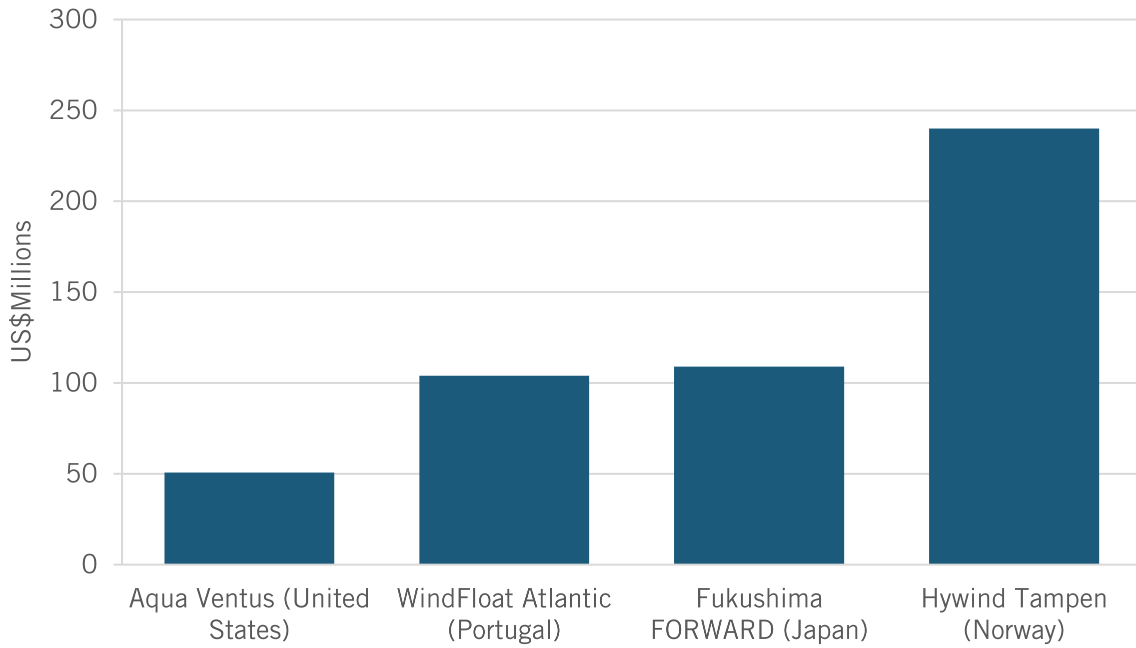
Most energy innovations in the past—even recent successful consumer products such as LEDs and batteries—have taken 20 to 70 years to go from the first prototype to a 1 percent market share.[8] If federal investment in renewables innovation continues at the current pace, critical technologies now in the pipeline will not reach maturity in time to meet the growing demand for zero carbon power in the coming decades.

WIND POWER BEYOND LIMITS

Even though wind power capacity in the United States has grown 40 times in the past three decades—from 0.2 percent of generating capacity in 1990 to 8 percent in 2020—constraints to further progress loom in the near future.[9] For instance, land for optimal sites may become more limited and expensive as onshore wind penetration increases. Innovations that reduce the land required for each megawatt (MW) generated would help overcome this constraint. Radical alternatives such as vertical-axis turbines—a much less common technology that uses towers just 10 meters tall and captures wind from any direction to produce 10 times the energy from the same amount of land—may be worth exploring.[10]

Offshore wind power also faces geographical limits. Fixed-foundation wind farms—in which turbines are rooted to the seabed—dominate this emerging sector. Yet, most of the nation's offshore wind resources lie in deep waters beyond the reach of fixed-foundation turbines. If the United States is to meet the Biden administration's target of 30 gigawatts of offshore wind by 2030, floating wind farms will be necessary to transcend these limits. Only innovation in conjunction with early deployment will bring down their costs, which are currently twice those of fixed-foundation wind farms and three times that of onshore wind.

Figure 2: Government funding for floating wind demonstration projects[11]



Floating offshore wind technology has been proven on a small scale, but large-scale investments in it remain extremely risky. No company in the United States has yet announced a commercially viable project.[12] Public-private partnerships to demonstrate this technology at scale are crucial to help it take the next big step.

Other countries are far outspending the United States in this regard. Aqua Ventus, off the coast of Maine, is the only such project under construction in the United States. The U.S. Department of Energy (DOE) is providing up to $50.7 million to create 11 MW of capacity, far smaller than comparable projects elsewhere in the world (see figure 2). The 25 MW WindFloat Atlantic project in Portugal, for example, has received $106 million in grants and loans from the European Investment Bank, an agency of the European Union.[13] And the 88 MW Hywind Tampen project in the Norwegian North Sea was awarded nearly $240 million by the Norwegian government in 2019.[14]

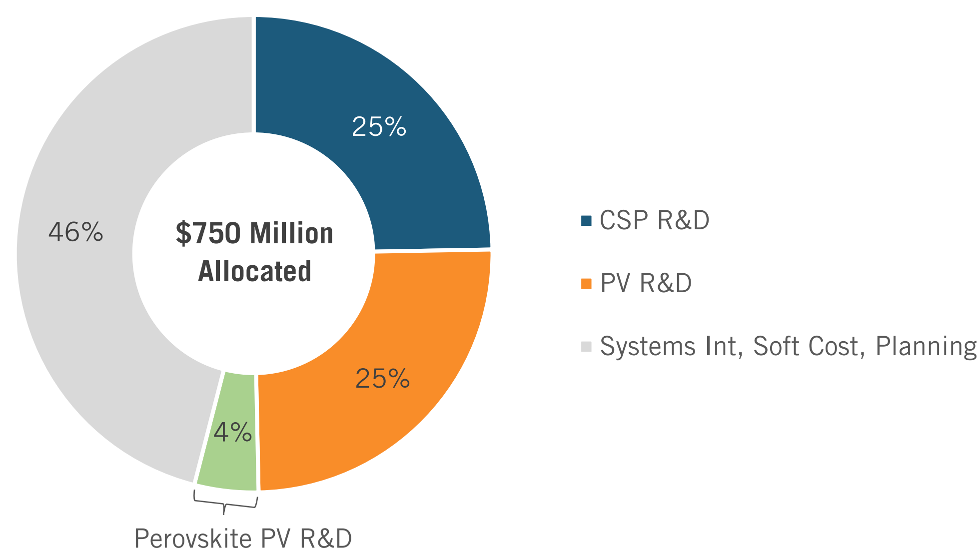
SOLAR POWER BEYOND LIMITS

C-Si solar PV cells have made extraordinary progress, with power-conversion efficiency improvements of over 50 percent over the last 15 years contributing to declining unit costs.[15] Yet, even though this technology dominates the global market, it is pressing up against significant limits. These cells have an efficiency limit of 30 percent, are thick and bulky, and are made through a complex and energy-intensive process.

Researchers are exploring several promising alternatives to c-Si cells. Organic PV materials composed of carbon-rich polymers, for instance, capture light with higher efficiency.[16] Quantum dots generate electricity using semiconductor particles a few nanometers wide and are easy to manufacture. III-V semiconductors can achieve exceptionally high efficiencies and have other advantageous physical properties.[17] Combining these materials and others, including c-Si, in hybrid architectures multiplies the opportunities.

Perovskite—a class of hybrid organic-inorganic PV material—is worthy of special attention. Perovskite has a flexible bandgap, which allows it to convert light from a wide swath of the solar spectrum into usable energy. This flexibility means perovskite can be paired with other PV materials for combined efficiencies over the 30 percent limit of c-Si alone. It is also deployable as thin films, which might be integrated into building components. Such technology would reduce the need to devote large land areas to solar farms.

Figure 3: DOE Solar Energy Technology Office spending for solar research and development, 2020[18]



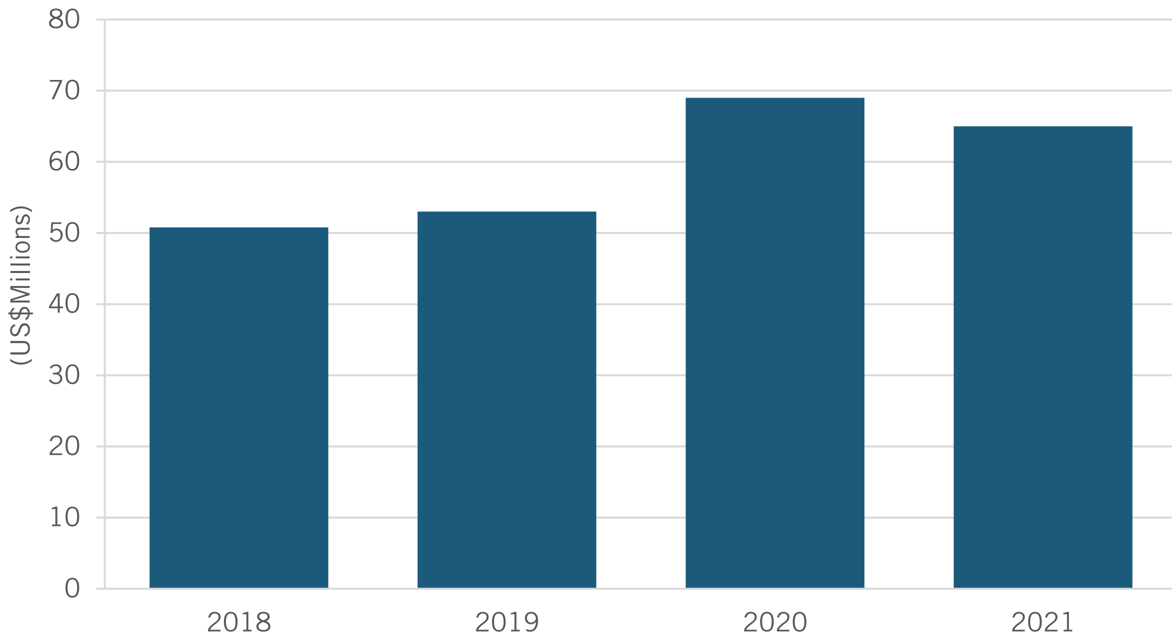
Federal funding for perovskite has inadequately reflected the scale of this opportunity. DOE only recently established a perovskite research and development (R&D) program within the Solar Energy Technology Office (SETO).[19] In FY 2020, only 4 percent of SETO's funding was allocated for perovskite R&D (see figure 3).[20] More broadly, appropriations for PV R&D within SETO have remained unchanged at $72 million annually for the past three fiscal years. Increased funding for PV R&D, with a specific focus on perovskite R&D, is essential to bring this promising technology to market on an accelerated time scale.[21]

GEOTHERMAL POWER BEYOND LIMITS

The growth of intermittent renewables such as wind and solar PV will bring with it a demand for firm, zero carbon power to fill in the gaps. Geothermal power has the potential to meet some of this demand. Virtually all commercial-scale geothermal projects today draw on conventional hydrothermal reservoirs (natural pockets of heat and water not far below the surface). However, only 2 percent of the Earth's geothermal resources are available through such reservoirs.[22]

Enhanced geothermal systems (EGS)—artificial reservoirs that draw heat from rock formations deep beneath the earth's crust—could provide access to the other 98 percent.[23] Government investments in next-generation high-temperature, high-pressure sensors, drilling tools, and well-casing materials, as well as commercial-scale demonstrations, are vital for EGS to become cost competitive with other power-generation sources.

Figure 4: DOE spending on EGS research, development, and demonstration, FY 2018–2021



EGS projects are very capital intensive, requiring significant upfront investment to cover drilling costs and mitigate geological risk during exploration. Despite the scale of investment required, DOE funding for EGS RD&D dropped from $69 million in FY 2020 to $65 million in FY 2021 (see figure 4).

EGS has received strong support from Congress, though. The Energy Act of 2020 authorized DOE $105 million to construct four EGS demonstration projects, and $300 million to develop three Frontier Observatory for Research in Geothermal Energy sites to study EGS for the period of FY 2021 through 2025. The Infrastructure Investment and Jobs Act, signed into law in November 2021, authorized DOE $84 million for the period of FY 2022 through 2025 to advance EGS reservoir simulation technologies and techniques. ITIF's "Innovation Agenda" report recommends congressional appropriators fully fund these programs in the coming years.[24]

CONCLUSION

The world is not on track to meet net zero emissions by mid-century unless renewables and other low-carbon power technologies become affordable and reliable enough to supplant unabated fossil fuel generation. The current scale of federal investment is too small to accelerate renewables innovation with the urgency the climate challenge demands, especially given the time it takes to bring new technologies into widespread use.

Federal investments in RD&D should focus on technologies that are higher performing, more efficient, viable in broader geographies, and better integrated with the grid. While advanced renewables are not the only options for reaching net zero emissions by mid-century, they would expand the portfolio in valuable ways. They could be the conduits linking the planet's limitless natural resources to clean energy a thriving global society can depend on.

FURTHER READING

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ENDNOTES

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