Testimony Before the United States Senate Environment and Public Works Committee

Legislative Hearing to Examine S. 2373, the Advanced Nuclear Infrastructure Act (ANIA) of 2021 and S. 1290, the Sensible, Timely Relief of America's Nuclear Districts' Economic Development (STRANDED) Act of 2021

ADVANCED NUCLEAR ENERGY: VALUE, REQUIREMENTS, THE ROLE OF POLICY

Testimony of Armond Cohen, Executive Director, Clean Air Task Force

February 9, 2022

Mr. Chairman, Ranking Member, and Distinguished Members of the Committee:

My name is Armond Cohen and I am Executive Director of the Clean Air Task Force (CATF), an environmental organization founded in 1996. CATF is a global nonprofit organization working to safeguard against the worst impacts of climate change by catalyzing the rapid development and deployment of low-carbon energy and other climate-protecting technologies. With 25 years of internationally recognized expertise on climate policy and a fierce commitment to exploring all potential solutions, CATF is a pragmatic, non-ideological advocacy group with the bold ideas needed to address climate change. CATF has offices in Boston, Washington D.C., and Brussels, with staff working virtually around the world. I appreciate the opportunity to testify today.

I will share CATF's thoughts on why clean firm power sources like nuclear energy could contribute meaningfully to managing global climate change, what would have to happen for nuclear energy to do so, and some immediate federal policy opportunities to support that possibility.

I. The value of clean firm electricity sources such as nuclear energy in addressing climate change

After thirty years of debate, it is becoming clear that the question is not whether we need to address climate change, but how. Since I last addressed this committee in August of 2020, there has been a momentous shift in public policy. Countries representing roughly 90% of world GDP, populations and CO2 emissions have committed to varying degrees of formality to reaching net

zero carbon emissions over the next few decades.[1] Zero carbon electricity is generally regarded as key to eliminating global carbon emissions, and more than half of U.S. electricity sales today are taking place in states or utility service territories that are committed to net zero emissions by mid-century, as shown in Figures 1 and 2 below:[2]

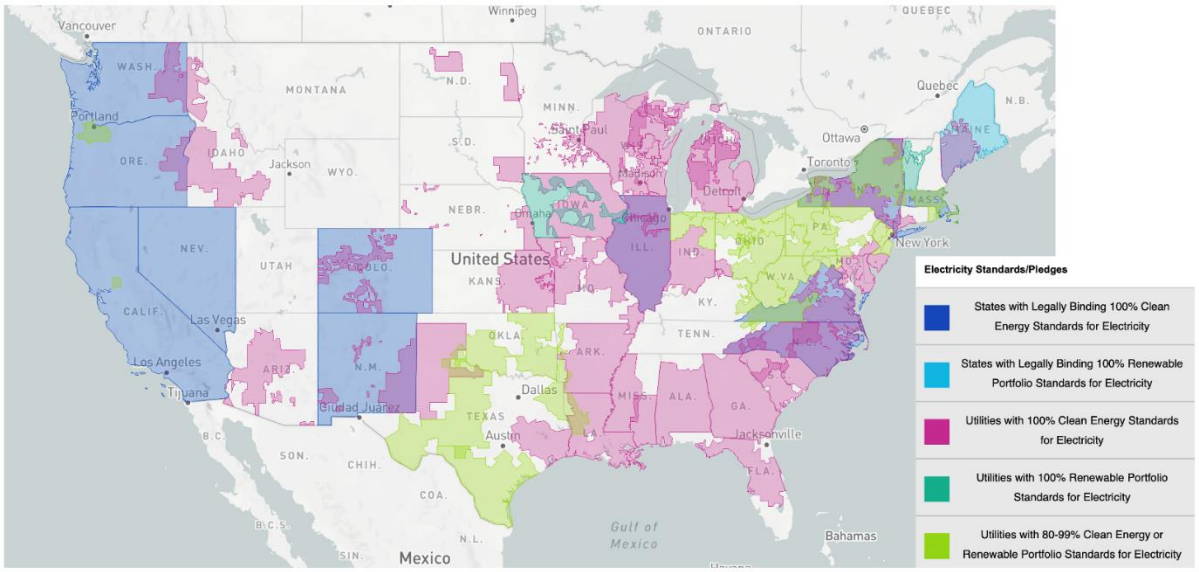


Figure 1: 100% carbon free electricity commitments by state and utility service territory

[1] See https://zerotracker.net/.

[2] Both figures taken from Clean Air Task Force, "State and Utility Decarbonization Commitments," https://www.catf.us/2020/10/state-and-regional-decarbonization-commitments/

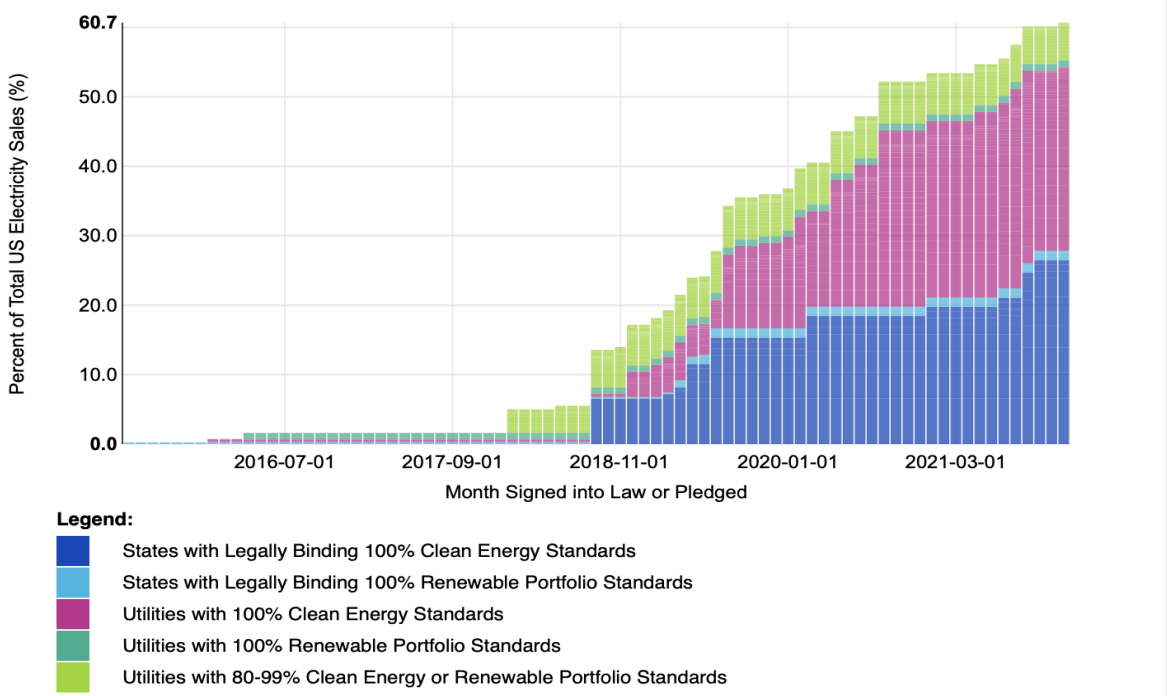


Figure 2: Percent of U.S. electric utility sales covered by zero carbon or similar pledges

Now comes the hard part: how do we actually achieve those goals in time and at an affordable cost?

Cost

A good part of the answer lies in the increasingly availability of low-cost wind and solar energy and energy storage, which today provide about 10% of U.S. electricity, and growing. Most economic studies, including ones commissioned by CATF, show that future lowest-cost decarbonized electric systems will be powered substantially, if not predominantly, by those sources. However, the same studies, whenever comparing various energy portfolio mixes, invariably conclude that the lowest costs are achieved by having a substantial fraction of energy provided by electricity sources that are available 24/7/365, regardless of season or weather.

Sometimes dubbed “clean firm power,” such generating sources can include geothermal energy, hydrogen combustion, gas with carbon capture, and nuclear fission.[3]

A recent literature review[4] of such studies in the U.S. commissioned by CATF shows that lowest cost decarbonized power systems include an average of 35% clean firm power, including nuclear energy, as shown in Figure 3 below.

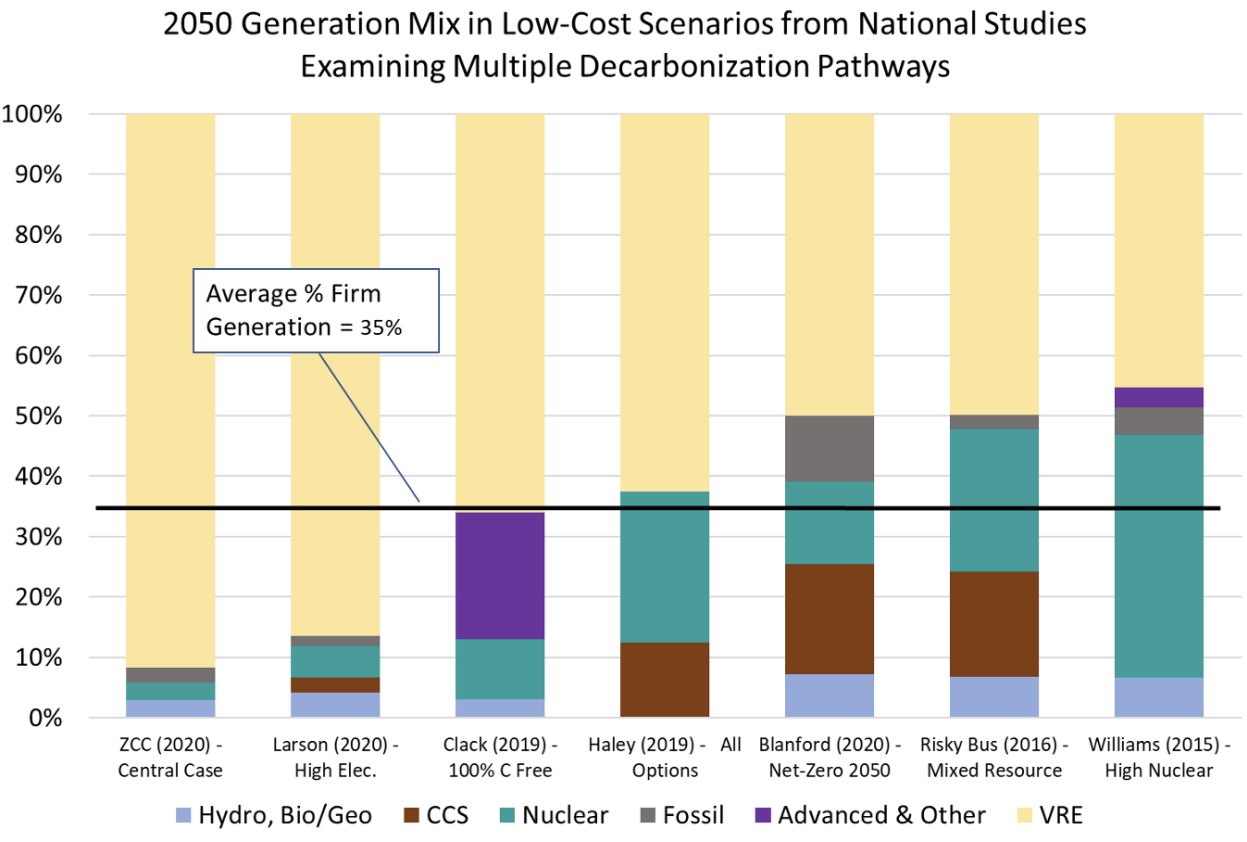


Figure 3: “Clean firm” power shares across U.S. studies. Source: see footnote 4.

[3] And possibly, in the future, fusion energy, not discussed here. But see Clean Air Task Force, “Fusion Energy,” https://www.catf.us/work/advanced-nuclear-energy/fusion-energy/

[4] See The NorthBridge Group, “Review and Assessment of Literature on Deep Decarbonization in the United States: Importance of System Scale and Technological Diversity” (2021). https://www.catf.us/wp-content/uploads/2021/06/NorthBridge_Deep_Decarbonization_Literature_Review.pdf

An October 2021 study[5] of a carbon free U.S. power systems by noted researcher Chris Clack reached a very similar result: the system is dominated by wind and solar, but contains a significant fraction of power from clean firm sources such as gas with CCS, and nuclear energy, even with an optimally designed transmission grid that maximizes all distributed energy sources such as rooftop solar energy and storage. (See figure 4 below)

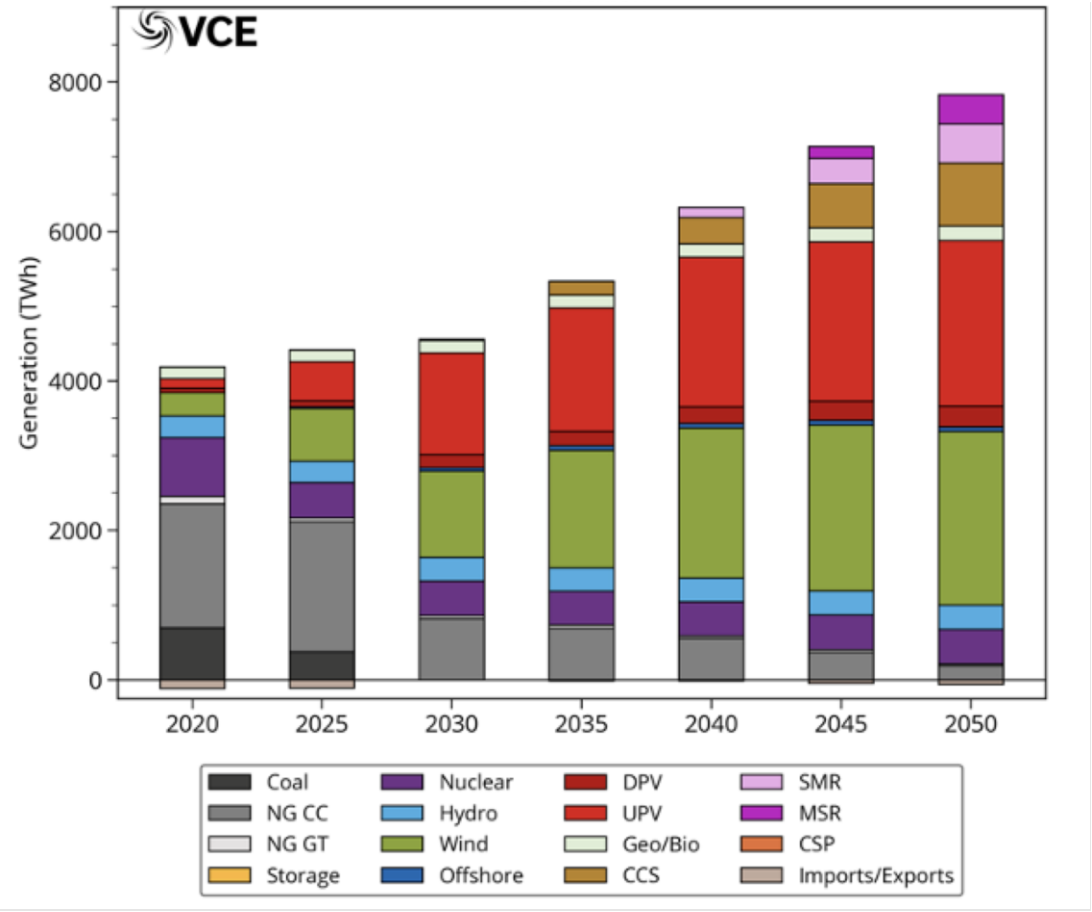


Figure 4: Optimal electricity shares in a zero carbon U.S. grid. ("SMR" is small modular light water reactors, and "MSR" is "molten salt reactors"). Source: see footnote 5.

[5] See Vibrant Clean Energy, "A Plan for Economy-wide decarbonization of the United States," (October 2021) https://www.vibrantcleanenergy.com/wp-content/uploads/2021/10/US-Econ-Decarb_CCSA.pdf

Similarly, a recent state-level study[6] of California by researchers at Stanford University and Princeton University, and the research firm E3, concludes that, when clean firm sources are allowed into the system, they supply 40-50% of annual power, as shown in Figure 5, including very high shares of nuclear energy:

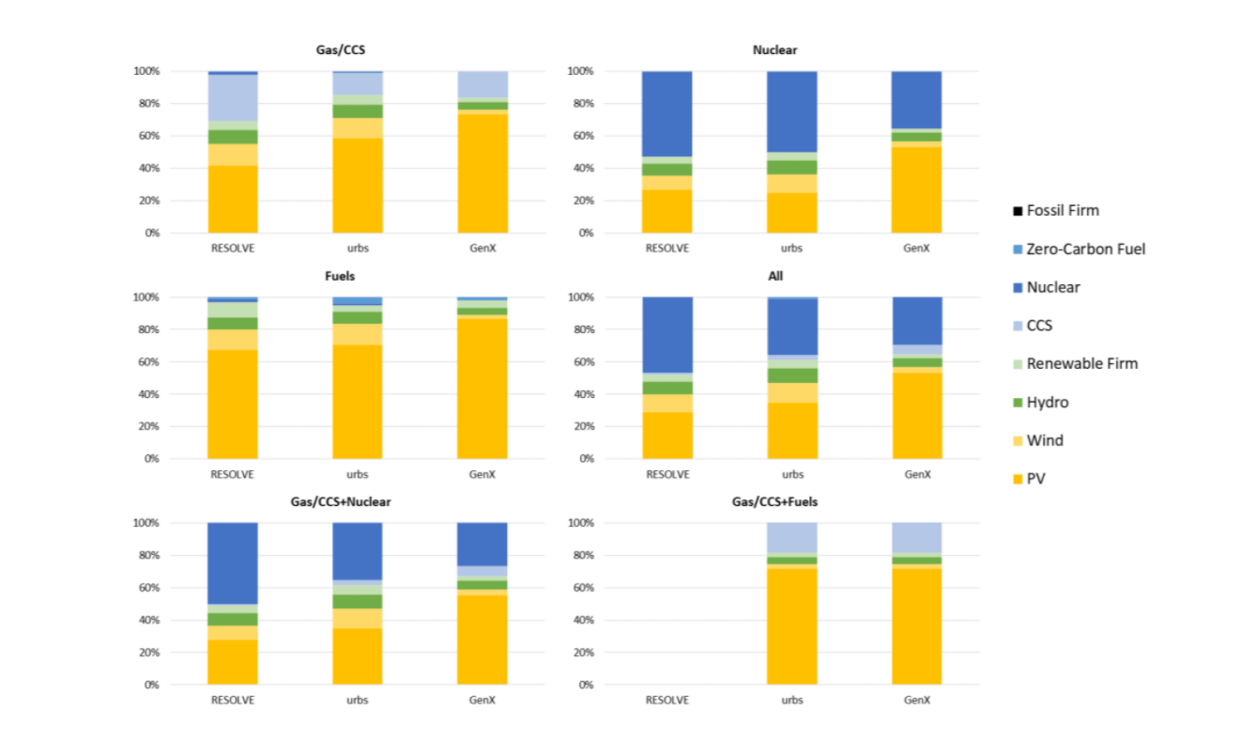


Figure 5: Shares of California power in a 100% zero carbon grid, varied by scenario. The "All" scenario allows nuclear, hydrogen and gas with CCS to compete. Source: see footnote 6.

What accounts for these large shares of clean firm power, with renewable energy becoming so inexpensive on a commodity basis? The central fact about wind and solar – versus firm

[6] JCS Long et al,, California Needs Clean Firm Power and So Does the Rest of the World, https://www.edf.org/sites/default/files/documents/SB100%20clean%20firm%20power%20report%20plus%20SI.pdf

resources – is that they are variable by ***week*** and ***season*** as well as days, as shown below in Figure 6 with data from the United States:[7]

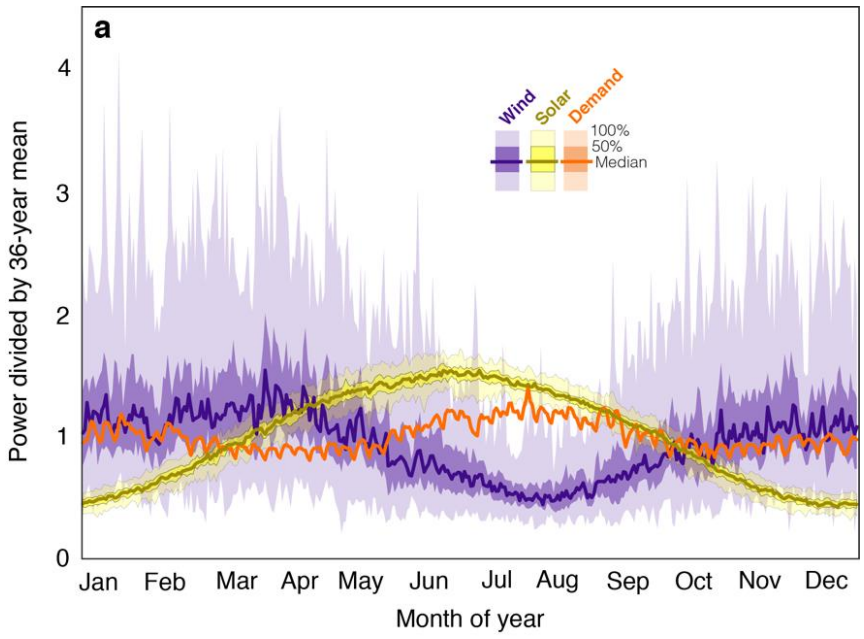


Figure 6: Seasonal variability of wind and sun versus relatively constant demand. Source: see footnote 7.

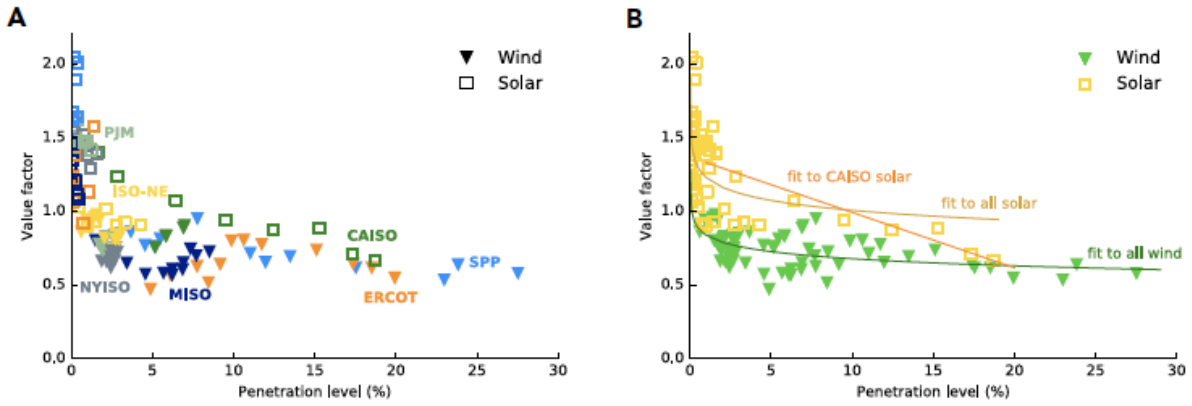
Compensating for this weekly and even seasonal variability on a large scale without firm generating resources would require one or more of the following physically and economically challenging strategies:

1. Building substantially more capacity than is required to meet peak demand and curtailing its output during times of high production.
2. Investing in expensive storage, much of it used at a low capacity factor.

[7] Tong, D., Farnham, D.J., Duan, L. *et al.* Geophysical constraints on the reliability of solar and wind power worldwide. *Nat Commun* **12,** 6146 (2021). https://doi.org/10.1038/s41467-021-26355-z

3. Having robust demand flexibility that allows for wide-spread, consistent, and frequent shifting of demand (e.g. reduction of factory output at times of low wind or sun).
4. Developing a vastly integrated, interregional transmission network.

As long as the wind and solar proportion of the system is small, the variability can be readily managed, and systems costs could even decline. As penetration of these resources increases as a proportion of electric system supply, however, the above strategies need to be employed, causing costs to rise substantially, and their value to plummet:[8]



Wind and solar value factors decline with increasing penetration

(A and B) VRE value factors generally decrease with penetration, but the path has tended to be convoluted (A). Despite the complexity, the relationship between value factors and penetration can roughly be described by a logarithmic function (B) though not for CAISO solar. Value factor refers to the ratio of wind or solar generation value to flat bock value. In this case, each value calculation includes both energy and capacity value. For solar, value is calculated for utility-scale plants, but the penetration level is defined by the sum of utility and distributed solar generation. See also Table S1.

Figure 7: Declining value of variable energy as shares increase, due to need for greater compensation for variability. Source: see footnote 8.

[8] From: Millstein, Dev, Ryan Wiser, Andrew D. Mills, Mark Bolinger, Joachim Seel, and Seongeun Jeong. "Solar and wind grid system value in the United States: The effect of transmission congestion, generation profiles, and curtailment." *Joule* (2021).

Metrics like “levelized cost of electricity” for individual resources, often used to compare nuclear and variable renwables, are therefore misleading in this context: variable resources may appear to cost less per asset, but to ensure reliability at scale, the overall system costs of a variable renewable based system escalate dramatically, as shown in Figure 8 below:[9]

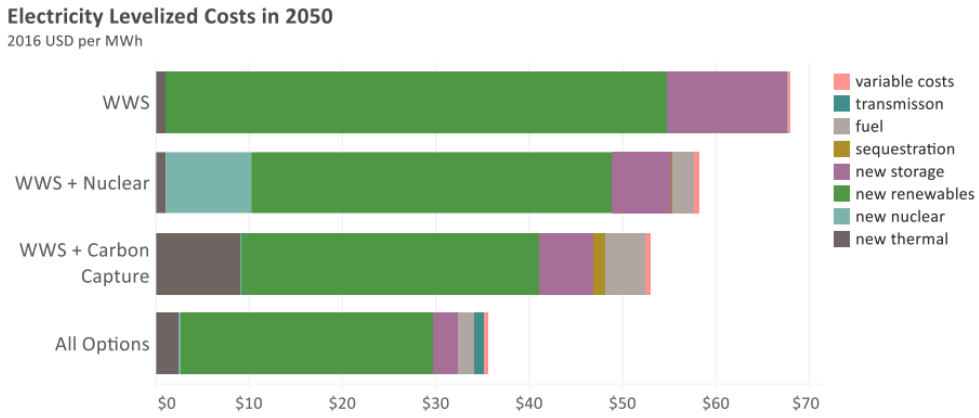


Figure 8: The cost of power systems with wind water and sun only (“WWS”) versus WWS and clean firm sources. Source: see footnote 9.

In short, if we are to transition affordably to zero carbon power, we will need some mixture of clean firm sources such as nuclear energy to complement increasingly inexpensive, and potentially dominant, renewable energy. Whether nuclear energy can serve that function at scale is a question taken up below. But before turning to that question, we must address another reason to consider nuclear energy: space.

[9] Evolved Energy Research, “Federal Policy for Low-Carbon, High-Renewables Electricity” (2020). https://www.evolved.energy/post/federal-policy-for-electricity-decarbonization

Space

While renewable energy offers great cost advantages, the scale at which it would need to be deployed without clean firm back up will pose serious feasibility challenges. Chief among these is land use. To illustrate the point, Figure 9[10] represents a hypothetical comparison of space required to supply all current electricity in the eastern U.S., as well as electricity to synthesize hydrogen to replace all liquid and gaseous fuels, by four energy sources: onshore wind, offshore wind, photovoltaic energy, and nuclear energy. While we would never choose to select only one energy resource, the figure does illustrate the relative land footprint required for each source:

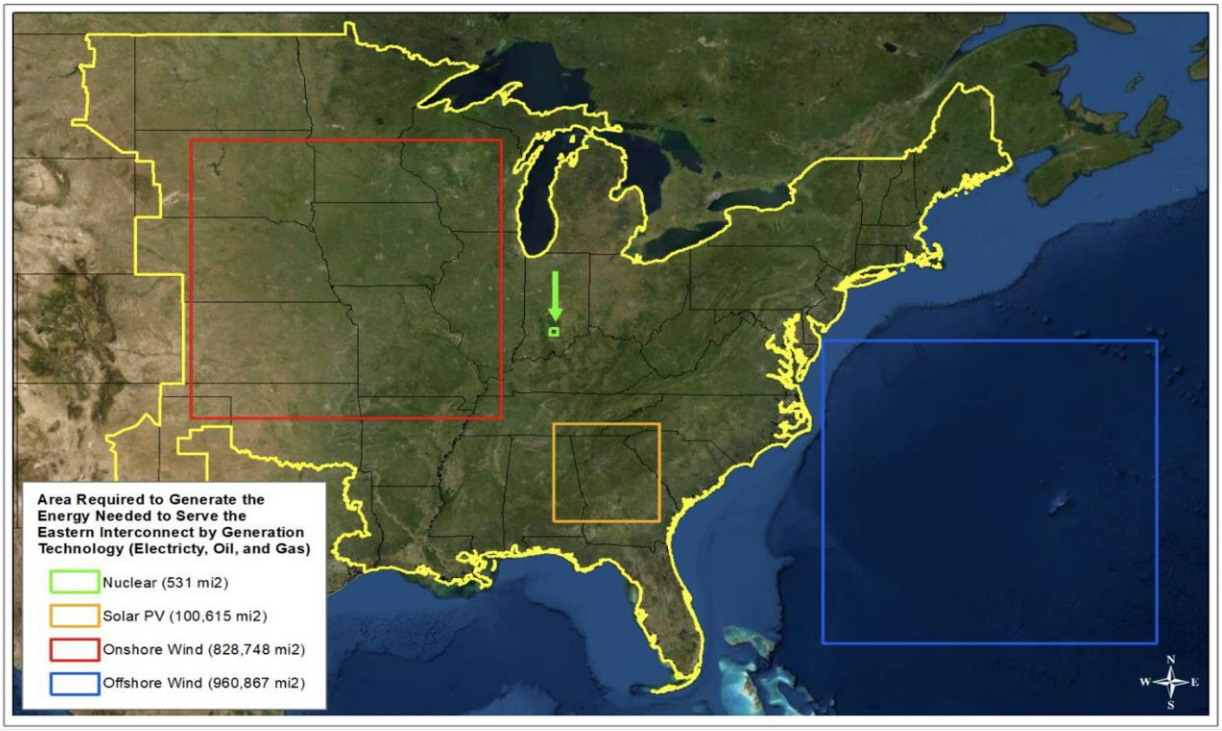


Figure 9: Comparison of land area required to supply all eastern U.S. energy with one source.

[10] Figure prepared by Lucid Catalyst for CATF (2021). Electricity, oil, and gas consumption estimates were sourced from the EIA, and conservative power density and capacity factor estimates from published literature and the National Renewable Energy Laboratory.

Recent studies looking at high variable renewable energy systems for the U.S., such as the one portrayed in Figure 10, also illustrate the large land areas required for energy infrastructure:

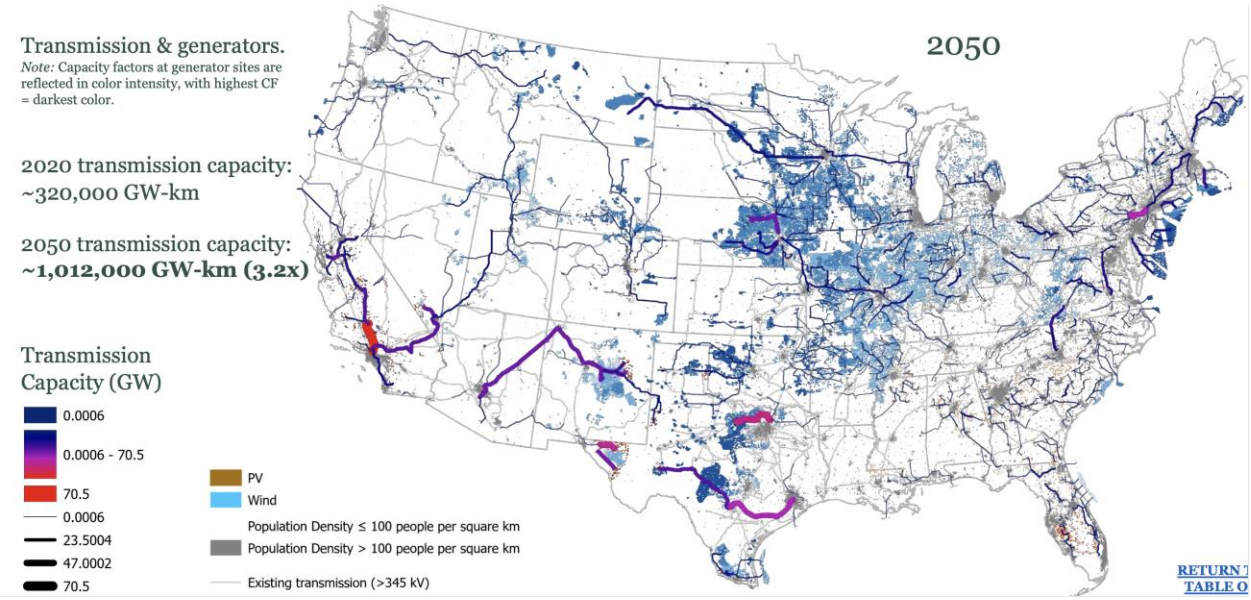


Figure 10: Land footprint for a U.S. electricity grid with 85% of energy supplied by wind and sun. Figure from Princeton University, Net Zero America Project, https://netzeroamerica.princeton.edu/the-report

In addition to large land areas required for generation, as variable renewable penetration increases, exponentially more transmission is needed to balance availability over long distances, as shown in Figure 11 below. In addition to the economic challenges of this transmission build-out, acquiring enough contiguous land for rights of ways would be difficult and would dramatically increase the land requirements of the system:[11]

[11] NREL "Renewable Electricity Futures Study. Volume 1: Exploration of High-Penetration Renewable Electricity Futures" https://www.nrel.gov/docs/fy12osti/52409-1.pdf

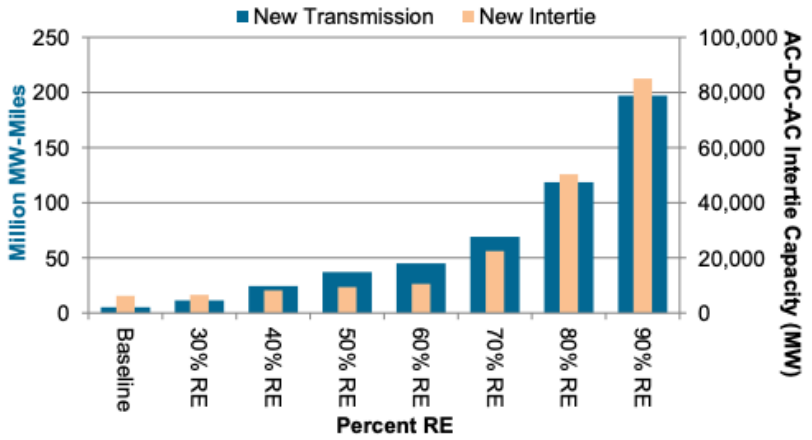


Figure ES-8. New transmission capacity requirements in the baseline and exploratory scenarios

Existing total transmission capacity in the contiguous United States is estimated at 150–200 million MW-miles[35]

Figure 11: Transmission miles as a function of renewable energy shares to the U.S. grid. Source: see footnote 11.

While it is often assumed that there should be no problem siting this amount of clean energy infrastructure because "America is a big place," and that a high renewable system requires only "a couple percent" of U.S. land area, a closer examination reveals constraints. A recent analysis sponsored by CATF, the Environmental Defense Fund and the Nature Conservancy examined the possible locations for central photovoltaic solar arrays in California, after excluding areas that are legally off limits, under administrative protection, have high conservation value, or are simply not suitable for large scale solar development due to technical and economic factors. The remaining areas, shown in red in the map in Figure 12, represent about 5 million acres out of a land mass of 105 million acres in the state. Since the total requirement for solar energy buildout in a renewables-dominated system has been estimated at approximately 1 million

acres,[12] the solar requirement is therefore close to 20% of *practically available land* in California.

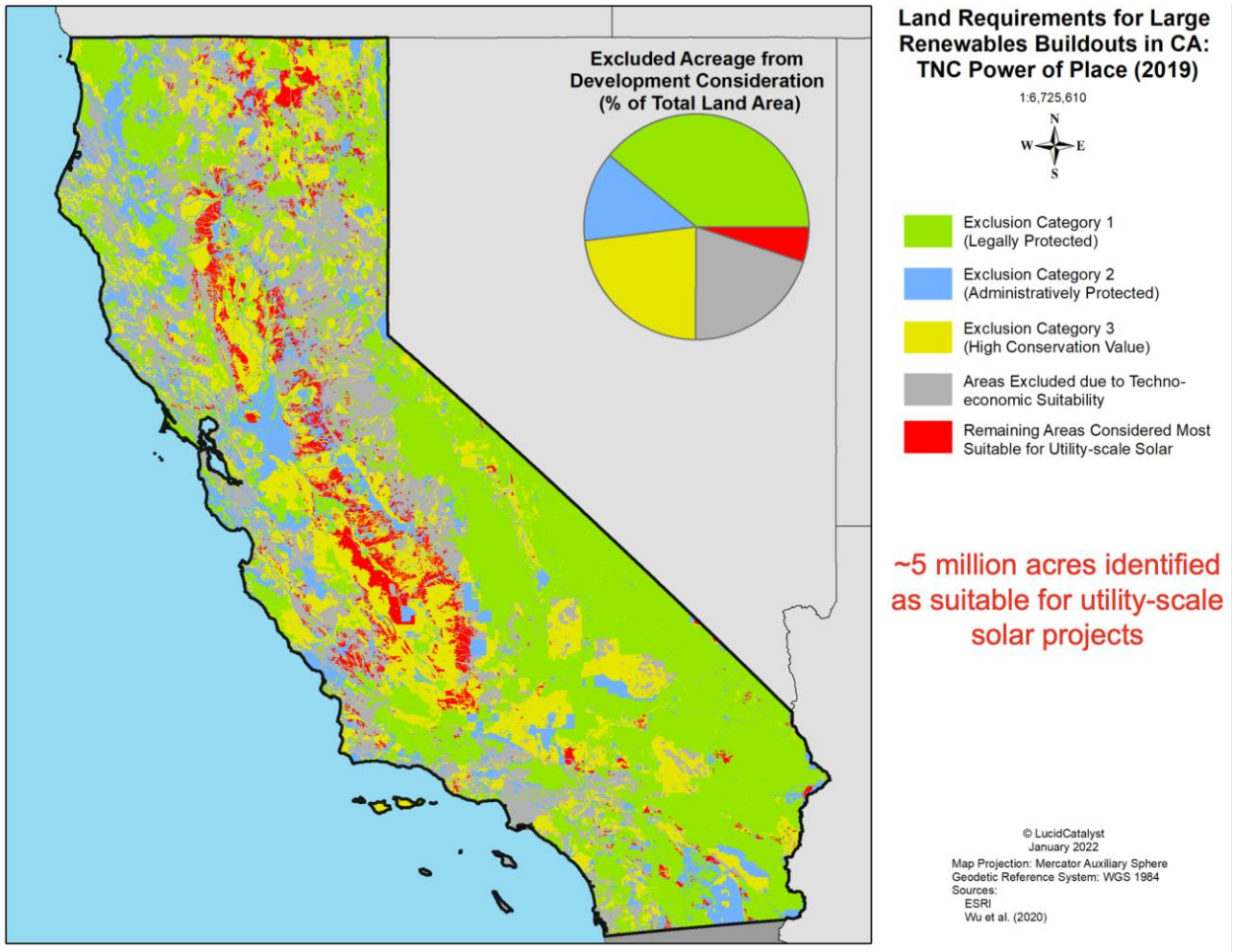


Figure 12: Land area available for utility scale solar energy development. From: Clean Air Task Force and Environmental Defense Fund, "California's Clean Energy Transition: Understanding Today's Challenges to Reach Tomorrow's Goals," Briefing for California Assembly staff, January 18, 2022.

[12] See source in Figure 10, with downscaled results for California.

This kind spatial requirement will pose challenges. Numerous recent press reports have documented a growing number of restrictive ordinances and citizen opposition. A recent comprehensive Columbia University survey report[13] concluded:

> In nearly every state, local governments have enacted policies to block or restrict renewable energy facilities and local opposition has resulted in the delay or cancelation of particular projects. Our research found 100 such local policies and 152 contested renewable energy facilities. ***Additionally, some of the states that have seen the most renewable energy development—such as Texas, New York, and Kansas—also have relatively greater incidence of opposition.*** This report demonstrates that "not in my backyard" and other objections to renewable energy occur throughout the country, and can delay or impede project development. (Emphasis added).

This suggests the problem may get worse, not better, as renewable deployment proceeds. Indeed, a recent analysis (see Figure 13 below)[14] documents that nations like Spain and Germany, which deployed wind and solar more extensively than the U.S., are experiencing an "S " curve in deployment rates, rather than the "hockey stick" deployment rates we would need to see to reach carbon goals:

[13] Columbia University School of Law Sabin Center for Climate Change Law, "Opposition to Renewable Energy Facilities in the United States" (February 2021), http://blogs.law.columbia.edu/climatechange/2021/02/24/opposition-to-renewable-energy-facilities-in-the-united-states-new-sabin-center-report/comment-page-1/. See also S. Gross, "Renewables, Land Use and local Opposition in the United States" (January 2020), https://www.brookings.edu/wp-content/uploads/2020/01/FP_20200113_renewables_land_use_local_opposition_gross.pdf

[14] Cherp, Aleh, et al. "National growth dynamics of wind and solar power compared to the growth required for global climate targets." *Nature Energy* 6.7 (2021): 742-754.

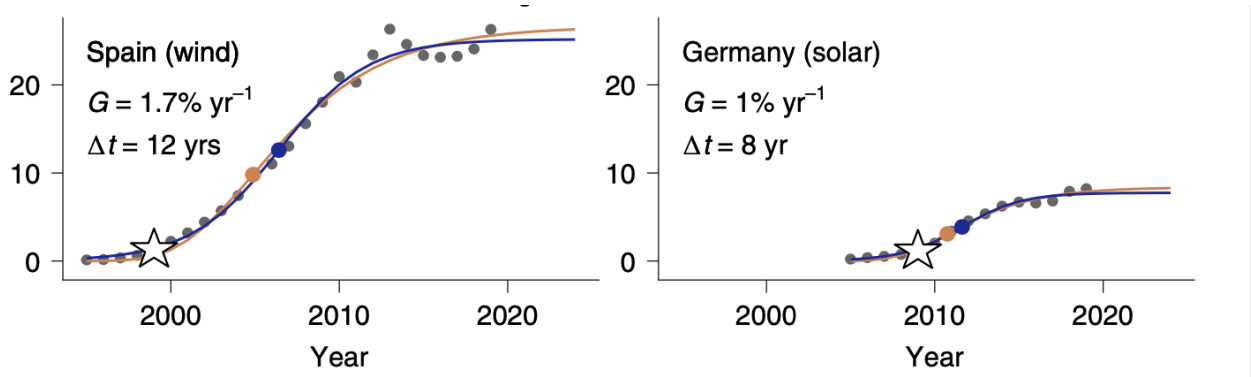


Figure 13: Wind and solar deployment rates in high renewables systems. Source: see footnote 14.

CATF is working hard with stakeholders in California and other states to develop planning, incentive and related approaches that can speed renewable energy and other clean energy development, but there is a risk that the scale of buildout required cannot be achieved in the few decades we have to solve the problem. Clean firm power with lower land use and transmission requirements could be a valuable tool to ensure we reach our goals. A comparison of the land requirements for a system with and without clean firm power in California in Figure 14, for example, suggests clean firm power, even in a renewable-dominated system, could reduce total land area requirements by a factor of three to ten and transmission mileage by a factor of 3:

Issue		With Clean Firm Power	Without Clean Firm Power
Costs for generation and transmission *California transmission and distribution costs are currently about 9 cents/kWh*		~9 cents/kWh	~15 cents/kWh
Solar and Wind Capacity *Entire US electric generating capacity is about 1,100 GW*		25–200 GW	470 GW
New Storage* *Largest battery facility now being built is 0.3 GW /1.2 GWh* *CA expects to have 2 GW battery capacity in 2021*	**New short-term battery capacity**	20–100 GW	160 GW
	New energy storage	100–800 GWh	1,000 GWh
Land Use *CA land area is about 164,000 sq miles*		625–2,500 square miles	6,250 square miles
Transmission *CA currently has about 15 million MW-miles of transmission*		2–3 million MW-miles	~9 million MW miles

**Energy storage beyond existing pumped hydro*

Figure 14: key system characteristics for a California zero carbon energy grid with and without clean firm power. Source: Long, Jane C.S., Ejeong Baik, Jesse D. Jenkins, Clea Kolster, Kiran Chawla, Arne Olson, Armond Cohen, Michael Colvin, Sally M. Benson, Robert B. Jackson, David G. Victor, and Steven P. Hamburg. "Clean Firm Power is the Key to California's Carbon-Free Energy Future." Issues in Science and Technology (March 24, 2021).

While this section of my testimony has focused on the electricity sector, nuclear energy also offers substantial opportunity for synthesis of zero carbon fuels such as hydrogen and

ammonia.[15] Indeed, since 80% of global energy is consumed as liquid and gaseous fuels rather than electricity, and we may not be able to electrify all sectors fully, nuclear-driven fuels production would be a critical option. The Infrastructure Investment and Jobs Act recognized this, in designating one of the funded hydrogen hubs to include nuclear hydrogen. Nuclear energy offers potentially three important attributes for large scale hydrogen production: greater efficiency of production via high temperature electrolysis using heat from high temperature reactors, a high capacity factor which will more efficiently utilize electrolyzers, [16] and a lower space requirement, as discussed above.

In short, clean firm energy like nuclear could be important, even essential, to achieve economy wide climate goals. But for nuclear energy to play a role at needed scale, we will need to see big changes.

II. Nuclear energy challenges and some possible solutions

Despite the promise of nuclear energy, its contribution to global electricity production has been stubbornly flat, as shown in Figure 15:

[15] See Aurora Energy Research, Decarbonizing Hydrogen in a Net Zero Economy (September 2021) at https://www.urenco.com/cdn/uploads/supporting-files/20210927_Aurora_Hydrogen_Study_-_Decarbonising_hydrogen_in_a_net_zero_economy_-_Executive_Summary.pdf; Energy Options Network, Zero Carbon Hydrogen: An Essential Climate Mitigation Option (July 2020), at https://energyoptionsnetwork.org/assets/uploads/Hydrogen_Report_final_long_080320_v2.pdf?_cchid=45b2875b85350c341a53d50425c4e3a9 ; Bridging the Gap: How Nuclear-Derived Zero-Carbon Fuels Can Help Decarbonize Marine Shipping, Clean Air Task Force, August 2021, https://www.catf.us/wp-content/uploads/2021/08/NuclearZCFMarineShipping.pdf

[16] See Aborn et al, "An Assessment of the Diablo Canyon Nuclear Plant for Zero-Carbon Electricity, Desalination, and Hydrogen Production," at p. 86 et seq., https://energy.stanford.edu/publications/assessment-diablo-canyon-nuclear-plant-zero-carbon-electricity-desalination-and

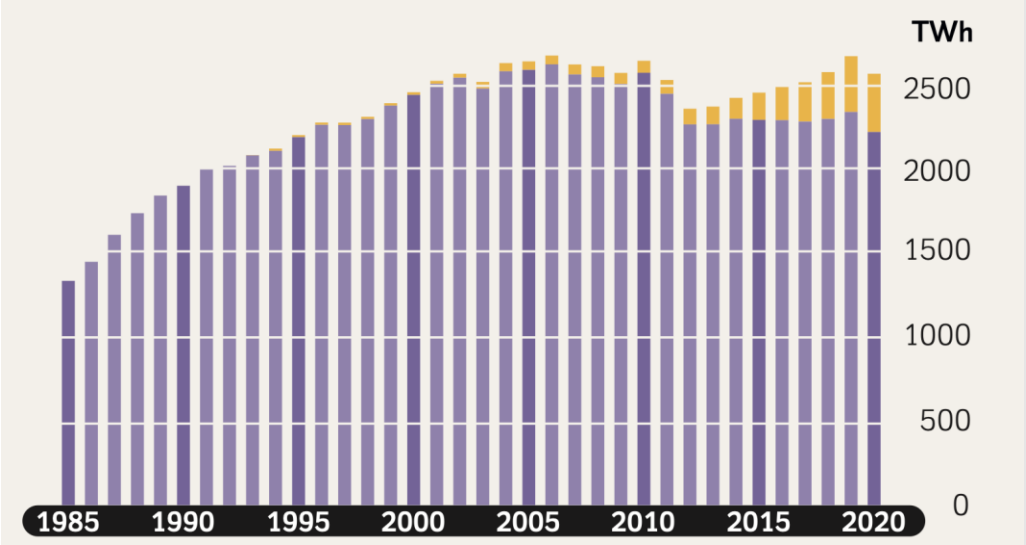


Figure 15: Annual global power production from nuclear energy (yellow bar portions represent China nuclear energy output). Source: M. Schnneider, "The World Nuclear Industry: Status Report 2021," https://www.worldnuclearreport.org/IMG/pdf/wnisr2021-hr.pdf

Foremost among the reasons for the global stall are the high cost and delays associated with recent American and European projects. The two are related, as delays result in additional interest costs during construction.

However, high cost and delay are not inevitable, as best construction and project management practices and the building of standardized multiple units have shown elsewhere. A recent study[17] for the UK-based Energy Technologies Institute analyzed the costs associated with more than two dozen large light water nuclear plants built over the last few decades. The first observation from the study is that nuclear costs have varied widely, by a factor of six, as shown in Figure 16 below:

[17] Energy Technologies Institute, "The ETI Nuclear Cost Drivers Project," Energy Technologies Institute (2018), https://d2umxnkyjne36n.cloudfront.net/documents/D7.3-ETI-Nuclear-Cost-Drivers-Summary-Report_April-20.pdf

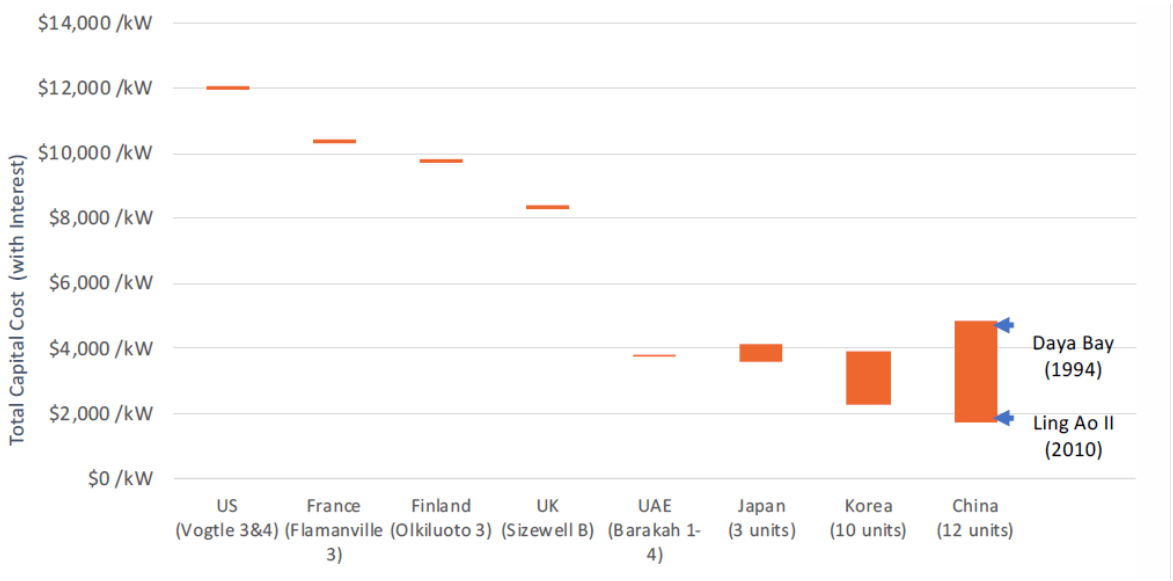


Figure 16: Variations in recent nuclear power plant costs. Source: see footnote 17.

The report, while showing Asian costs to be lower than OECD costs, decomposed cost drivers through a detailed scorecard method and found that ***the difference in unit costs was not primarily driven by differences in regulation or unit labor costs in Asia***, but rather by the efficiency of project management and other best practices. Specifically, top factors that led to higher costs included:

- The challenges of a delivery model that relies heavily on a bespoke "project" model that relies heavily on on-site construction of civil works (a substantial portion of which is necessary to contain water under high pressure) rather than upstream manufacturing and pre-assembly.

- Commencing construction with only a partially completed design.
- Doing “one off” projects rather than multiple builds, thus sacrificing learning by doing and economies of scale.

Conversely, attributes that led to lower cost units included the following factors:

- Design at or near complete prior to construction
- High degree of design reuse
- Experienced construction management
- Productive labor
- Experienced EPC consortium
- Experienced supply chain
- Detailed construction planning prior to starting construction
- Intentional new build program focused on cost reduction and performance improvement
- Multiple units at a single site
- “Nth of a kind” design

This argues for a fundamentally different U.S. strategy for nuclear energy commercialization and scale up. Historically, U.S. policy has provided support for R and D through first demonstration. This has resulted in repeat failures – “first of a kind, last of a kind for a generation” – because, inevitably, first units are most costly because they bear all the learning costs. A U.S. program to make nuclear real would emphasize standardization, support for multiple builds of the same design (not just first of a kind demonstration), high manufactured

content, design for cost, and an intentional focus on management of delivery for cost. These factors, as shown, could result in cost reductions even in current Generation III+ reactors of the kind being built in UAE.

Further cost reductions may be achievable through more advanced designs many of which rely on coolants other than water. Small modular light water reactors as well as microreactors offer opportunities for entry into new markets for nuclear energy, and potentially new revenue streams. Examples of some advanced nuclear plants[18] being developed in North America and around the world include but are not limited to those in the table below:

Coolant	Thermal Neutron Spectrum	Fast Neutron Spectrum
Water	Small Modular Reactor (SMR)	
Helium	High Temperature Gas-Cooled Reactor (HTGR) and Very High Temperature Reactor (VHTR)	Gas-Cooled Fast Reactor (GFR)
Liquid Metal	—	Sodium Fast Reactor (SFR), Lead-Cooled Fast Reactor (LFR)
Molten Salt	Fluoride-Cooled High Temperature Reactor (FHR), Molten Salt Reactor–Fluoride (MSR–fluoride)	Molten Salt Reactor–Chloride (MSR–chloride)

Figure 17: Advanced nuclear plant types. Source: see footnote 18.

Some advantages of these reactors:

- Fast reactors use more energetic neutrons to propel the reaction, potentially increasing fuel utilization and/or reducing back-end waste.
- Reactors operating with liquid metal coolant operate at high power density, therefore reducing overall radioactive material and size, due to the thermochemical properties of the coolant. Liquid metals also have higher boiling points (in the hundreds to thousands

[18]https://energy.mit.edu/wp-content/uploads/2018/09/The-Future-of-Nuclear-Energy-in-a-Carbon-Constrained-World.pdf?fbclid=IwAR09CR2mjhsZq6uh9cy2N0PDGSvbUUmy9zbaOp79mt_6OKfbcJMPeGRdYjU

degrees Celsius) and can reduce the risk and/or severity of a “loss of coolant” event such as occurred in the three major nuclear accidents to date.

- Molten Salt has a high boiling point, similar to liquid metal, but allows for fuel to be mixed in solution with coolant, in some designs, reducing overall volume.
- Gas cooled reactors can leverage existing gas technology, and some utilize more robust fuel designs such as TRISO.
- Many reactors cooled by substances other than water can operate at reduced pressures compared to existing reactors offering potential benefits such as decreasing the need for expensive high pressure containment.

Across the board, these advanced reactor concepts utilize passive safety characteristics, such as reduced pressures, higher coolant boiling points, and/or meltable release plugs that eliminate auxiliary equipment and improve economics while reducing accident probability as well as the consequences of accidents.

The value proposition of these advanced reactors could be substantial:

- Significantly lower capital and/or operational costs than existing plants
- Reduced material inputs
- Manufacturability or rapid deployment capability
- Passive safety systems and inherent safety strategies
- Ease of operation and maintenance
- Reduced emergency planning zones

- Reduced offsite impact during an accident and increased flexibility/scalability of siting
- Increased proliferation resistance, decreased waste production and/or actinide management capacity, and more efficient use of fuel resources
- Hybrid generation adaptability (e.g. hydrogen production, desalination, etc.) and/or load following

All of these attributes could lead to substantially lower capital, licensing and operating costs. A detailed study[19] of cost inputs to eight different advanced reactor offerings concluded that the levelized cost of energy from these designs was likely to average $60/MWH, with some as low as $40/MWH. These costs are well within the range of other firm generating capacity options in North America such as combined cycle gas, and even competitive with other zero carbon energy sources such as wind and solar (sources with much lower firm capacity value) in many parts of the country. The estimated cost spread is shown in Figure 18 below.

[19] Energy Innovation Reform Project, "*What will advanced nuclear power plants cost?" (2016),* *https://www.innovationreform.org/wp-content/uploads/2018/01/Advanced-Nuclear-Reactors-Cost-Study.pdf*

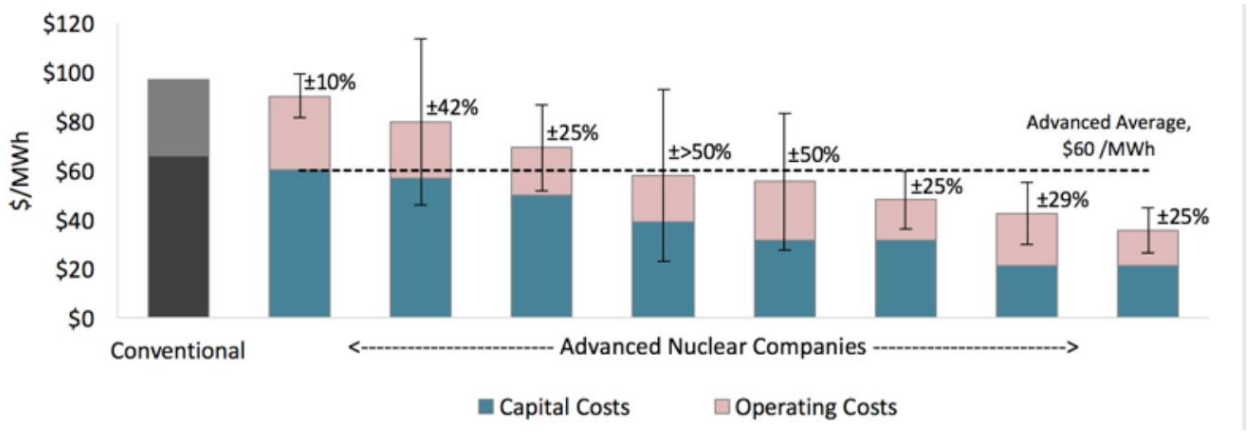


Figure 18: Advanced reactor cost estimates. Source: see footnote 19.

Another option to speed deployment of modern reactors in the U.S. at lower cost is to repurpose existing retired or retiring fossil fuel sites being used for mining, extraction, and electricity production, as is currently being pursued by Terrapower in Wyoming.[20] There are hundreds of such sites in the United States, as shown in Figure 19 below:

[20] https://www.terrapower.com/natrium-demo-kemmerer-wyoming/

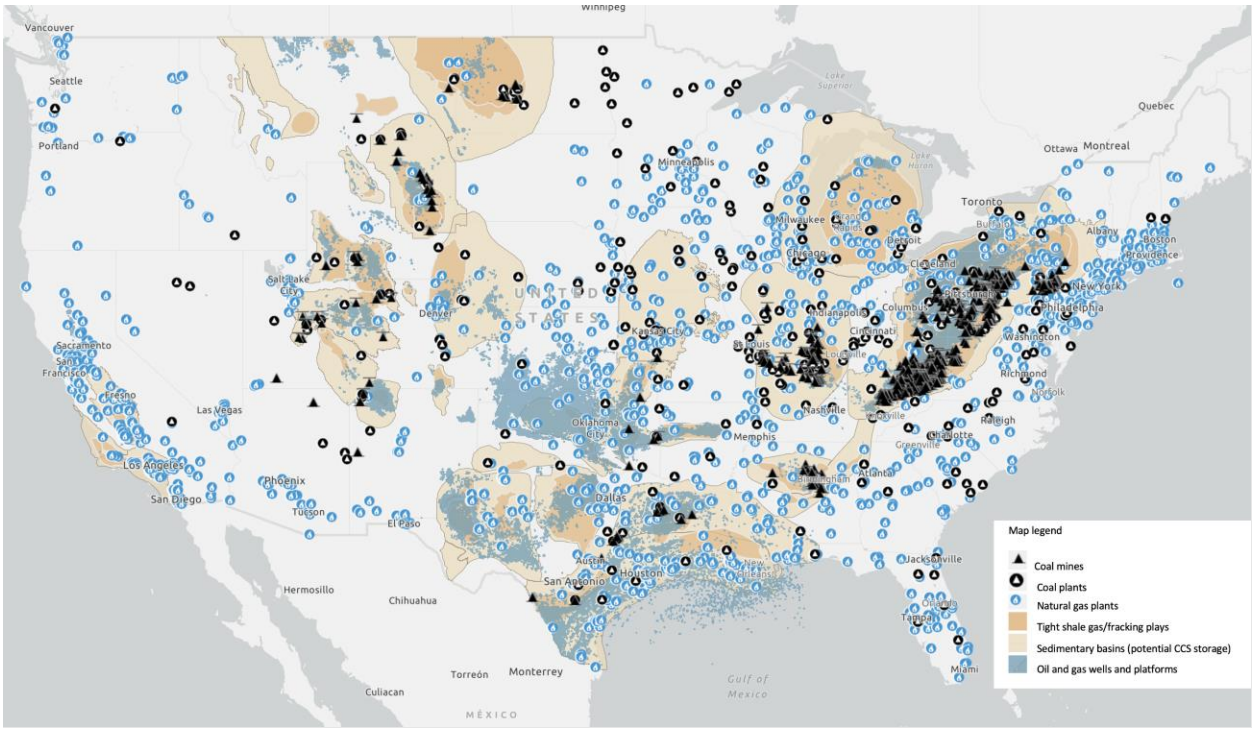


Figure 19: Existing U.S. fossil energy mining, extraction and power production sites. Source: https://atlas.eia.gov/pages/energy-maps

Site repurposing could reduce costs and speed deployment of modern nuclear energy systems by reducing site preparation requirements and utilizing existing transmission connections and infrastructure. In addition, many coal and mining communities may welcome such plants more than others, to preserve lost jobs and tax base. The Infrastructure Investment and Jobs Act (IIJA), as enacted, and the reconciliation package, contain some initial provisions that aim to capitalize on the opportunity for repurposing existing coal site:

- Authorizations for advanced energy manufacturing and recycling at or near retired coal mines and coal power plants (IIJA, Sec. 40209),
- Authorizations for clean energy demonstration on current and former mine land (IIJA, Sec. 40342)

- Increased adders for the clean energy investment and production tax credits if the facilities were built at or near retire coal mines and power plants. (Senate Finance Committee, Reconciliation Package Title (Sec. 126101(f)(11) and Sec. 126801 [45AA(g)(7))]

However, a more comprehensive all-of-government strategy is needed to realize the potential. This approach would expand upon the provisions listed above and include additional support for remediation, feasibility studies, and demonstration.

III. Other policies to enable nuclear energy at scale

Two other federal policy initiatives could help to make nuclear energy a meaningful climate management tool: re-setting U.S. policy on spent fuel, and ensuring that the NRC is adequately supported in licensing innovative plants and performing reactor oversight while enabling developers to effectively navigate the licensing process.

Spent Fuel

Nearly everyone agrees that after forty years of deadlock, a serious re-set of federal spent fuel policy is required. It is not impossible to site a permanent geological repository for nuclear waste; other advanced industrial nations like Sweden[21] and Finland[22] have done so. But a substantial rethink will be required. CATF believes this will require a bottom-up approach in which state and communities are asked to identify their priorities and under what conditions

[21] https://www.dw.com/en/sweden-approves-plans-for-forsmark-nuclear-waste-storage-site/a-60584787
[22] https://www.forbes.com/sites/jamesconca/2021/05/31/finland-breaks-ground-on-its-deep-geologic-nuclear-waste-repository/?sh=525fcaf76103

they would host waste facilities, and for the federal government to respond; and that may require a wholesale change in program structure and approach, as was necessary in Sweden. [23] The Department of Energy's recent Request for Information on this topic[24] is welcome, and CATF intends to respond.

An Adequately Supported NRC and Functioning Licensing Environment for Advanced Reactors

There has been substantial debate around the financial structure for reactor safety oversight and licensing at the Nuclear Regulatory Commission. CATF believes it is paramount that the NRC has sufficient funding to license advanced reactors under existing regimes, develop new licensing pathways more suited for advanced rectors, as well as perform existing and future activities related to reactor and nuclear technology oversight. However, any accompanying fee structure should not raise insuperable or unnecessary barriers to advanced reactor companies, many of them thinly capitalized until their first project and stranded in the "valley of death." We believe there are serious risks for advanced reactor deployment if these balancing factors are not thoughtfully addressed.

Congress made recent laudable steps forward in the Nuclear Energy Innovation Capabilities Act of 2017 and the Nuclear Energy Innovation and Modernization Act (NEIMA) of 2019 in instructing the NRC to pursue risk-informed and performance-based regulatory pathways for

[23] Kaiserfeld, Thomas, and Arne Kaijser. "Changing the System Culture: Mobilizing the Social Sciences in the Swedish Nuclear Waste System." *Nuclear Technology* 207.9 (2021): 1456-1468.

[24] https://www.federalregister.gov/documents/2021/12/01/2021-25724/notice-of-request-for-information-rfi-on-using-a-consent-based-siting-process-to-identify-federal

advanced innovative reactors. This will require considerable effort and reorientation of the NRC's approach, and in fact, CATF recently submitted comments[25] on the NRC's Part 53 strategy, in which we called for a reduced focus on prescriptive requirements, and instead, the development of a flexible process that can accommodate current practicable and future methods.

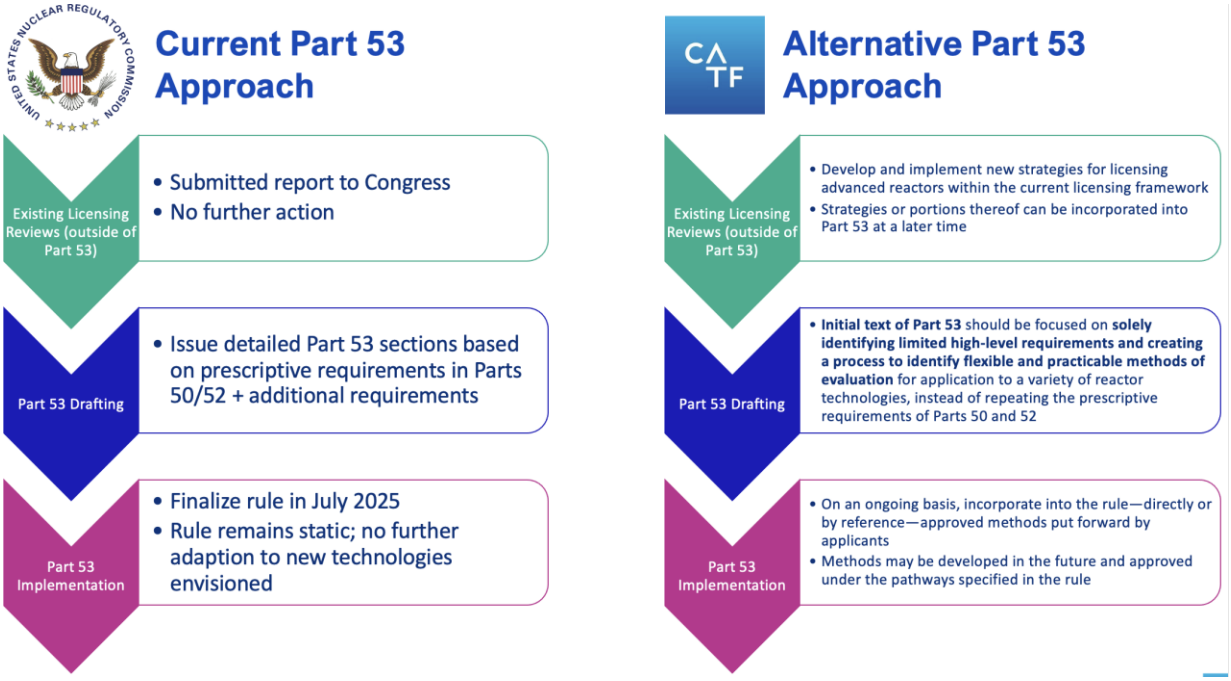


Figure 20: CATF recommended approach to advanced reactor licensing contrasted with current NRC approach.

This is not a light lift; however, we believe Congress and the NRC both recognize the need for more discussion, as well as action, as evidenced by:

- Discussion of legislation to advance licensing fee prizes, that provide fee relief to the first advanced reactor developers to achieve licensing success.

[25] "Comment of Clean Air Task Force in Response to the U.S. Nuclear Regulatory Commission's Proposed Rule on a "Risk-Informed, Technology-Inclusive Regulatory Framework for Advanced Reactors," 53https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML22011A284

- Discussion around and the introduction of HR 6154, the Accelerating Nuclear Innovation through Fee Reform Act.
- The recent Nuclear Regulatory Commission Report to the U.S. House and Senate on Recommendations and Improvement for Budgeting and Fees based on implementation of NEIMA.

CATF believes that Congress should strike an appropriate balance between the importance of sufficient funding for the NRC to carry out its duties while not stifling development of advanced nuclear projects by making the cost of licensing fees an obstacle for innovative reactor companies. In achieving this balance, we believe Congress should be guided by the general principles outlined in a recent report by the Nuclear Innovation Alliance[26] (see below):

1. **Expand public funding for advanced reactor regulatory infrastructure. Recent increases in off-fee funding at NRC have helped NRC prepare to review advanced reactor designs, but individual license applications are also innovation activities.** Large increases in non-fee funding are needed to develop the regulatory infrastructure to maintain NRC as a world- leading nuclear regulator.
2. **Significantly reform, modify, or replace the user fee cost recovery model to exclude or substantially reduce fees for new license applicants at NRC.** Multiple aspects of U.S. nuclear regulation bring benefits to the public and entities other than the applicant. Reduced fees, especially for new designs and innovative technologies, can reflect these broad benefits. Increasing the fraction of the NRC's budget that is funded from general revenues can incentivize more innovation, improve regulatory efficiency, and ensure the American regulatory environment remains competitive. If fees are not completely replaced, excluding pre-application, topical reports, and environmental reviews from fees can still bring substantial benefits. Alternative fee designs, such as fixed fees or deferred fees, could also offer flexibility compared to the current model.
3. **Alternatively, expand options for Department of Energy (DOE) funding of advanced reactor licenses.** Although the Nuclear Energy Innovation Capabilities Act authorized a program for DOE funding for advanced reactor licenses, it does not appear the program has yet funded AR licensing activities. While this would not fully address the challenges

[26] I note that I am a member of the Board of Directors of the NIA.

of the current NRC structure, Congress could consider funding this authorization, as well other measures such as licensing prizes, fee caps, flat fees, or fee deferrals.

IV. Conclusion

As social consensus emerges around the urgency of addressing climate change, so has public receptivity to nuclear energy as part of the solution toolkit. At the thought leadership level, consider the following recent opinion pieces in leading publications:

Financial Times
"The Climate Case for Nuclear Power" https://www.ft.com/content/0d0e300c-18da-449f-a545-100ab2dd207e

Bloomberg
"Nuclear Power Is More Important Than Ever" https://www.bloomberg.com/opinion/articles/2022-02-02/nuclear-power-is-essential-in-fighting-climate-change

The Economist
"The discreet charm of nuclear power" https://www.economist.com/leaders/2021/11/13/the-discreet-charm-of-nuclear-power"

"Will the climate crisis force America to reconsider nuclear power?" https://www.economist.com/united-states/will-the-climate-crisis-force-america-to-reconsider-nuclear-power/21806194

Wall Street Journal
"A European Revelation on Climate" https://www.wsj.com/articles/a-european-revelation-on-climate-green-energy-nuclear-natural-gas-france-germany-11641228156

Washington Post
"Closing California's last nuclear power plant would be a mistake" https://www.washingtonpost.com/opinions/2021/11/16/closing-californias-last-nuclear-power-plant-would-be-mistake/

"Germany is closing its last nuclear plants. What a mistake." https://www.washingtonpost.com/opinions/2022/01/01/germany-is-closing-its-last-nuclear-plants-what-disaster/

Herald Dispatch
"Editorial: WV should consider nuclear power as an option" https://www.herald-dispatch.com/opinion/editorial-wv-should-consider-nuclear-power-as-option/article_556d8f77-dad3-5aaa-88bf-eb79f2220580.html

Denver Gazette
"EDITORIAL: Colorado needs nuclear power, too" https://denvergazette.com/opinion/editorials/editorial-colorado-needs-nuclear-power-too/article_99be5a06-78ae-11ec-8977-63d6676fb60f.html

On the level of public opinion, consider these recent polls, which show a recent uptick in support for nuclear energy in the context of climate change awareness, most notably among Democrats (a greater than 50% increase in the last three years):

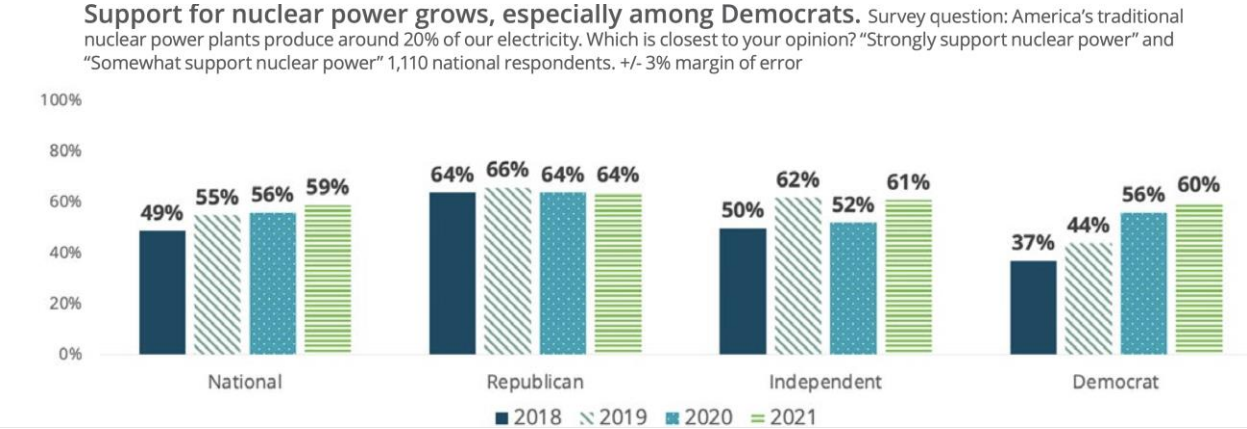


Figure 21: Source: EcoAmerica, "Energy Attitudes: Americans Support Clean Energy," https://ecoamerica.org/wp-content/uploads/2021/11/acps-2021_energy-attitudes-report.pdf

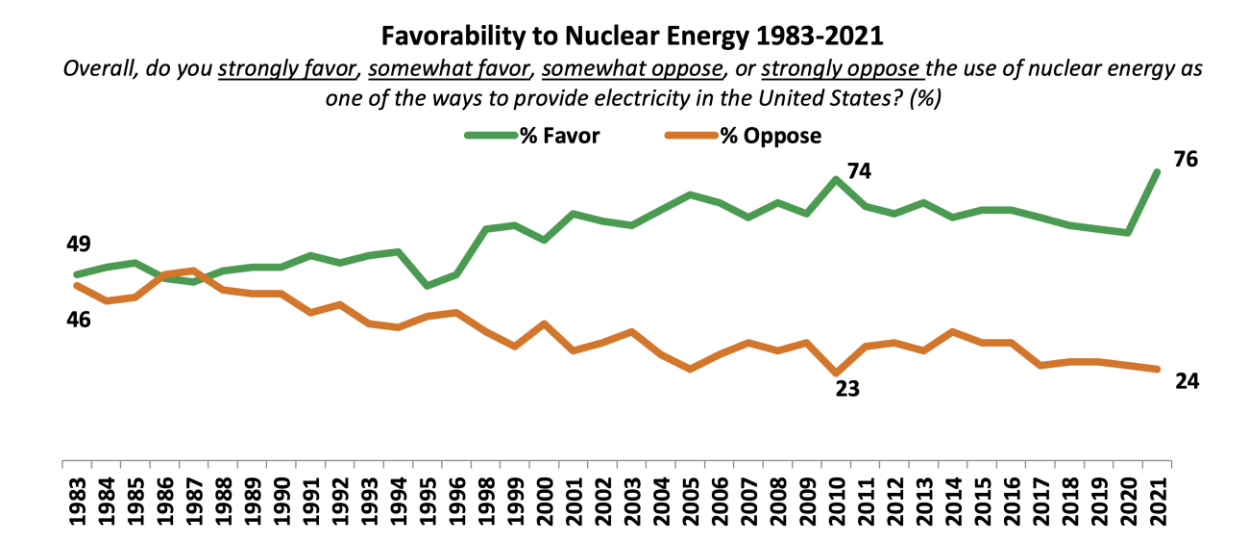
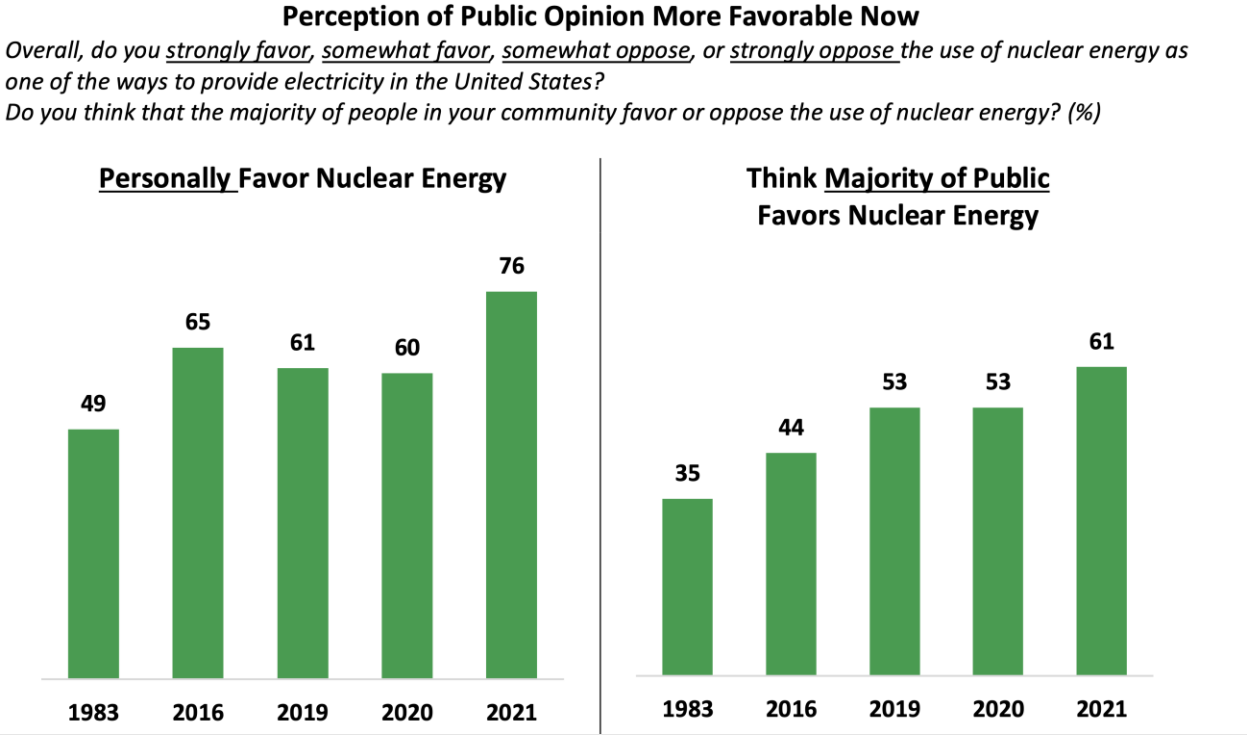


Figure 22: Bisconti Research, Inc., "Support for Nuclear Energy Grows with Climate Change Concerns" (June 2021)

http://www.bisconti.com/articles/Summary%20of%20May%202021%20Survey%20on%20Nuclear%20Energy.pdf

Most interestingly, some of the polling suggests that Americans are more favorable to nuclear energy than they ***think*** (erroneously) their fellow Americans are, which suggests room for cultural and political leadership on this topic to reduce barriers to its deployment:



Figures 23: Source: Bisconti Research, Inc., "Support for Nuclear Energy Grows with Climate Change Concerns" (June 2021)
http://www.bisconti.com/articles/Summary%20of%20May%202021%20Survey%20on%20Nuclear%20Energy.pdf

This suggests the time is ripe for nuclear energy to come back fully into the climate change strategy to complement our nation's remarkable successes with renewable energy. Policymakers must lead with bold new initiatives, building on the successes of the last few years. While many such initiatives are in development, we believe several are immediately actionable:

- Providing incentives for cost-effective scale up of advanced nuclear energy, beyond initial demonstration, to achieve scale and lower costs
- Supporting licensing processes and fee structures appropriate for advanced reactor designs both in the United States and for application of U.S. designs globally
- Fundamentally re-setting U.S. nuclear spent fuel policy by pursuing community-driven consent-based siting policies that have been successfully deployed to license permanent geological repositories in other advanced industrialized nations
- Expanding support for repurposing of retired or retiring fossil fuel sites for advanced nuclear

Thank you for your attention.