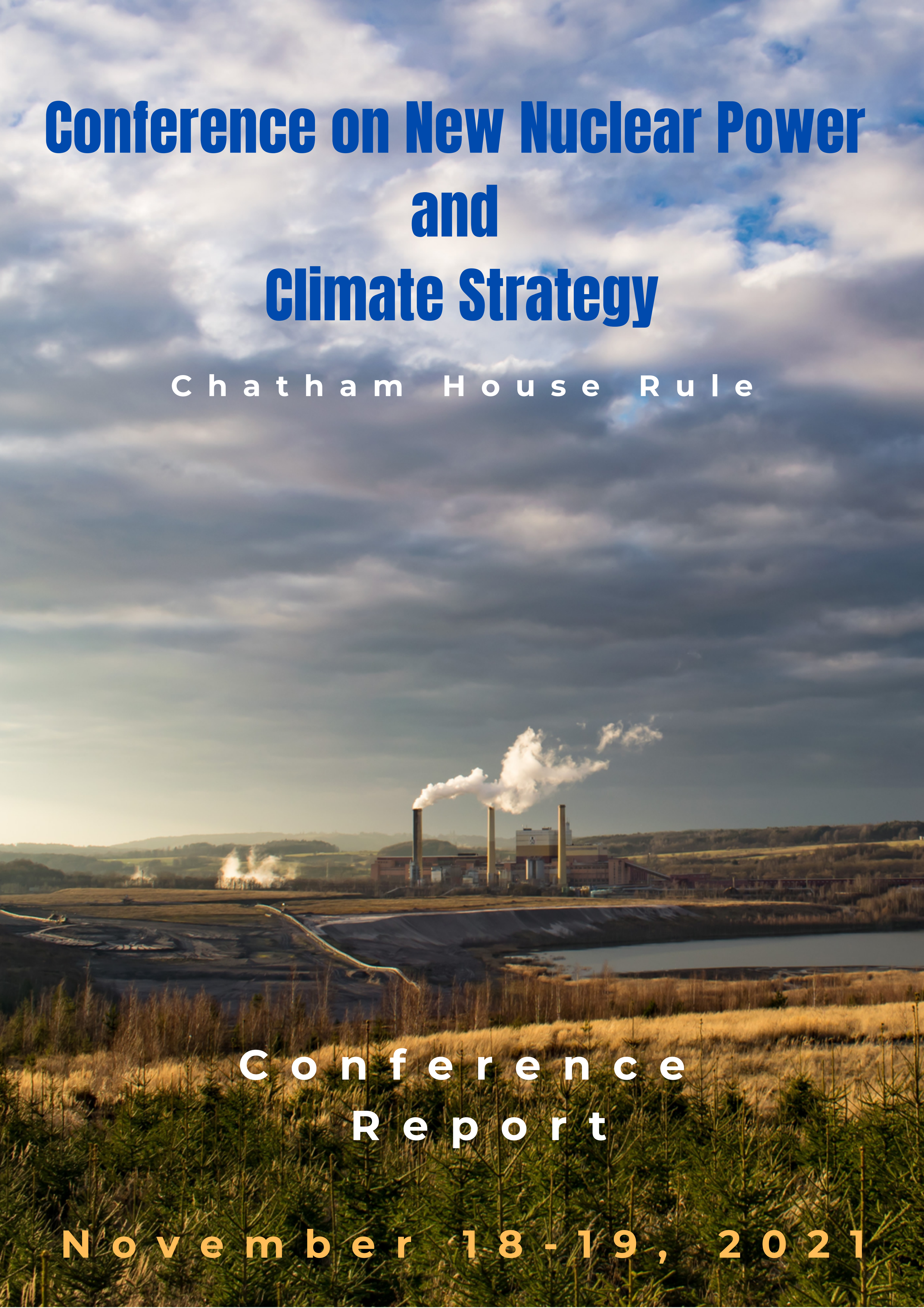
Conference on New Nuclear Power and Climate Strategy

Chatham House Rule



Conference Report

November 18-19, 2021

ENERGY CENTER
UNC KENAN-FLAGLER BUSINESS SCHOOL

New Nuclear Power and Climate Strategy

Stephen.V. Arbogast

The University of North Carolina's Kenan-Flagler Business School Energy Center organized a November 18-19, 2021, conference on the above topic. The conference brought together leaders of nuclear utilities, members of the NGO (Non-Governmental Organization) community including historic critics of nuclear power, and various academics and subject area experts. The objective was to foster a conversation among these groups as to whether recent developments were going to bring new nuclear power forward as an important contributor to climate strategy and the Energy Transition.

This conversation was organized around two questions: 1) is new nuclear power going to be needed as part of a feasible Energy Transition? and 2) if needed, could the nuclear industry deliver the needed technologies and projects? This report will summarize the different answers offered by the participants, their areas of convergence and their ongoing disagreements.

One Energy Center goal was to better define the different outlooks and underlying assumptions which shape today's debate about new nuclear power. By sharpening the definition of what the parties disagree on, it is hoped that ongoing discussions can focus constructively on what truly is at issue.

At the conclusion of this Report, the UNC Energy Center will offer what it sees as the key conclusions from the event and their policy implications. These observations are based on what was said at the event and in subsequent exchanges with participants who reviewed drafts of this Summary.

Consistent with the Chatham House Rule prevailing at the event, nothing in this Report will be attributed to any speaker.

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Conference Report:

Executive Summary (ES)

Is New Nuclear Power is going to be needed for a feasabible climate strategy?

It was generally accepted that climate risk is a serious threat requiring extensive decarbonization of the global economy. One speaker argued that the threat was exaggerated and not worth the extensive costs required to decarbonize, but this view was not supported by other participants.

There is a rough consensus that new nuclear will play some role in global climate strategy. The principal debate is over how great a role.

Nuclear advocates foresee a significant need for clean, firm electric power. This is especially the case in developing nations, such as China and India, where there is a need to balance robust power demand growth and decarbonization.Others believe that nuclear's high capital costs and economics will ultimately compare unfavorably with a deeper commitment to renewables and improved versions of storage, hydrogen use, carbon capture and other alternatives.

Here it is worth noting that long term forecasts made by the IEA and EIA forecast nuclear growth in the developing world; this growth more than offsets facilities closures in OECD countries.

Today some 53 reactors are under construction around the globe, almost all of these in the Eastern Hemisphere.

Will new nuclear be part of climate strategy in the U.S.?

This is a matter of sharp disagreement. Utilities argue there is a compelling case that new nuclear will be needed.

Their Net Zero 2050 cases start from the premise that existing nuclear plants must be life extended. They go on to show large gaps in needed generation, with new nuclear as a lead candidate to fill such gaps. These observers see a need for 'clean, firm electric power' (i.e., baseload and/or load following, reliable) that can be resilient in the face of grid disruptions or extreme events like weather. They cite power quality issues and compensating for increasing amounts of non-dispatchable generation as other factors. Finally, they cite bi-partisan majorities in Congress, supported by both the Trump and Biden Administrations, for making significant investments in advanced nuclear. By enacting these measures, they argue Washington supports the view that new nuclear must be developed as an option for the Energy Transition.

Those skeptical or more reserved about new nuclear's potential offer a different U.S. outlook.

This formed the most fundamental area of disagreement at the conference.

In this alternative Transition outlook, deep decarbonization of U.S. electricity can be accomplished without new nuclear. Most existing plants stay online, but **new nuclear plants are primarily seen as economically uncompetitive versus alternatives.** In this view steadily improving renewables and storage are combined with retaining gas-fired plants for ~20% of generation and running these plants on hydrogen or other low carbon fuels.

Complementary contributions come from hydro, geothermal, biofuels and new long-distance transmission. **Advocates of this view say its approach will not only outcompete new nuclear economically but also avoid nuclear's safety, waste and proliferation externalities.** This outlook will be discussed at more length in the full report below.

Can new U.S. nuclear be based on existing Large Light Water Reactor technology?

Here, **the challenges facing deployment of new large U.S. light water reactors (LWRs) are formidable.** After the results at Summer South Carolina and Vogtle in Georgia, today's **utility CEOs are emphatic in saying they will not 'bet their companies'** on future such projects.

There is **a minority view** that **large LWRs** (Gen-3) **are the type now being built around the world.** Results in the UAE and elsewhere suggest that these plants can be completed without the delays and large overruns that characterized Summer and Vogtle. **In this view, the mistakes at the U.S. locations should be used as learning experiences;** future large LWRs should therefore not be ruled out.

Do Next Generation reactors offer a path forward for New Nuclear?

The 'next-gen' reactor designs are in the early stages of being proven technically. **Their developers promise an attractive array of benefits not typically provided by large LWRs. These include:**

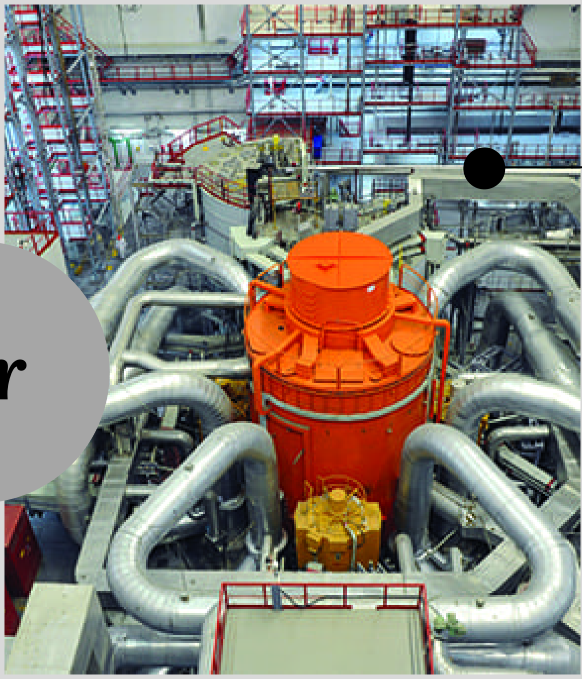
- **Smaller footprints, simplified construction, faster project schedules, all reducing capital costs.**
- **No operator action or AC/DC power needed to shut down reactors; no need to add water for reactor safety; no need for grid connections for safety; capable of having fence line Emergency Planning Zone (EPZ)**
- **Daily Load following; Island-operation capable, First Responder power in weather events**
- **Can be paired with hydrogen manufacture to provide storage, 40+ % power surge capacity that would pair well with renewables**

Most important, these **next-gen designs offer utilities the flexibility to size new nuclear** in a range from ~100-900 Megawatts (MW). This smaller size combined with the smaller footprints and promised construction benefits could offer utilities **relief from the 'bet the company' risk** that presently deters their undertaking new large LWR projects.

While the next-gen reactors come with promises of improved safety performance and reduced capital costs, they will be giving up 'scale.' As currently envisioned, next-gen projects will offer 1/10-1/3 the power of typical large LWRs. Moreover, the new designs need to address residual concerns related to terrorism, waste handling, and nuclear proliferation. These issues could also affect next-gen reactors' economic viability. Some observers **say that next-gen reactors have yet to demonstrate they can meet a minimum standard of being as safe as the current LWR fleet**. Potentially less economic than existing plants and with enhanced safety claims yet to be proven, skeptical observers see new nuclear playing only a marginal role in U.S. climate strategy.

To prove their economics, the next-gen reactors will need to 'count on' being able to build a series of plants.

Or



Next-gen reactors emphasize modular construction, much of which is done at the factory rather than the plant site. This makes manufacturing economies of scale of special importance for the new reactor types. An ongoing set of projects would allow the industry to reestablish manufacturing and contractor capabilities. Doing so could allow next-gen reactors to move down the cost curve in a manner like what happened with renewables. That said, **next-gen reactor gains will be relative to competing technologies like renewables, battery storage and hydrogen which could also see unit cost improvements over time.**

Assuming some of the next-gen designs demonstrate enhanced safety and dispatchable power features, their **'first of a kind' projects** would also need to show potential to be economic investments. Thus, the **'demonstration economics'** of the first 'at-scale' next-gen projects will be critical to the industry being willing to risk follow-on projects.

*There are **three ways in which the next-gen demonstration projects can be given the best opportunity to show their economic potential:***

01. First, design sponsors and the U.S. utilities can **direct initial next-gen project to 'brownfield sites,'** including former fossil fuel facilities. Using such sites offers existing infrastructure that will reduce investment costs and cut the risk of project overruns.

02. Second, it can happen **by the U.S. landing on a 'next-gen reactor product' for international sales.** Such a product would combine technical and economic feasibility with U.S. government protocols covering safety and proliferation risks. Successful efforts overseas would enable next-gen reactors to demonstrate their viability in locations committed to facilitating nuclear power. It could also generate an international order book for U.S. manufacturers and contractors.

03. Third, some parts of the U.S. or **the Federal government could establish zero carbon power mandates that contain specific targets for nuclear.** Directionally this has already happened at the state level, where new nuclear can be counted against the state's Clean Energy Standard. Expanded Portfolio standards of this type would contribute to the buildout of the next-gen reactor supply chain.

ES Conclusions

Competitive Power markets will limit U.S. New Nuclear unless restructured

Competitive U.S. power markets generally do not recognize important attributes of nuclear plants. This has contributed to the early closure of plants in states like New York and California. **The potential of next-gen designs to contribute to the U.S. Transition will thus be limited by the structural hostility of these current market designs.** Initial next-gen reactors will most likely be located in traditional power markets where such plants can enter the utility's rate base.

Competitive U.S. power markets will need restructuring if new nuclear is to be a major U.S. Transition contributor. This restructuring should recognize the contributions from all technologies of firm capacity, load following capability, resiliency and low carbon. Such a restructuring would go far towards fairly valuing the full grid contributions of next-generation U.S. nuclear reactors.

Next-gen reactors could enable new U.S. nuclear to contribute to Net Zero power at home and provide a strong American product for developing countries. If realized, their promised improvements in terms of lower capital costs, improved safety, load-following flexibility, and reduced risk of cost overruns could go far in a addressing the issues which have deterred nuclear investments in the U.S. Such an outcome would add a major zero carbon option to global decarbonization efforts. Much however depends upon what is learned from the demonstration projects taking shape overseas and in a couple of U.S. locations. A comparison will be made with these project results versus cost trends in renewables + storage. Repurposing coal plants and/or winning a series of international orders would offer the best prospects for 'first of a kind' new U.S. nuclear project to succeed.

This Report will now examine these high-level conclusions and the associated conference discussions in more detail.

Conference on New Nuclear Power and Climate Strategy

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Questions Discussed

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CONFERENCE REPORT

The conference unfolded by exploring a series of questions, which issues are replicated below. The discussion revealed some areas of convergence, others of serious disagreement, and some conclusions which point to policy implications.

The UNC Energy Center's view of these conclusions and policy implications is provided at the end of this report.

Questions Discussed

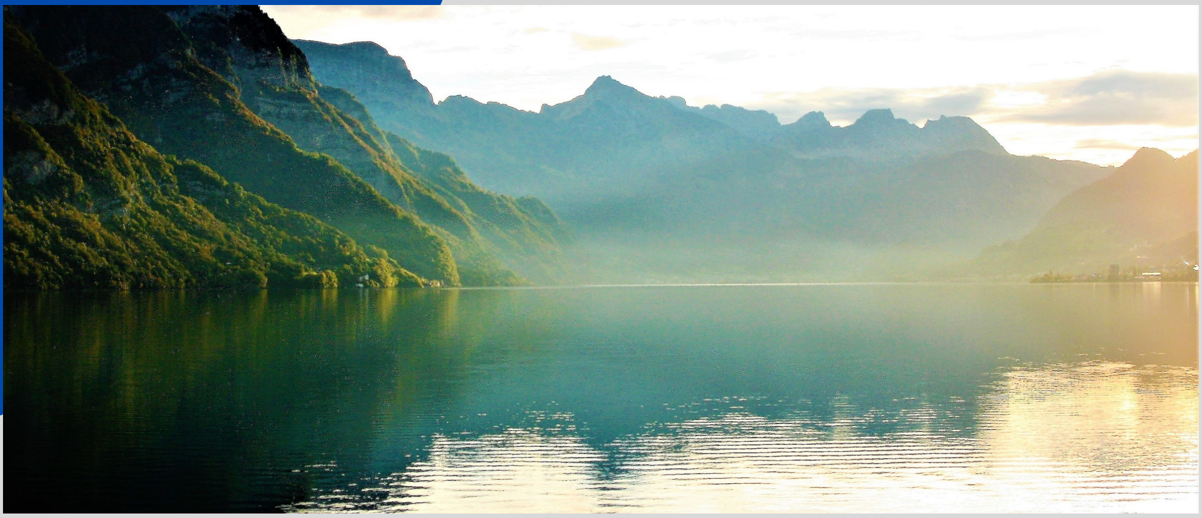
#1

Is Nuclear Power going to be needed as part of climate strategy?

- **New Nuclear power will be needed as part of the global approach to the energy transition. Virtually all energy outlooks foresee a rapid growth of electricity demand accompanying the economic development of emerging market economies.** Meeting this growth while simultaneously de-carbonizing their power sectors will be a formidable challenge. New nuclear power offers scale, zero carbon power with high-capacity factors that can complement growing capacity from intermittent renewables.

- Today, countries like China and India account for almost half of global greenhouse gas emissions. Climate studies expect emissions from these and other developing countries to continue growing throughout this decade. These countries start with a sharper conflict between their economic/growth goals and climate concerns. Other developing nations start with weaker electricity grids and possess both fewer energy options and limited financial resources. **Emissions progress in the developing world would thus seem to require contributions from many low carbon sources, with those selected being as cost effective as possible.**

- **Discussion at the conference reflected a range of perspectives on how much new nuclear will contribute globally.** Utility executives and some subject area experts foresaw extensive growth in power needs across the developing world and that large scale new nuclear was well suited to provide clean, firm power to meet this demand. In effect, **this view sees the scale of the energy demand growth as the key factor driving an important role for new nuclear. Other perspectives felt that developing countries have more options** than are recognized, that renewables will be cheaper than new nuclear and that high capital costs and the challenges of addressing nuclear's externality issues will tend to dampen developing country nuclear appetite.



- **New nuclear in the developing world poses certain advantages even as it raises challenging questions.** New nuclear offers developing economies clean, firm, large scale power to address their growing loads. **Once built, it also constitutes domestic-sourced power; consequently, it helps developing economies address the security risks associated with importing oil and gas. Finally, once built it is relatively immune to price inflation.** These factors largely account for the attraction new nuclear holds for countries like China, India and possibly others like Brazil.

- That said, **conference participants also identified issues that may impact new nuclear's potential in developing countries.** All the reactors under construction in these countries are large, light water plants. **As such they are expensive in terms of upfront capital cost. Not all developing countries will be able to afford such projects. Many also use Chinese or Russian technology. Developing countries vary in terms of their regulatory/safety regime robustness or their ability to address issues like waste and proliferation.** A large, developing-world buildout of Russian or Chinese nuclear technologies thus poses a variety of risks. More to the point, it also poses the potential **that developing country new nuclear might progress on a basis that marginalizes the kind of safeguards which conference observers feel are essential to avoid catastrophic risk events which can discredit new nuclear as an option.**

- **Next-gen U.S. technologies packaged with western and proliferation protocols could mitigate some, possibly many of these risks. As of today however, the U.S. does not have a next-gen technology 'in the race.'** The U.S. was successful in applying its regulatory/proliferation protocols to the new plants coming online in the United Arab Emirates (U.A.E.) That precedent will be helpful to follow-on efforts by the next-gen U.S. companies. This will be discussed further below in the section on 'Can the Industry Deliver?'

- **Finally, it is worth noting that in its 2021 Energy Outlook the IEA foresees global nuclear power usage growing from 2020's 2696 Terawatt hours (TWh) to 4449 and 4714 TWh in 2050 respectively under its Announced Pledges and Sustainable Development scenarios (see Exhibit 1). China's nuclear fleet grows from 366 TW in 2020 to 1450-1522 TW in 2050.** The comparable figures for India are 46 TW and 292-303 TW. Also of interest is that IEA projects nuclear's Levelized Costs of Electricity (LCOEs) in these two countries at 50-60% of costs forecast for the U.S. or Europe.

- This outlook suggests that a significant international nuclear industry will exist, contributing a large amount of zero carbon electricity to the locations currently most associated with rising GHG emissions and persistent use of coal-fired generation.

#2 Is Nuclear Power going to be needed as part of U.S. Climate Strategy?

- This question exposed **one area of consensus** and also **the largest topic of contention at the conference. Existing nuclear utilities all affirm they cannot achieve targets for Net Zero emissions by 2050 without preserving their existing nuclear capacity. By and large this view was supported by the NGOs,** though specific plants with locational issues or problematic histories may not, in their view, be worth preserving.

- The question of whether new nuclear will be needed for U.S. de-carbonization exposed sharply divergent views. **The utility perspective, echoed by some other observers, was that new nuclear is a leading candidate to provide the 'clean, firm' power demand they see in their forecasts. The NGO perspective strongly doubts this.** In their view, there will be other alternatives that can supplement the buildout of renewables and battery storage. **These alternatives will offer dispatchable power and, given nuclear's history of disappointments on cost, are likely to prove more economic.** These NGOs are also skeptical of next generation reactors' ability to address nuclear's longstanding safety, waste, and proliferation risks.

- The utility perspective here is shaped by four factors:

1. Projected load growth driven by de-carbonization,
2. The challenge of replacing high-capacity fossil fuel plants with lower capacity intermittent power,
3. Load following, and resiliency issues associated with deep renewables penetration, and
4. Power quality.

They see the growth in electricity load from de-carbonization as requiring a massive build out of new generation capacity to replace existing coal and possibly natural gas plants. As illustrated in Exhibit 2, to achieve Net Zero by 2050 Duke Energy foresees having to expand their generation fleet from 57 Gigawatts (GW) to 105 GW. This expansion includes a renewables buildout to 40 GW and installation of 12 GW of storage. Even with these efforts, all of Duke's existing nuclear fleet must have its operating life extended. Moreover, there are 13 GW of 'unidentified' in the buildout. Duke then identifies and discusses next-gen, small modular reactors as one of two leading candidates (along with carbon capture) to fill this gap.

- **A generation buildout of this nature has never been attempted by U.S. utilities. This is a challenge that combines huge growth with the issues associated with integrating massive amounts of intermittent power into operations.** For traditional regulated utilities who are charged with 'an obligation to serve,' this transition involves increasing risks of struggles 'to keep the lights on,' maintain power quality, and handle the ebbs and flows of demand within each day.Power quality is a particular concern. More frequent and more volatile fluctuations in generation can impact the voltage and frequency ranges that must be maintained to assure machines and plants can operate without disruptions. Adding more intermittent power to generation will put pressure on these power quality dimensions. Consequently, the utilities see value in having an adequate foundation of 'clean, firm' power which will be resilient in the face of weather events, sustain consistent power quality and which can assure that battery storage can be recharged within a 24-hour period. **After surveying this slate of challenges, utility CEOs at the conference affirmed that they 'cannot reach Net Zero 2050 without nuclear.'**

- **Utilities in competitive markets currently see little incentive to invest either in new capacity or in grid resiliency. Some of these firms are also under economic and political pressure to close existing nuclear plants.** Consequently, they are unlikely to invest in new nuclear capacity unless/until their markets are restructured. **Clean Energy Standards (CES) that incorporate nuclear into the qualifying power sources have been adopted in some competitive market U.S. states.** These could, if combined with fiscal incentives like long term capacity markets and/or zero carbon credits, incentivize merchant generators to consider next-gen nuclear, especially if they see load growth growing in response to de-carbonization.

- **The NGO perspective presented at the conference is different on many counts.** This perspective is based in part on 'deep de-carbonization' models of the U.S. electricity market. These **models suggest the feasibility of deploying renewable and other low carbon solutions to meet up to 80-90% of electricity market demand.** Exhibit 3 shows power contributions provided by a large buildout of solar capacity and storage with contributions from onshore and offshore wind. Hydro, biofuels, geothermal, contribute smaller amounts of capacity to the ultimate 2050 generation stack. **Much existing nuclear capacity is kept online, but little net new capacity is added.** Nuclear's share of GW capacity and TWhs remains roughly consistent with today. **This suggests at most a marginal role for new nuclear in this view of the future.**

- Another feature of this deep de-carbonization study is its approach to handling the intermittency inherent in its extensive reliance on wind/solar power. **The study asserts it will be viable to keep the grid operating with a remaining fleet of natural gas plants that are operated as peaker plants. Moreover, these plants will no longer run natural gas but be fired by hydrogen or biogas.** A relatively constant fleet of 500-600 GWs sees its production drop from 700-800 TWhs to ~200 TWhs by 2050. By the end of this period, such plants will be fully depreciated assets, possibly allowing them to be operated economically in a strictly load following capacity.

- **Several premises lay behind this Deep Decarbonization Study. One is that new nuclear will be too expensive relative to renewables plus storage,** the costs of which are perceived to have declined sharply. Here the history of nuclear's project delays and cost overruns is cited. These examples apply not only to the recent Vogtle and Summer project execution debacles but to other large nuclear projects dating back to the 1980s. The second is that **new nuclear will continue to present versions of the historic safety, waste and proliferation issues which contributed to its losing favor several decades ago.** A third is that **new reactors will take too long to build to contribute materially to timely decarbonization.** This concern reflects the urgency on emissions reduction expressed in recent IGCC and other climate reports. These issues will be discussed in more detail in the 'Can the Industry Deliver?' section below.

- **Certain premises in the Deep Decarbonization Study were critiqued** by the industry participants. One concerned the grid reliability and power quality assumptions embedded in the Study. **Industry participants questioned whether the 24/7 customer expectations on power availability would be met under the study's assumptions. They argued that renewable and storage capacity that would have to be overbuilt to assure that the last 10-30% of capacity was reliable;** they further questioned whether power supplies would be reliable even with such overbuilding. **They also argued that such overbuilding would prove very inefficient, resulting in rising, not falling power costs.** Germany was cited as a case supporting this concern.

- **Another premise challenged by industry was the Study's reliance on long distance transmission** lines to move wind and solar from good natural resource locations to demand centers. Such transmission is also needed to balance load and move surplus renewable power across regional markets. **Industry participants were skeptical that states and local communities would soon allow such transmission buildouts to occur.** Here they cited efforts to bring Oklahoma wind to eastern markets, which plans were blocked by resistance in states like Arkansas. **The time needed to overcome such obstacles raises doubts in their minds about whether the generation strategy outlined in the Study can be achieved within the urgent timeframe laid out in the IGCC and other climate studies. The time needed to gain acceptance for new projects will thus be a factor determining the relative contributions of both new nuclear and new wind/solar to the generation capacity growth envisioned for Transition.**

#3 Can the U.S. Industry Deliver 'New Nuclear' if it is Needed for Climate Strategy?

- **The answer to this question is decidedly TBD (To Be Determined).** The industry faces many obstacles to delivering new nuclear projects and there are more than a few reasons for expecting that it will be challenged in doing so. Next generation nuclear designs promise an array of benefits which, if demonstrated, could make them attractive options for utilities implementing Net Zero emissions strategies. As of the date of this conference, none of the next-gen designs has completed an at scale project demonstrating what it can deliver.

- The promised array of benefits is extensive. Exhibit 4 provides an example of such claims by one Next-gen reactor firm. The biggest is relief from the 'bet the company risk' which large LWR projects like Summer SC and Vogtle GA dramatically presented. Some of this relief comes from smaller scale. The next-gen reactors are all small modular designs where project size will reflect some compilation of individual ~40-60 MW modules operated in series. Most industry estimates see this approach producing projects in the 100-900 MW range, approximately 1/20-1/2 the size of Southern Company's Vogtle project. Smaller equals less capital cost and a smaller impact from overruns on a given project. Next-gen firms also emphasize that building the reactors in factories will simplify project construction and reduce the risk of recycle and delay which large LWR projects repeatedly demonstrated.

- Next-gen reactors also promise to be safer than their predecessors. A key claim is that they can shut down without human intervention. The technologies here vary from passive shutdown features also claimed for Gen-3 LWRs to reliance on different coolants (e.g., liquid sodium) or heat repositories (molten salt). If demonstrated, these advantages could go some distance towards lessening longstanding fears of catastrophic accidents at nuclear plants.

- **Next-gen nuclear's biggest challenge is economic.** Many existing nuclear plants are struggling, especially in competitive power markets. These plants have sunk investment costs and long lives, yet they often cannot compete on price with renewables and natural gas. Thus, **observers ask: how can new nuclear plants, which must amortize heavy upfront capital costs, hope to compete? Next-gen reactors compound this issue with aforementioned loss of scale.** Given problematic economics and a need to demonstrate the technology at scale, some observers also doubt that next-gen nuclear will materialize in time to help on climate mitigation.

- **The next-gen reactor economic challenge is compounded by expectations that the first projects will cost 2X or more capital versus what 'lined-out' plants will require.** The risk here is that another round of large cost overruns will discourage follow-on projects. This risk is mitigated by the fact that smaller scale comes with a smaller capital price tag and thus less 'bet the company' risk. Still, the new technologies will likely need the prospect of steady orders over time to see supply chains develop and mature. This will be especially important for next-gen nuclear, given that the existing U.S. LWR supply chain has atrophied since the 1980s.

- **Next-gen nuclear may offer other credits that could compensate for its loss of scale.** First among these is the plan to construct reactors in factories as modular designs. This accounts for several benefits which next-gen reactors claim:

1. unit capital costs should decline as standardized designs benefit from line-out factory production, and
2. project overrun and delay risks should be reduced, as the complexity of field installation is simplified. Here it is worth noting that the massive workforces to be mobilized for large LWRs are markedly downsized when project development changes to installing and connecting completed reactor sets.

- **Other credits may materialize if next-gen reactor claims of enhanced safety and operating flexibility prove true.** Several of the new reactor technologies state that they can 'fail'/shut down 'passively,' i.e., without human intervention. As such, they claim not to need several of the safeguards typically required for large LWRs. For example, they indicate no need for large Emergency Planning Zones (EPZ) outside the plant fence; backup diesel generators and the O&M associated with keeping them ready may also be reduced or eliminated. One next-gen producer indicated it had already received NRC guidelines within which it could define its technology's EPZ to be the plant fence line (see Exhibit 4). **Here is should be noted that several observes consider these benefits as at best unproven and more likely doubtful to materialize.**

- **As regards operating flexibility, running 5-10 next-gen reactors in series may open up more possibility for such plants to be 'load-following.'** Some large LWRs were originally designed to allow ramping up/down, but designs were then modified to emphasize the economics of running full-out. Presumably, **small reactors operating in series offer more potential for individual units being ramped up or down. Whether this is more economic than planning for running in base load is TBD. Some next-gen technologies also envision channeling off-peak power into hydrogen production,** which fuel would then be available for use in combustion turbines. In one example, a 350 MW next-gen reactor claimed that through the use of molten-salt storage during non-peak hours, it could surge to 540 MW by channeling off-peak hydrogen production into subsequent peak-time combustion.

- **Foreign orders for next-gen U.S. reactors could also help industry economics.** At present, the U.S. doesn't really have a proprietary nuclear technology that can economically compete with lower cost Russian and Chinese designs. Next-gen designs could provide that product and possibly secure multi-year orders. These would help build out the needed U.S. supply chain. **Interest from Canada and some East European countries in next-gen designs suggests the possibility of future orders along these lines.**

- **The net economics from these cross current claims are undefined and won't be known for years. The economics of next-gen reactors will only be known after the following occur:**

1. Demonstration plants provide more data on capital costs, construction ease, and the validity of plant safety claims
2. The NRC, after listening to testimony from industry and the NGO community, decides which safety claims, if any, support changes in plant footprint, design and operating requirements
3. One or more at scale projects are completed and demonstrate the potential for economic returns for future plants; then some level of government subsidy improves the economics and financing of the first wave of at scale, next-gen reactors.
4. A supply chain for future plants comes into being on the basis of an order book, foreign and domestic, sufficient to justify investments along the chain.

- **In sum, the nuclear industry's ability to deliver new projects is going to depend upon the successful demonstration of the next-gen technologies and an industry judgement that numerous projects can be justified.** Such a decision could bring into being a supply chain which could deliver lower costs and progressively more favorable plant economics. The successful demonstration of these technologies outside the U.S. could go far towards encouraging U.S. utilities to adopt next-gen reactors as a major component of their Net Zero game plans.

> ***We can not get to net zero by 2050 without Nuclear.***
>
> *Major Utility CEO.*

Areas of Convergence on Nuclear, Climate Strategy, & Can the industry Deliver?

- There were several broad areas of consensus among the participants. **Even the most skeptical agreed that climate warming was real and that emissions reductions should be pursued.** One presenter made the case that climate change would not be that costly economically and combating it with far reaching revisions to global energy infrastructure may not be justified. This position was not endorsed by other speakers.

- **There was also broad agreement that the existing nuclear fleet is an important contributor of low carbon power.** Most should be preserved even at the cost of modifying existing power markets. Going forward, rigorous safety criteria should be applied to site-specific decisions.

- **Implicit in the consensus to preserve existing nuclear was agreement that overall, the U.S. nuclear industry has operated large light water reactors safely.** Such operations set a minimum standard to be met by any advanced nuclear technologies.

- That said, **there was also broad agreement that large light water reactors are not likely to be the project of choice for new U.S. nuclear.** Shareholder utilities see these as 'bet the company' choices with too great a likelihood of losing the bet. If new nuclear is to happen in the U.S., the first projects will most likely employ small modular reactor designs that limit the financial downside for investor-owned utilities.

- **There exists a rough consensus that NRC regulatory oversight is not a significant obstacle to the nuclear industry delivering new projects.** Expectations are that the new Part 53 rules hold the potential for a simplified licensing framework for the new nuclear technologies, and that Part 50 is better than Part 52 for the next-gen demonstration projects.

- **Another major point of convergence is that merchant power markets will need to be restructured if new nuclear projects are to become a) economic and b) sufficiently numerous to materially impact U.S. climate strategy.** Competitive markets will have to develop structures which recognize new nuclear's full slate of contributions: e.g., zero carbon, firm capacity, high resiliency and load following capability.

- **Finally, there is general agreement that the U.S. nuclear project execution supply chain has atrophied and would have to be rebuilt for new nuclear to contribute materially to U.S. climate strategy. Also, there was broad concern that NIMBY resistance (Not in My Back Yard) may be a big obstacle to the timely progress of U.S. climate strategies.** Whether the subject was land for solar and wind power, rights-of-way for transmission lines, or siting new nuclear plants, local community and state resistance is seen as likely to delay projects, drive up costs and generally impede the Energy Transition.

Areas of Divergence: Nuclear, Climate Strategy, & Can the industry Deliver?

- Unsurprisingly, there were major areas of disagreement. **The biggest involved the reliability, timeliness and costs associated with the non-nuclear U.S. deep decarbonization scenario. The study could be considered as posing a competitive decarbonization plan versus ones incorporating significant new nuclear capacity.**

- **There is fundamental disagreement about whether the 80-90% renewables penetration outlined in the deep decarbonization study can be achieved without major issues in reliability and power quality.** Study authors cite high levels of penetration which have been achieved in some U.S. states for parts of a year. They further argue that demand-side management, more storage and long-distance transmission can mitigate power quality risks. They further see hydrogen-fueled combustion plants, concentrated solar, hydro and geothermal as providing the dispatchable power needed to complement a high renewables-base grid.

- **Other participants argued that such macro projections overlook the real-time problems which deep penetration by intermittent power will impose on the grid.** To cite two examples, observers noted the grid connectivity upgrade issues currently impacting solar project execution. Current projects are facing extensive delays because of studies required to identify transmission and other upgrades required to accommodate more intermittent power. These observers further outlined the economic and physical 'ramping issues' which surviving gas plants would face when called upon to offset the intermittency of wind/solar at 80-90% penetration (see Exhibit 5). Longer term an extensive buildout of DC microgrids may be required to accommodate such high levels of renewable generation. If those issues materialize, skeptics argue they will feed back on the capital needed for grid modifications and on power costs.

- **Another area of disagreement concerned the likely economic attractiveness of new nuclear power. The case against new nuclear is that there will be cheaper and safer ways to accomplish targeted emissions reductions.** The deep de-carbonization study presented at the conference is a representative model of this alternative. Those skeptical of new nuclear's potential point to nuclear's historical record of large overruns and project delays and compare this with wind and solar's histories of declining electricity costs. They then emphasize the aforementioned issue of loss of scale via the adoption of small, modular nuclear designs. Studies by EIA and others showing advanced nuclear LCOEs exceeding $88/MWh versus stand-alone solar and onshore wind at $37-40/MWh are cited to buttress the case.

- **The response to this critique emphasized that new nuclear's economics will be determined by a manufacturing and construction model very different from historic LWR projects.** They further noted that new nuclear's competitiveness must be judged relative to the alternatives available as decarbonization unfolds. Here they emphasize that renewable costs must be calculated on an 'all-in' basis, i.e., providing the same capacity and dispatchable power as a nuclear plant. They further note that the deep decarbonization study relies on buildouts of battery storage and long-distance transmission, plus demand-side management and a range of power sources, e.g., hydrogen, geothermal, and biogas, whose availability and future costs are hard to predict.

- **Several NGOs can be expected to remain skeptical regarding industry/next-gen company claims for new nuclear technologies. This reflects past NGO experience with Gen-3 reactors, which industry touted as both safer and easier to construct.** Some NGOs continue to point out that whatever benefits next-gen reactors may claim, all serious risks will not be eliminated. As an example, they point out scenarios where new coolants can catch on fire under certain circumstances; such risks underlie their concern that the new technologies should not justify a relaxation of current operating and safety rules. They further see little improvement in next-gen reactor proliferation risk. This is especially the case for those technologies requiring more highly enriched fuel, little of which is produced within the United States.

- **While more open to persuasion, major nuclear utilities are also in 'show me' mode regarding next-gen reactors.** Their Transition plans show a range of options rather than an unequivocal commitment to new nuclear. They are unclear about the economics of next-gen reactors, especially given their expectation that the first at-scale plants will cost 2+X the capital of 'Nth plant' projects. With that said, **they do believe that modular designs will mitigate 'bet the company risk.' They also believe that the enhanced safety, once demonstrated, could justify relief from specific current rules, e.g., the extent of Emergency Planning Zones.**

UNC Energy Center Conclusions and Policy Implications

- The deep decarbonization study presented at the conference is an important reference case for comparative analysis. It sets out what would have to happen to accomplish decarbonization of the U.S. power industry with little contribution from new nuclear power. In effect, this case indicates that new nuclear will compete with a massive buildout of solar and wind + storage, plus the creation of a hydrogen/biogas industry that fuels natural gas plants operated as peakers. Significant new long-distance transmission is also embedded in this case to assure that the new wind and solar are located where land is affordable, and the natural resource is robust.

- There is much that 'would have to happen' for this deep decarbonization scenario to be realized. Consequently, critiques of new nuclear as 'not ready in time' for the Transition must consider whether the non-nuclear alternative suffers from the same issue. Perhaps a better perspective would be to consider both pathways as options that could crystalized in the 2030s, and to let them compete as such. It may also be the case that each will be realized in part, and that they may even be complementary.

- Current regulatory approaches towards U.S. infrastructure will be one of the biggest barriers to realizing deep decarbonization, either with or without new nuclear. Changing this will require popular support to back corrective legislation. The NGO community can help this come to pass by deciding that climate is the top priority issue, and that legacy environmental concerns should not constitute an absolute barrier to infrastructure development. Common sense reforms incorporating costs/benefits and limiting the number and time devoted to court challenges would benefit most if not all transition options currently in play.

- The current energy crisis in Europe is improving the chances of new nuclear projects coming online sooner than 2030. Both France and the U.K. have announced ambitious nuclear building programs. These projects will likely be of the large LWR variety. Their realization and the associated revival of a large, non-Chinese/Russian LWR supply chain, may provide U.S. utilities with a chance to reconsider whether such projects should again be contemplated.

- European programs may at some point incorporate next-gen reactors. The odds of Eastern European countries progressing already-planned trials of next-gen reactors are improving. This acceleration favors light water reactor SMRs, which technology these countries know better how to operate. Countries which have closed large LWR plants, such as Germany and Italy, should closely follow next-gen projects in Eastern Europe. If they succeed, these countries can consider installing such reactors on the sites of their closed plants. See the discussion below of 'brownfield sites. These developments also constitute an opportunity for the U.S. to learn what the new designs offer in terms of cost, performance, and time to build. These learnings would illustrate what becomes possible inside a regulatory environment where there is commitment to building nuclear as part of an integrated climate and energy security policy.

- There is a strong need for a U.S. nuclear technology to be available to developing nations. Despite NGO claims to the contrary, developing nations have fewer options for powering their higher rates of economic growth. This can be seen in many nations' continued reliance on coal and indications they plan to continue growing GHG emissions for years to come. Existing nuclear offers these nations immediate decarbonization possibilities while bringing scale and firm power to their grids.

- Financing and technology transfer issues will be constraints in many developing countries, but the largest ones, China, India, Brazil, South Africa and the Persian Gulf states, have demonstrated capacity to overcome these hurdles. Today however, Chinese and Russian nuclear technology is readily available, and those countries actively promote its adoption by developing nations. This poses a variety of risks, including less than robust safety and proliferation safeguards. Without a U.S. 'horse in the race,' the chances of widespread adoption of Russian and Chinese nuclear technology and associated fuel supplies is considerable. Getting one or several U.S. options into the international market should be both a climate and a national security goal.

- U.S. next-gen technologies could provide that U.S. 'horse in the race. There is a significant win-win opportunity here. The smaller capital costs of SMR projects can expand new nuclear's feasibility to developing countries with less financing capacity. Meanwhile, international demonstration projects can inform U.S. utilities about the veracity of next-gen safety, operating and economic claims. The U.S. government should support foreign demonstration projects with diplomatic protocols and financing geared to harvesting learnings for the U.S. market.

- There are clearly more obstacles in the U.S. to new nuclear's participation in the Transition. U.S. utilities' ability to deliver sufficient new nuclear projects face many obstacles. Foremost among these are problematic economics, especially in the geographically extensive merchant power markets. If next-gen reactor projects produce cost results like those of recent LWR projects, a U.S. new nuclear renaissance could prove stillborn. Restructuring merchant power markets to incentivize capacity, resiliency and low carbon power would go far towards expanding the U.S. market for new nuclear. Existing capacity markets, like that in PJM, do not at present provide such incentives.

- There exist several other ways for next-gen nuclear's economic challenges to be mitigated. Two of these can be undertaken by U.S. companies: 1) plan next-gen nuclear projects at utility 'brownfield sites;' and 2) undertake international projects in locations where public policy and regulatory regimes are supportive. The third option, a Nuclear Portfolio Standard, requires action by states and/or the federal government.

- Nuclear utilities should evaluate and publicize the economic advantages of demonstrating next-gen reactors at 'brownfield' sites. Some are existing nuclear plants originally designed for more reactors than were built. Others are closed LWR or coal-fired plant sites. These sites offer many benefits:

  1. They already enjoy site approvals covering a range of issues from geologic soundness to community acceptance
  2. They can become repurposed locations capitalizing on existing installed infrastructure, e.g., transmission lines, control buildings, etc.
  3. Site prep, including access roads, logistics and utilities, may be in place

Here it is worth noting that Terra-Power's next-gen demonstration project will be at a Wyoming coal plant site. Brownfield sites could materially lower the capital needed for the initial at-scale next-gen reactor projects. This may assist such projects to demonstrate the economic viability needed to encourage utility commitments to the further projects needed to coax a supply chain into being.

- Undertaking international projects is the second way for next-gen reactors to encourage a U.S. supply chain to develop. Here we would note the activity of firms like NuScale and the interest of governments in Poland and Romania in a U.S.-backed next-gen product. The NRC but also agencies, like the State Department and DOE should work to support the leading next-gen reactor technologies so they can compete for business with a U.S. approved package of operating, safety and non-proliferation rules.

- A Nuclear Portfolio Standard (NPS) lodged inside a broader Clean Energy Standard (CES) would be a third way to help next-gen reactors buildout a supportive supply chain. Such a standard would operate much like the Renewable Portfolio Standards, i.e., it would require a certain percentage of new low carbon generation to be nuclear. As a subset of a broader CES, it could be targeted initially towards utilities in regulated markets or merchant markets with adequate capacity and zero carbon pricing structures.

- To deal with the nuclear waste issue, the industry and the NGO community should explore whether consensus environmental law overseen by a federal agency can be achieved for waste repository sites. To date, attempts to craft such law have failed to achieve either consensus or legislative passage. That said, an emerging consensus that new nuclear may be needed for climate strategy could pave the way for more fruitful negotiations on waste. Recent efforts to define geologic secure storage for captured CO2 have achieved some results. If such law can be crafted for nuclear waste, it may enable several states to agree with the industry on new storage sites. Migrating from at-installation storage to closely regulated, multiple repositories could mitigate concerns regarding waste handling, transportation and nuclear proliferation risks.

- Finally, the nuclear utilities should, upon completion of their life-extension efforts for existing plants, publicize the conditions under which next-gen reactors would be favored as building blocs of their Net Zero plans. This would set firm targets for the next-gen reactor firms and provide a basis for supply chain providers to plan their own expansion.

Exhibits

#1

IEA Electricity Sector Outlooks, Announced Pledges and Sustainable Development Scenarios

Table A.3b: World electricity sector

	Announced Pledges Scenario (TWh)						Shares (%)			CAAGR (%) 2020 to:	
	2010	2019	2020	2030	2040	2050	2020	2030	2050	2030	2050
Total generation	**21 520**	**26 959**	**26 762**	**34 362**	**45 618**	**54 716**	**100**	**100**	**100**	**2.5**	**2.4**
Renewables	4 250	7 114	7 593	15 917	28 390	38 959	28	46	71	7.7	5.6
Solar PV	32	681	833	4 190	9 262	14 194	3	12	26	18	9.9
Wind	342	1 421	1 596	5 115	10 508	14 384	6	15	26	12	7.6
Hydro	3 446	4 236	4 347	5 080	5 975	6 852	16	15	13	1.6	1.5
Bioenergy	360	672	709	1 249	1 891	2 375	3	4	4	5.8	4.1
of which BECCS	-	-	-	47	284	443	-	0	1	n.a.	n.a.
CSP	2	13	13	78	359	589	0	0	1	20	14
Geothermal	68	91	94	190	331	449	0	1	1	7.3	5.3
Marine	1	1	1	15	63	115	0	0	0	27	16
Nuclear	2 756	2 790	2 692	3 282	4 040	4 449	10	10	8	2.0	1.7
Hydrogen and ammonia	-	-	-	100	376	517	-	0	1	n.a.	n.a.
Fossil fuels with CCUS	-	1	1	131	1 152	1 729	0	0	3	74	31
Coal with CCUS	-	1	1	43	804	1 113	0	0	2	56	29
Natural gas with CCUS	-	-	-	89	348	616	-	0	1	n.a.	n.a.
Unabated fossil fuels	14 480	17 019	16 440	14 899	11 627	9 029	61	43	17	-1.0	-2.0
Coal	8 671	9 911	9 467	7 926	5 779	3 047	35	23	6	-1.8	-3.7
Natural gas	4 843	6 356	6 257	6 522	5 488	5 691	23	19	10	0.4	-0.3
Oil	966	752	716	450	361	291	3	1	1	-4.5	-3.0

Exhibits

#1

IEA Electricity Sector Outlooks, Announced Pledges and Sustainable Development Scenarios - continued

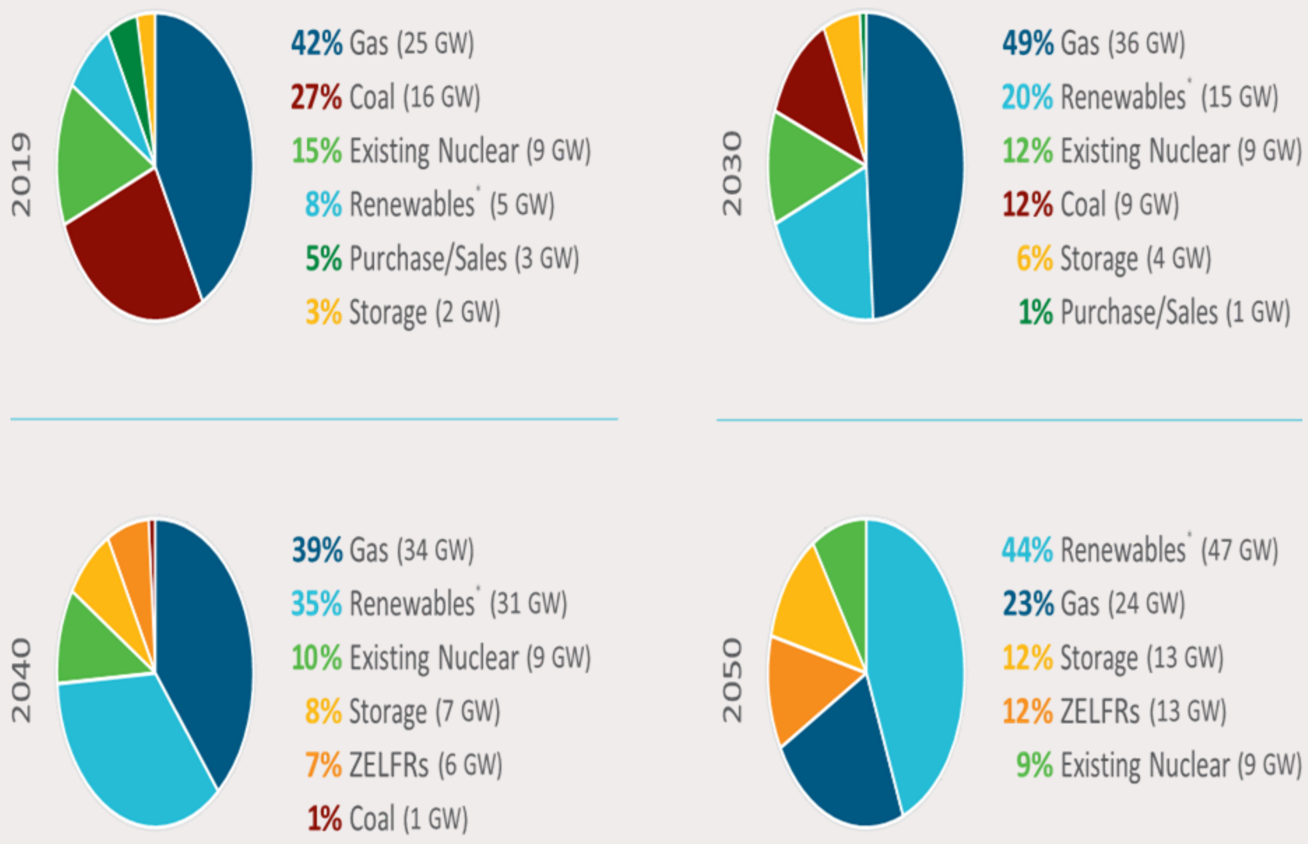
Table A.3c: World electricity sector

	Sustainable Development Scenario (TWh)						Shares (%)			CAAGR (%) 2020 to:	
	2010	2019	2020	2030	2040	2050	2020	2030	2050	2030	2050
Total generation	21 520	26 959	26 762	34 424	45 885	57 950	100	100	100	2.5	2.6
Renewables	4 250	7 114	7 593	18 283	34 349	48 436	28	53	84	9.2	6.4
Solar PV	32	681	833	4 989	11 273	17 433	3	14	30	20	11
Wind	342	1 421	1 596	6 115	12 817	17 577	6	18	30	14	8.3
Hydro	3 446	4 236	4 347	5 387	6 599	7 921	16	16	14	2.2	2.0
Bioenergy	360	672	709	1 362	2 336	3 199	3	4	6	6.8	5.2
of which BECCS	-	-	-	42	328	593	-	0	1	n.a.	n.a.
CSP	2	13	13	129	717	1 377	0	0	2	26	17
Geothermal	68	91	94	284	538	801	0	1	1	12	7.4
Marine	1	1	1	16	69	129	0	0	0	28	16
Nuclear	2 756	2 790	2 692	3 395	4 293	4 714	10	10	8	2.3	1.9
Hydrogen and ammonia	-	-	-	100	389	805	-	0	1	n.a.	n.a.
Fossil fuels with CCUS	-	1	1	323	1 480	1 790	0	1	3	91	31
Coal with CCUS	-	1	1	226	1 019	1 046	0	1	2	84	29
Natural gas with CCUS	-	-	-	97	460	744	-	0	1	n.a.	n.a.
Unabated fossil fuels	14 480	17 019	16 440	12 290	5 341	2 172	61	36	4	-2.9	-6.5
Coal	8 671	9 911	9 467	5 618	1 559	42	35	16	0	-5.1	-17
Natural gas	4 843	6 356	6 257	6 345	3 610	2 011	23	18	3	0.1	-3.7
Oil	966	752	716	327	172	119	3	1	0	-7.5	-5.8

Exhibits

#2

Duke Energy 2020 Study for Net Zero 2050.
Duke Energy Regulated Generating Capacity, GW



Renewables include hydro, wind, solar, landfill gas, biomass, etc.

Exhibits

#2

Duke Energy 2020 Study for Net Zero 2050 - continued.

Duke Energy Regulated Generating Capacity, GW

Zero-Emitting Load-Following Resources

Our analysis makes it clear that advanced very low- or zero-emitting technologies that can be dispatched to meet energy demand are needed for Duke Energy to transition to its net-zero carbon future.

There are several technologies that could play the role of zero-emitting load-following resources (ZELFRs), such as:

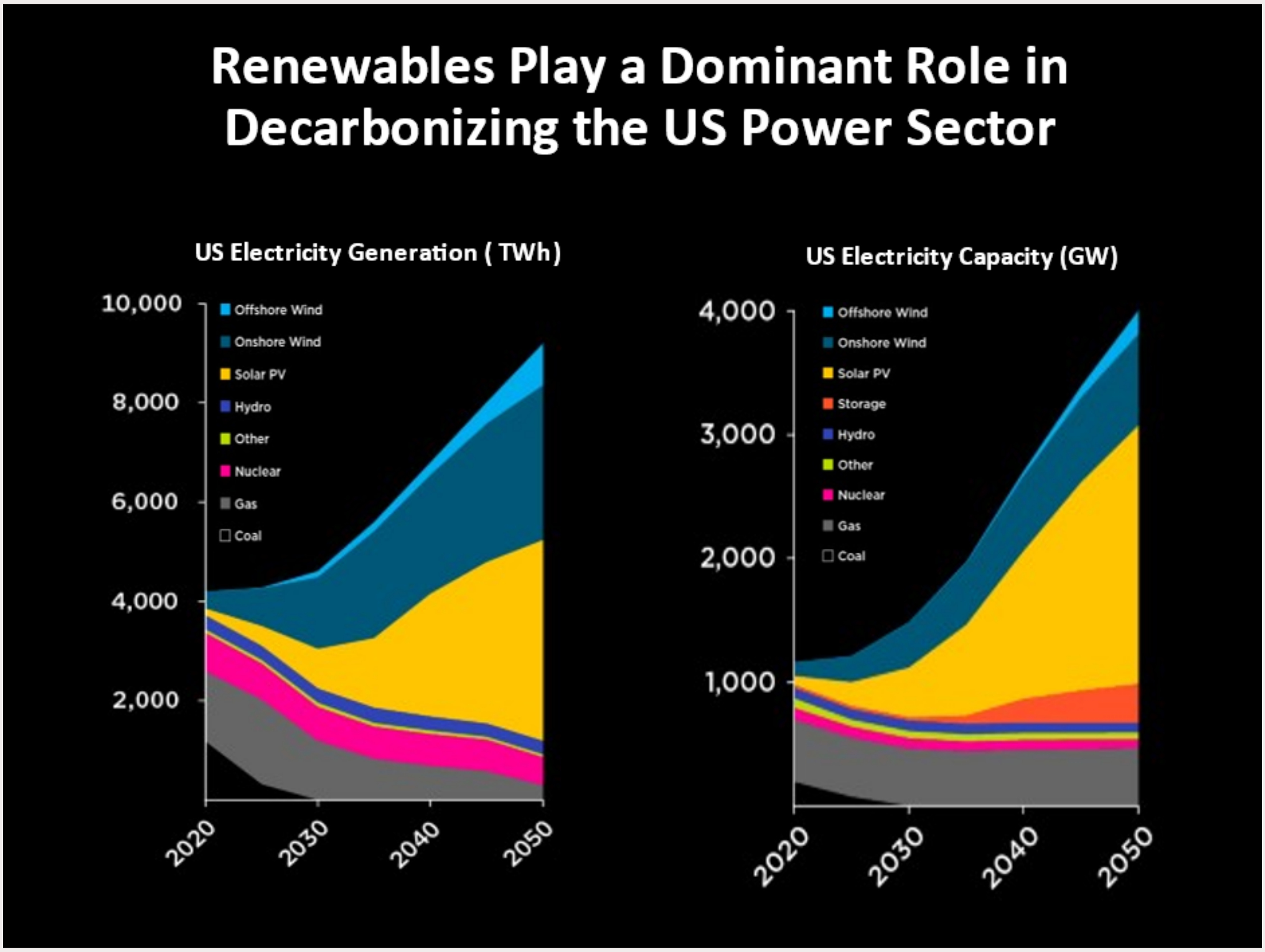
- **Advanced nuclear** – Advanced nuclear includes a wide range of small modular light-water reactors (SMRs) and advanced non-light-water reactor designs. Small modular light-water reactors are closest to commercial deployment, with early designs targeting commercial operations in the mid-to-late 2020s. Advanced non-light-water reactor concepts are also under development and are expected to be commercially available in the 2030s.
- **Carbon capture, utilization and storage (CCUS)** – CCUS technologies for the power sector are in the early stages of deployment, with a few small-scale projects on coal having achieved commercial operation and several natural gas projects currently in development, spurred by the 45Q tax credit, which provides an incentive for utilizing or storing captured CO_2. Demonstration of CCUS at scale for natural gas power plants is an important milestone for commercial deployment in the power sector, as is building public, environmental and regulatory confidence around the transportation of captured CO_2 and its utilization and geologic storage.
- **Hydrogen and other gases (including renewable natural gas)** – Hydrogen and other low- or zero-carbon fuels are increasingly gaining attention for their potential to contribute to a net-zero carbon grid. For example, many existing natural gas turbines are already capable of co-firing hydrogen, and vendors are focused on developing models capable of firing 100 percent hydrogen. Key opportunities include costeffectively producing hydrogen (or other gases, including renewable natural gas) from very low- or zerocarbon processes and ensuring safe and effective methods of transportation.
- **Long-duration energy storage** – Long-duration energy storage includes a wide range of thermal, mechanical and chemical technologies capable of storing energy for days, weeks or even seasons, such as molten salt, compressed/liquefied air, sub-surface pumped hydro, power to gas (e.g., hydrogen, discussed above) and advanced battery chemistries. These technologies are at various stages of research, development, demonstration and early deployment

Other technologies will also be important. We continue to explore pumped storage hydro opportunities (a mature technology), as well as advanced renewables (such as offshore wind and advanced geothermal and solar), energy efficiency and demand response.

Exhibits

#3

Generation Mix in U.S. Deep-Decarbonization Study



Exhibits

#4 ***Benefits Promised by Small Modular Reactors***

Only SMR Design Approved by the NRC

NuScale's technology is the only U.S. NRC approved design with the following features:

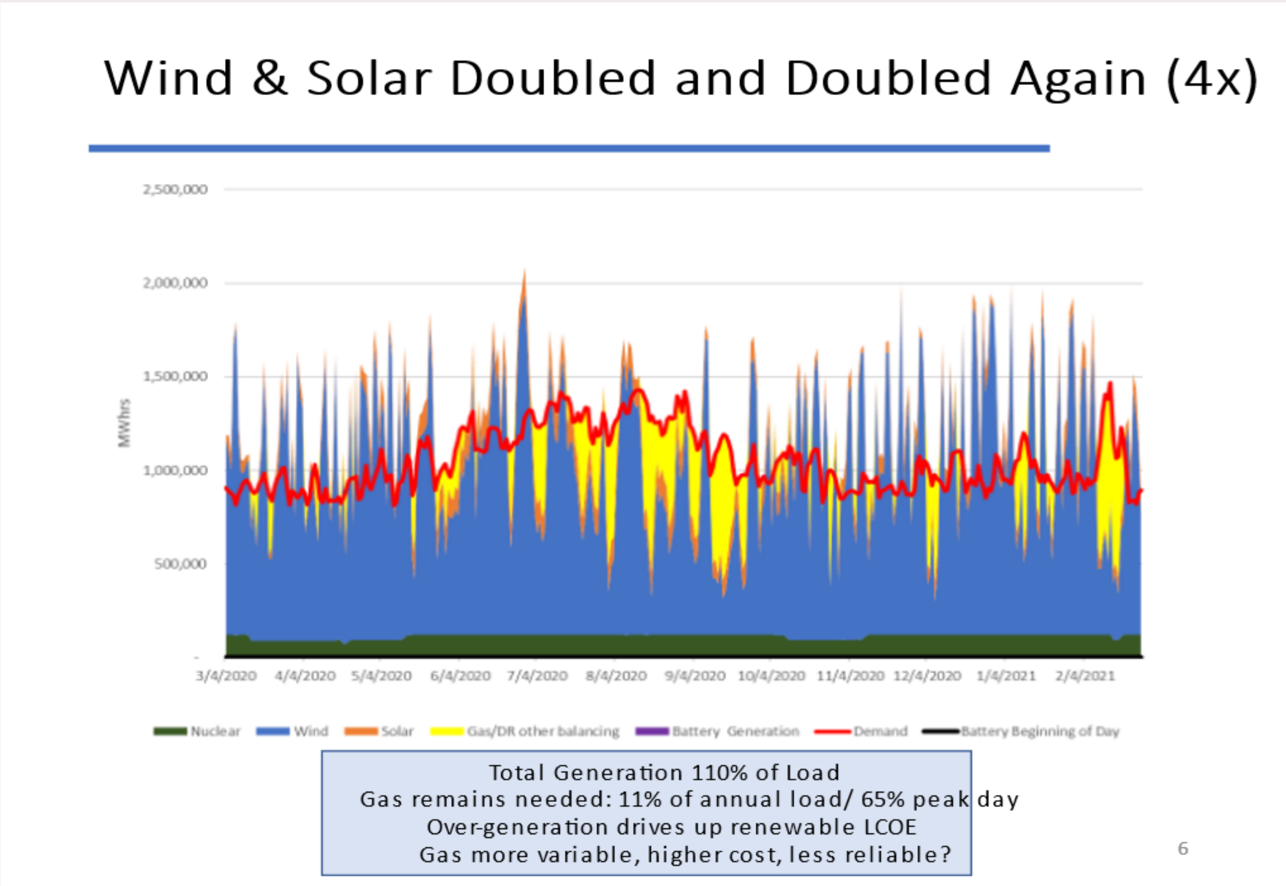
- No operator action, or AC/DC power needed to shut down reactors and no need to add water to keep reactors safe for an unlimited time.
- No connection to the grid required for safety.
    - Permits siting at "end of line"; distributed generation applications, coal plant repurposing.
- Island mode operation capable
    - **Regulations permits "off-grid" operation** - A very important feature for providing reliable power and process heat to industrial applications.
- Black-start capability.
- Three modes of load following.
- First responder power for severe weather events.
- Capable of achieving site boundary EPZ.

Exhibits

#5

Projected Buildout of Texas Renewables and Implications for Natural Gas Plant Operations.

Presented 3/22 to Texas Energy Bar Association by Chris Vlahoplus, former head of Scott Madden Clean Tech and Sustainability practice

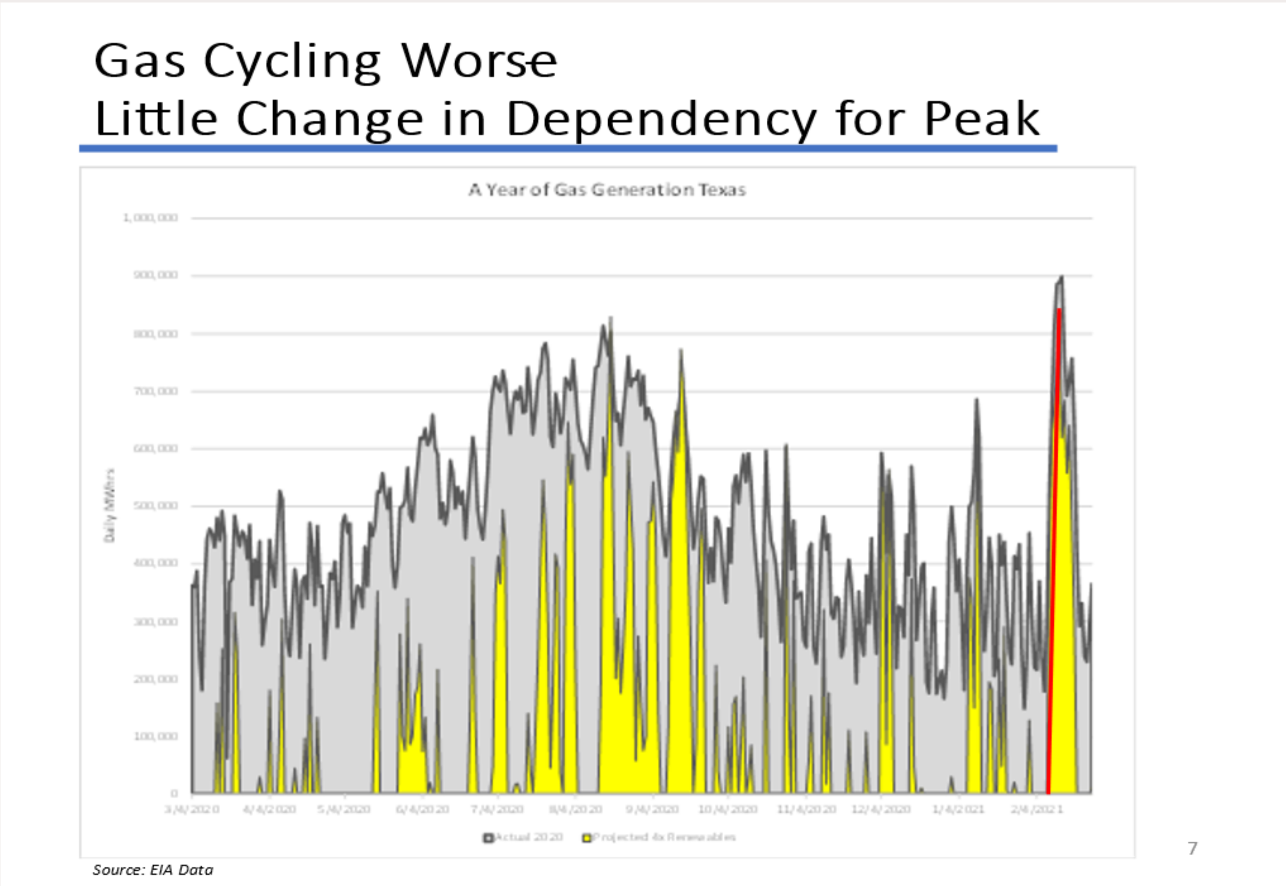


Exhibits

#5

Projected Buildout of Texas Renewables and Implications for Natural Gas Plant Operations- continued.

Presented 3/22 to Texas Energy Bar Association by Chris Vlahoplus, former head of Scott Madden Clean Tech and Sustainability practice



Conference on New Nuclear Power and Climate Strategy

Program

WEDNESDAY, Nov 17

3–7:00 PM	CHECK IN AND CONFERENCE REGISTRATION	
7:30 PM	ICEBREAKER RECEPTION @ RIZZO CENTER	

THURSDAY, Nov 18

8:00 AM	WELCOME REMARKS	Stephen Arbogast Director, UNC Kenan-Flagler, Energy Center
8:15 AM	Keynote Address I	Nuclear as an Essential Part of Climate Policy
8:45 AM	Keynote Address II	• Reasons for skepticism that nuclear can make a material contribution to de-carbonization • What issues need to be addressed?
9:15 AM	Framing the Discussion	• How to progress a nuclear dialogue • Status of discussion on policy initiatives
9:30 AM	BREAK	
10:00 AM	Speaker	• Why we stopped building new plants • Nuclear market structure issues • Nuclear's role in Duke 2050 'Net Zero'
10:45 AM	Speaker	• The Nuclear Dilemma Today • Policies/conditions for avoiding early plant closures & Nuclear's longer term role in national climate strategy
11:15 AM	Panel Discussion	Can de-carbonization of electricity be achieved without new nuclear?
12:00 PM	LUNCH BREAK	
12:45 PM	Luncheon remarks	New Nuclear, Climate Strategy, Necessary Innovation
1:45 PM	Panel Discussion	• Nuclear's other historic concerns: security • Waste & proliferation – showstoppers or risk management challenges?
2:30 PM	Scholars Report	"US nuclear regimes vs. Other Countries"
3:00 PM	BREAK	
3:15 PM	How we regulate Nuclear Today	• New Nuclear licensing, operations • What went right/wrong with CFR52-103; new regime of SMRs?
4:00 PM	Discussion & Dialogue	Nuclear Licensing & Economics

4:30 PM	Can we still build New Nuclear?	• Is it possible to rebuild U.S. Nuclear Execution capability? • Would SMRs help?
5:15 PM	Summary	Issues for Discussion
5:30 PM	ADJOURN & RECEPTION	
7:00 PM	SPEAKER'S DINNER – Thursday, Nov 18	
	After-dinner Remarks	• What's involved in building 'New Nuclear' • What lessons from recent efforts; needed reforms • Will only SMRs/ARs be built from now?

FRIDAY, Nov 19

6h30 – 7:45	BREAKFAST in DuBose House, The Rizzo Center	
8:00 AM	'Net Zero'	A 'Net Zero' Utility looks at SMRs/ANRs as a possible source of "Zero emissions-load following Resources' (ZELFRs) & Brownfield site New Nuclear economics
8:45 AM	New Nuclear Technologies	• What are the New Nuclear Technologies? • Small Modular Reactors • Advanced Reactors • Implications & commercialization status
10:00 AM	BREAK	
10:20 AM	Issues with Advanced & SMRs	Issues facing Advanced and Small modular Nuclear reactors: security, waste, safety & economic risks
11:10 AM	Frame & Debate	The pros and cons of SMRs & ANRs
12:00 PM	LUNCH BREAK	
1:00 PM	Q&A Survey	'Truth or Fiction' An exercise in the Facts about Nuclear Energy, Historic & Risks, & the current level of U.S. activity
1:45 PM	Tradeoffs #1	SMRs/ANRs what regulatory changes/exemptions tied to what cost saving do they need to become economic?
3:00 PM	BREAK	
3:15 PM	Tradeoffs #2	What changes are needed in power market models, price structures for SMRs/ARs to be economically viable at scale? How do these differ for merchant vs. regulated markets?
4:15 PM	Possible Paths Forward	Moderator poses Questions
5:00 PM	Summing Up	• Key Issues for the future • Possible Action Program and Next Steps
5:30 PM	ADJOURN	

FEATURED SPEAKERS

Stephen Arbogast
UNC Kenan-Flagler Energy Center - Director

The author of "Resisting Corporate Corruption: Cases in Practical Ethics from Enron through the Financial Crisis" (Wiley, 2017). His Exxon career spanned 32 years & included assignments as finance manager of Esso Brasileira, treasurer of Exxon Capital Corporation & finance director of Esso Standard Thailand. He received a master's degree in public affairs from the Woodrow Wilson School of Public and International Affairs at Princeton University, his BA in government from Cornell University & a master's degree in theological studies from the University of St. Thomas, Houston

Dan Domeracki
UNC Kenan-Flagler Energy Center

Dan serves as Associate Director for the Energy Center. He retired from Schlumberger with 41 years of global industry experience. As a member of Schlumberger's corporate team, he was responsible for Schlumberger's government affairs program, managing the non-lobbying, non-political, interactive working relationships with governments in North America, Europe & Asia Pacific. Dan was also responsible for building Schlumberger Global Stewardship

Steve Koonin
NYU, former Under Secretary of Energy

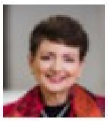
Steven Koonin, a University Professor at NYU, he served as Under Secretary for Science at the U.S. Dept of Energy, as Chief Scientist for BP, and professor at Caltech. He is member of the U.S. National Academy of Sciences and the JASON group of government advisors, a Governor of Lawrence Livermore National Laboratory, and a Trustee of the Institute for Defense Analyses. He holds a BS in physics from Caltech and a Ph.D. in theoretical physics from MIT

M.V. Ramana
University of British Colombia

The Simons Chair in Disarmament, Global and Human Security and Director of the Liu Institute for Global Issues at the School of Public Policy and Global Affairs, University of British Columbia. Ramana is a member of the International Panel on Fissile Materials, the Canadian Pugwash Group, the International Nuclear Risk Assessment Group, and the team that produces the annual World Nuclear Industry Status Report.

Scott Tinker
BEG

Scott Tinker works to bring industry, government, academia, and nongovernmental organizations together to address major societal challenges in energy, the environment, and the economy. He is Director of the Bureau of Economic Geology, the State Geologist of Texas, holds an endowed chair at UT at Austin, and is a filmmaker. In his visits to some 60 countries, he has given over 900 keynote and invited lectures.



Lynn Good
Duke Energy

Chair, president and chief executive officer of Duke Energy, one of America's largest energy holding companies. Duke Energy is executing an aggressive clean energy strategy to achieve its ambitious climate goals – at least a 50% carbon reduction by 2030 and net-zero carbon emissions by 2050. Good currently serves on the boards of directors for Boeing, the Edison Electric Institute, the Institute of Nuclear Power Operations, the World Association of Nuclear Operators, the Business Roundtable, myFutureNC and New York City Ballet

Steve Clemmer
Union of Concerned Scientists

As director of energy research for the Climate and Energy program, Steve conducts research on the economic and environmental benefits of implementing renewable energy technologies and policies at the state and national levels. He directs UCS research on coal, natural gas, and nuclear power, and on solutions to reduce carbon emissions and water use in the electricity sector.

Bradley Staats
UNC Kenan-Flagler Business School

Bradley Staats is a professor at the University of North Carolina Kenan-Flagler Business School and best-selling author of *Never Stop Learning: Stay Relevant, Reinvent Yourself, and Thrive*. He is the Associate Dean of MBA Programs and Faculty Director of the UNC Center for Business and Health. His research and teaching focus on learning, healthcare and analytics

FEATURED SPEAKERS

Elgie Holstein
Environmental Defense Fund

As Senior Director for Strategic Planning, Elgie works on energy, natural resources, and environmental policy. He has previously worked in senior positions at the White Office of Management and Budget, the National Economic Council, NOAA, DOE, and the Obama transition team. He also has worked as a congressional staffer and as a consultant to local governments, the FBI and the U.S. Army

Preston Gillespie
Duke Energy

Preston is senior vice president & chief generation officer for Duke Energy, responsible for integrating & advancing the company's nuclear, fossil, hydro & regulated renewable generation strategies to support Duke Energy's 2050 net-zero carbon emissions goal. A mechanical engineer, he has over 30 years' experience in the industry. He is a registered professional engineer in South Carolina & previously held a senior reactor operator license for Oconee Nuclear Station

Joe Hezir
Energy Futures Initiative (EFI)

As Executive Vice President of EFI, Hezir leads key research projects including reports examining federal support for carbon dioxide removal (CDR) research technologies; the US nuclear enterprise and its key role in national security, and white papers on the Dept. of Energy's budget priorities and federal tax incentives for energy innovation. He serves on the Advisory Board of the Scott institute of Energy Innovation at Carnegie Mellon University

Geoff Fettus
NRDC

As Senior Attorney Geoff litigates in federal courts & testifies before Congress on the beginning & end of the nuclear fuel cycle. Key cases include the "Waste Confidence" victory over the Nuclear Regulatory Commission in the United States Court of Appeals for the D.C. Circuit and the successful challenge to the Environmental Protection Agency's radiation protection standards for the proposed Yucca Mountain nuclear waste repository. He is a graduate of the University of Wisconsin Law School and Haverford College

Bob Perciaseppe
C2ES - Senior Advisor

Bob served as Deputy Administrator of the U.S. Environmental Protection Agency (EPA) he has built a reputation for bringing stakeholders together to solve issues. He also joined the National Audubon Society, as senior vice president for public policy. He served as Secretary of the Environment for the state of Maryland and as a senior planning official for the city of Baltimore. He holds a master's degree in planning & public administration from the Maxwell School of Syracuse University and a Bachelor of Science degree in natural resources from Cornell University

Rod Ewing
Stanford University

Professor of Nuclear Security and Co-Director of the Center for International Security and Cooperation at Stanford University. Rod has written extensively on issues related to nuclear waste. Appointed by President Obama to chair the Nuclear Waste Technical Review Board, which provides scientific and technical reviews of the U.S. Department of the Energy's programs for the management and disposal of spent nuclear fuel and high-level radioactive waste

Chris Levesque
TerraPower

President and chief executive officer of TerraPower. Levesque leads this nuclear innovation company in the pursuit of next-generation nuclear energy solutions and oversees TerraPower's new venture into therapeutic medical isotopes. His proven track record in scoping, planning and implementing complex projects began with his service in the U.S. Nuclear Navy and features more than 30 years of experience in the nuclear field

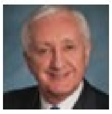
Chris Vlahoplus
ScottMadden

Chris serves as advisor & liaison for key relationships. Prior this, Chris had been a management consultant to the energy & utility industry for 28 years. He led ScottMadden's clean tech & sustainability practice area for six years, including a role as co-leading the firm's nuclear consulting practice. Chris worked in nuclear safety at Duke Power Company. He earned a B.S. in mechanical engineering for the University of South Carolina, an M.S. in nuclear engineering from MIT and a M.B.A. from UNC, Chapel Hill.

FEATURED SPEAKERS

Nathaniel Margolies
UNC Kenan Flagler Energy Center Scholars

An investment advisor at Goldman Sachs, he advises wealthy individuals, family groups, and non-profit organizations. He graduated cum laude from Washington University in St. Louis with a BA in both Chemistry and Economics. Additionally, he holds an MBA from the University of North Carolina where he served as Chair of the Graduate and Professional Schools Honor System and researched as a Kenan Energy Scholar



Dale Klein
Nuclear Regulatory Commission (NRC) – Former Chairman

Sworn into the U.S. NRC & appointed Chairman by President George W. Bush. Dale also served as the Assistant to the Secretary of Defense for Nuclear, Chemical and Biological Defense Programs. Appointed by same President & confirmed by Senate in 2001. Currently at The University of Texas at Austin he is the Associate Director of The Energy Institute, Associate Vice President for Research and Professor of Mechanical Engineering (Nuclear Program)

Dan Dorman
Nuclear Regulatory Commission (NRC) - DED

Dan Dorman is the NRC's 12th Executive Director for Operations. He has served in senior management positions at the NRC for over twenty years in research, security, fuel cycle and reactor safety programs and as regional administrator. Before joining NRC in 1991, he served as a Navy submarine officer

Scott Brown
Exelon Corporation

Former Vice President, Strategic Initiatives, Brown led a group responsible for analysis of key Federal, state, retail and wholesale energy policy issues, support of significant state and market initiatives and serves as a resource on energy business efforts and emerging commercial matters. Over 35 years of industry experience working with utilities, generators, government officials, non-governmental organizations and trade associations

Peter Bradford
Nuclear Regulatory Commission (NRC) – Former Commissioner

Peter Bradford is a Vermont Commissioner on the Texas/Vermont Low Level Radioactive Waste Compact Commission. He has been a commissioner on the U.S. Nuclear Regulatory Commission & has chaired the New York and Maine utility regulatory commissions. He has taught nuclear power and energy policy courses at Yale and at Vermont Law School

Maria Korsnick
Nuclear Energy Institute (NEI)

Maria Korsnick is president and CEO of the Nuclear Energy Institute. She works to increase understanding of nuclear energy's economic, environmental, and national security benefits among policymakers and the public. She began her career at Constellation Energy and holds a bachelor's degree in nuclear engineering from the University of Maryland

Ed Finley
Nuclear Regulatory Commission (NRC) – Former Commissioner

Ed currently practices Law in Raleigh for clients in utility related matters. He served as Chairman of the North Carolina Utilities Commission. While there he served as First Vice President, as a member of the Executive Committee and Chair of the Electricity Committee of the national Association of Regulatory Commissioners. He also served on the Advisory Council the Board of Directors of the Electric Power Research Institute

Michael McBride
Van Ness Feldman

Michael is a partner with Van Ness Feldman & heads the firm's nuclear practice and has practiced in nuclear law & licensing for over 40 years. He also represented several U.S. electric utilities in litigation with the railroads over the obligation to carry spent nuclear fuel and radioactive waist. More recently he served as counsel to Blue Ribbon Commission on America's Nuclear Future. He advises various entities on nuclear transportation and liability issues.

Ed Lyman
The Union of Concerned Scientists

Edwin is the Director of Nuclear Power Safety at the Union of Concerned Scientists in Washington, DC. He earned a doctorate in physics from Cornell University in 1992. He is a co-author (with David Lochbaum and Susan Q. Stranahan) of the book *Fukushima: The Story of a Nuclear Disaster* (The New Press, 2014). He is the recipient of the 2018 Leo Szilard Lectureship Award from the American Physical Society

FEATURED SPEAKERS

Jeff Lyash
Tennessee Valley Authority

President and Chief Executive Officer of the Tennessee Valley Authority, the nation's largest public utility. TVA operates one of the nation's largest, most diverse energy fleets. Jeff previously held leadership roles with Ontario Power Generation, CB&I Power, Duke Energy and Progress Energy. He also worked for the Nuclear Regulatory Commission and held a senior reactor operator license

Jeffrey Merrifield
Nuclear Regulatory Commission (NRC) – Former Commissioner

Former presidential appointee to the NRC, Jeff is a partner and leader to the Pillsbury's prestigious Nuclear Practice. He advises his clients with a unique perspective on strategic problem-solving given his wide-ranging experience. He utilizes the broad experience he has gained over 30 years having worked as an attorney in the U.S. Senate and as a senior non-legal executive at the larger power engineering and construction company in the US

Jane Nakano
Center for Strategic and International Studies (CSIS)

As Senior Fellow in the Energy Security and Climate Change Program at CSIS her research include U.S. energy policy: global market and policy development concerning natural gas, nuclear energy and critical minerals as well as energy security and climate issues in the Asia-Pacific region. She testified before Congress on China's competitiveness in energy technology manufacturing and exports as well as U.S. liquefied natural gas exports.

Paula Sims
Pinnacle West

Paula over 30 years of leadership experience in utility and aviation industries. She recently served as a professor of the practice of organizational behavior for eight years at Kenan-Flagler Business School. She currently serves as a director for Pinnacle West Capital where she chairs the nuclear and operations committee and is a member of the governance, public policy and audit committees. She serves on the boards of McKim & Creed & Strata Clean Energy

Tom Fanning
Southern Company

Chairman, president, and CEO of Southern Company, America's premier energy company. His experience covers more than 40 years and includes roles in finance, strategy, international business development, and technology. Mr. Fanning is tasked with securing the grid as co-chair of the Electricity Subsector Coordinating Council and a member of the Cyberspace Solarium Commission

John Hopkins
NuScale Power

Chairman and CEO of NuScale Power, LLC, a leading U.S.-based advanced small modular reactor technology development company. Prior to joining NuScale in 2012, Hopkins was with Fluor Corporation since 1989. Hopkins held numerous leadership positions in both global operations and business development. John served as a corporate officer from 1999 until 2012

David Hill
Terrestrial Energy USA

David Hill is CTO/Director of Terrestrial Energy USA and a Director of Terrestrial Energy Inc. He retired as the Deputy Laboratory Director for Science & Technology at the Department of Energy's Idaho National Laboratory in 2012 and previously held senior positions at Oak Ridge National Laboratory and Argonne National Laboratory. He is a Fellow of the American Nuclear Society

Jim Kerr
Southern Company

Jim is executive vice president, chief legal officer & chief compliance office for Southern Company. He oversees the legal, corporate governance, audit & compliance functions. Kerr also coordinates the company's approach to ESG issues & engagement with institutional investors & other stakeholders on ESG and related matters. He was a member of the NC Utilities commission for 8 years and served as president of the National Association of Regulatory utility Commissioners.

Our Center strives to advance sound, conscientious and innovative leadership in the energy space through comprehensive programming for UNC Kenan-Flagler students

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