Rescuing U.S. Merchant Nuclear Power: Advancing National Security, Economic, Energy, and Environmental Imperatives

U.S. merchant nuclear plants face reduced revenues and, in some cases, cash operating losses that can lead to early and permanent closure for economic reasons. A program which leverages incremental electricity pricing support through contracts for difference can avoid these needless early retirements of vital assets.

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I. Introduction

Nuclear history can be elusive. While its role may not be as obvious today, the U.S. remains a recognized pioneer in the civil nuclear power industry, largely as a result of its historic development of the very nuclear technologies that have been and are being used safely and effectively around the world.[1] This national commitment, and the corresponding national investment (by U.S. taxpayers) over decades, produced a sophisticated, highly successful sector and a substantial U.S. nuclear power plant fleet – the largest number of currently operating nuclear units in any nation. Paralleling our leadership in the commercialization of nuclear innovation, the U.S. nuclear industry has been a global leader in optimizing commercial nuclear plant operations, with U.S. nuclear power plants regularly achieving world-record capacity factors (translating to

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millions of megawatt-hours in baseload, carbon-free electricity), while meeting ever-more comprehensive safety standards.[2] Nuclear plants provide more than electricity, and the national security benefits that a secure electric system confers, however.[3] Operating nuclear power plants are staffed by educated, well-paid workforces that contribute to, and in some cases define, the vibrant local and regional communities surrounding the stations. These benefits are clear, direct, and in some instances essential to local and regional economies.[4] Even acknowledging the realities of anti-nuclear sentiment that has waned over time (but not disappeared), there is no credible dispute that U.S. nuclear power plants also are a major force in advancing carbon-free electricity generation – a core mission for those committed to arresting climate change.[5]

Despite these salient benefits, the U.S. nuclear sector, particularly the merchant nuclear sector, recently has faced unanticipated setbacks. This article addresses one setback too significant to ignore: the contribution of unanticipated electricity market conditions to the premature retirements of nuclear power plants with existing useful lives. Specifically, the restructuring of electricity markets has led to a devaluation of long-term, stable-cost, baseload generation, particularly from nuclear power plants. In these electricity markets, nuclear power plants experience reduced revenues and, in some cases, cash operating losses. It is no surprise that, under these circumstances, some owners have decided to permanently retire operating nuclear power plants that otherwise would have continued to provide needed baseload, carbon-free electricity and a host of other benefits during their initial and license renewal periods.

There is no credible dispute that U.S. nuclear power plants are a major force in advancing carbon-free electricity generation.

In Section II, we discuss the evidence that merchant nuclear power plants are at risk in 2014 and beyond. In that section, we also discuss the non-trivial ramifications of premature retirements of operating nuclear power plants. Once the problematic dynamic for existing merchant nuclear power is explained, and the serious risks of loss of the units are identified (in Section III), action becomes a priority. In Section IV, we outline our proposed remedy of the problematic dynamic identified in Section II, a remedy that avoids further closures of operating nuclear power plants. We believe it is an accessible, elegant, and efficient proposal, one that we expect an Administration to attend to national interests and embrace. Section V is our wrap-up.

II. The Risk to Merchant Nuclear

In this section, we outline some of the key factors that have placed merchant nuclear power plants at risk. We then focus on identifying the problems these facilities face (e.g., negative cash flow) in order to tailor a functional and effective solution.

A. Background on electricity markets

Conceptually, restructured or deregulated electricity markets[6] were designed to provide price signals to facilitate efficient, market-based dispatch of existing generation in the short term, and to incentivize rational investment in new generation in the long term. A premise of deregulation was that demonstrated success in certain bellwether markets, e.g., New York and California, would lead to fairly rapid adoption of deregulated systems on a nationwide basis, with the result that relative parity among the 50 state electricity markets would exist over time.

With more than a decade of hindsight, the promise of deregulation has proved ephemeral, and the realities of market-based systems far more

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problematic than we anticipated. Deregulated markets may work in the short-term *for electricity consumers* by dispatching electricity generated by existing units in a mostly affordable manner, but the evidence is increasingly clear that deregulated markets have failed to meet the long-term investment needs of the industry and therefore future consumer demand.[7] Certainly, electricity markets have tended to focus on short-run marginal costs to consumers, and not properly incentivized long-term investment, particularly in baseload generation. What this means – in real terms – is that existing markets *appear* to function because of historic regulated capacity planning, but lack the ability to encourage or deliver future functionality and affordability. Likewise, because the expected national rollout did not occur, market parity between and among states does not exist. This latter dynamic has served to emphasize the shortcomings of deregulated markets and the challenges facing the power plants operating within those markets.

Understanding how electricity markets work is important to fully appreciating the disproportionate impacts that these markets have had on merchant nuclear facilities. Most electricity markets, by design, reduce electricity to a short-term fungible commodity – a market good. The electricity markets clear bids associated with this commodity in the short term (e.g., 15 min, an hour, or 24 h), with the objective of minimizing short-run marginal costs within existing electric system constraints, relegating reliability to ancillary services. This short-term market signal – that is, rewarding short-term bidding behavior – critically depends on the existence of a functional network of generation assets that have been developed and owned with a long-term focus. Because regulated markets materialized under conditions that already had benefited from past long-term planning (under regulated incentives), the importance of and need for long-term planning are masked. As a result, system operators have had the luxury of presuming that system functionality was a given, because past regulated decision-making had made it so.

The evidence is increasingly clear that deregulated markets have failed to meet the long-term investment needs of the industry.

In the future, however, system operators will not be so fortunate. It is clear that short-term electricity market price signals have not provided incentives for long-term generation capacity investments, which are not valued in the bidding process. Indeed, the problem is as widely discussed (''missing money'' in industry parlance), as it is intractable – on a global basis.[8] The historic long-term generation planning process undertaken by vertically integrated electricity utilities – and the state commissions that oversaw these utilities – that secured the system, because it is not valued, has not been perpetuated over the last decade. Thus, for instance, it is not uncommon for peaking facilities – those that function only when the market price is high enough – to dominate the new generation pipeline in deregulated markets, an indication that the market signal encourages short-term profit optimization or skimming, not long-term reliability planning. Without sufficient incentives to construct new baseload generation, system reliability and affordability can only falter. As the global economic downturn recedes in the nation's rearview mirror (particularly in New York and California), this dynamic is episodically evident at periods of peak demand where existing installed generation capacity is marginally insufficient to meet electricity needs, with the result that system reliability flags and prices rise; while the causes and antidote remain debatable, the existence of the dynamic, although not its magnitude, is certain.[9]

While perhaps less obvious, the commoditizing of electricity also has inadvertent, but serious,

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adverse effects on some of the existing generation portfolio, particularly merchant nuclear power plants. By commoditizing electricity, electricity markets obfuscate salient differences among differing generation sources, e.g., fuel type, decommissioning benefits, air quality considerations, carbon emissions, and employment considerations. This means that differential carbon emissions, for instance, are not addressed through electricity markets, and therefore must be addressed in other ways, such as through new carbon legislation or environmental regulation, in order to send signals regarding preferred generation attributes and pricing. It also means that out-of-market subsidies, particularly those undertaken on a piecemeal basis, have the potential to distort electricity market price signals.[10]

B. Evidence of merchant nuclear failures

The evidence of the crisis facing the merchant fleet of U.S. operating nuclear power plants is as yet anecdotal, but damning. It includes the following:

- The failure of most proposed new merchant nuclear power plants that began development under the Energy Policies Act of 2005 (EPAct2005) to proceed, with the recent Comanche Peak decision as an example. Indeed, the only new nuclear projects in the U.S. (i.e., Summer and Vogtle) are regulated investments in states that declined to restructure their electricity industry and retained a traditional regulated electricity industry. Watts Bar 2 and Bellefonte are being completed by the Tennessee Valley Authority, a government utility operating outside any electricity market.
- The public announcements of the Kewaunee and Vermont Yankee nuclear power plant closures for economic reasons.

The failure of U.S. merchant nuclear projects can be viewed in stark contrast to the United Kingdom, which is implementing a significant revamp of the Great Britain electricity market.

- The announcement that a number of operating merchant nuclear power plants would delay or cancel up-rates and license renewal filings – largely because the benefits of doing so were questionable in light of the electricity markets in which these plants operate.
- The failure of the EPAct of 2005 initiative to achieve its goals of restarting the U.S. nuclear power industry.
- The maintenance-related closures of certain nuclear stations, even those in regulated markets, such as the Crystal River and San Onofre nuclear power plants, can indirectly be linked to the expected future market value of the output of these plants, had they been repaired and returned to operation.

In short, U.S. electricity markets have failed to provide, as needed, incentives for investment in new nuclear power plants in the long term, and sufficient revenue to allow continued profitable operation for existing merchant nuclear power plants in the short term. Even some regulated facilities are at risk, suggesting a fleet-wide concern.

The failure of U.S. merchant nuclear projects can be viewed in stark contrast to the United Kingdom, which is implementing a significant revamp of the Great Britain electricity market aimed at advancing merchant nuclear and other clean generation investment. As discussed below, the United Kingdom's approach is to use a long-term power support contract (known as a contract for differences) and other financial incentives for new nuclear investment to value the distinct nuclear benefits. The United Kingdom's experience underscores the appropriateness of our proposed approach, and offers a clear model for success.

C. Merchant nuclear challenges

The examples of failed merchant new facilities and economic closures in Section II.B suggest that merchant nuclear power plants face a

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disproportionate competitive disadvantage in U.S. electricity markets. This is not surprising, as merchant nuclear power plants operate under a unique set of financial and operational characteristics that make them particularly vulnerable to electricity market shortcomings.

A nuclear power plant that depends on electricity market prices for revenue may face greater market risk than a conventional power plant in the same electricity market. This is because nuclear power plant operating costs are substantial and fixed (i.e., capital cost, fixed O&M, and to a lesser extent nuclear fuel), with the result that the effective short-run marginal cost of a nuclear power plant is zero. This means that reducing output or shutting down a nuclear power plant does not reduce costs, but only reduces revenue. Accordingly, the profit-maximizing strategy for a nuclear power plant is to maximize output. This is different from a fossil-fueled power plant, which can significantly reduce total costs by reducing fuel cost by lowering output and/or temporarily shutting down. Also, unlike a nuclear power plant for which a protracted shutdown can precipitate permanent retirement, most fossil fuel power plants can be (and in fact have been) put into a low-cost mothball status for later restart.

While a full-scale review of the issues facing merchant nuclear plants is beyond the scope of this article, select key disadvantages to the nuclear sector – highlighting those related to environmental externalities and electric-system reliability that are well established as important to the American public – are summarized below, and help to explain the anecdotal evidence in Section II.B.

- Nuclear facilities internalize, through mandatory decommissioning funds sufficient to greenfield nuclear power plants at the end of their license lives, the full expected cost of post-operation site remediation. Among generation sources functioning in deregulated markets, only the nuclear sector has such requirements. Fossil fuel electricity generators, by contrast, are neither required to internalize, nor assume the substantial costs of remediating power plants sites.

Congress' disinclination to deal directly with carbon emissions has the direct effect of perpetuating the competitive disadvantage between the nuclear and fossil-fuel sectors.

- Nuclear facilities emit no material greenhouse gases in connection with their electricity generation, whereas fossil fuel facilities do. Thus, for example, natural gas – an electricity generation alternative competing with nuclear in every electricity market – nonetheless externalizes carbon emission costs by releasing carbon to the atmosphere in an uncontrolled manner. This amounts to an avoided cost for (or an indirect U.S. taxpayer subsidy to) the fossil fuel owners for the management of these emissions. Further, the U.S. Congress has declined to deal directly with carbon emissions, an omission that has the direct effect of perpetuating the competitive disadvantage between the nuclear and fossil-fuel sectors. In addition to providing no benefit to nuclear power plants for their carbon-free electricity, Congress and many states have implemented renewable subsidies that, however laudable, have the potential to distort electricity market prices (e.g., low or even negative off-peak prices).[11] Worse, an inadvertent *systemic* effect of subsidizing intermittent renewable generation is that electric systems that rely on renewable generation require load-following generation, increasingly natural-gas-fired, to redress intermittency considerations to ensure that renewable generation does not adversely impact system reliability.[12] This need for load-following generation can have the further inadvertent effect of displacing nuclear facilities which – owing to their operating costs – cannot or do not act in a load-following manner. Indeed, in some regions, preferences for intermittent renewable generation precipitate reliance on

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load-following generation that results in a net *increase* in total system carbon emissions.[13]

• Nuclear power stations, on average, each employ 500–800 people, mostly well educated, at compensation profiles that are typically better than those at other industrial and energy facilities. Indeed, one highly detailed case study, of Yankee Rowe, underscores the myriad economic, social, and cultural benefits that nuclear power plant communities experience.[14] By contrast, fossil fuel generation facilities provide minimal full-time employment compared to a nuclear power plant – ''two guys and a match'' in industry parlance. As a consequence, nuclear power plants incur a substantial workforce ''expense'' that their fossil fuel competitors do not. While this is a boon to the local communities hosting a nuclear power plant, it can place these nuclear power plants at a competitive disadvantage.

Given the market dynamic and fact that nuclear stations internalize costs that fossil facilities either do not experience or externalize, today fossil-fuel generation facilities reasonably can be said to operate in a less intrusive, and less costly, regulatory environment.

III. Preserving Merchant Nuclear Plant Benefits

Despite facing competitive disadvantages, nuclear power plants continue to provide uncompensated value above and beyond the value assigned to nuclear power plant output by short-term electricity market prices. These benefits include zero carbon emissions, increased system reliability, lower electricity cost, community benefits, and a future workforce that can support American families and ideals.

These are summarized as follows.

• Nuclear facilities help the U.S. meet environmental responsibility and climate change goals in a clear and material manner. To the extent that global climate change represents a national security and economic threat, the contribution of nuclear power deserves to be recognized and compensated.

• Nuclear power plants provide essential affordable baseload power supply, particularly in restructured markets. These nuclear power plants enhance fuel diversity and help address the downside risk of natural gas volatility and delivery system failures. Electric system reliability and affordability is enhanced by having nuclear power plants in the system. For instance, undue reliance on natural gas ties electricity system reliability to the gas transmission system – with pipeline facilities that are strained by home heating loads in cold weather,[15] oversubscribed, and aging.[16] Unrecognized baseload nuclear electricity supply should earn a premium price above short-term electricity market prices for its base load service.

• Nuclear facilities are large employers of well-compensated, educated workforces, champions of local communities and committed corporate citizens. The economic benefit from nuclear power plant employees to the local and regional economy is significant, as demonstrated by what occurs when nuclear facilities are permanently shuttered. Indeed, as the Yankee Rowe closure reflects, the Rowe Township and nearby communities rapidly sunk into economic stagnation and a form of cultural despair following Yankee Rowe's closure.[17] Indeed, the experts that performed the Yankee Rowe case study determined that closing a nuclear plant is not comparable to closing a factory or military base, and that the former nuclear communities – once uniquely prosperous and vibrant – face overwhelming losses from which they cannot recover, and will continue to decline. The experts knowing the Rowe situation considered such closures a matter of national

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significance. These local, regional, and arguably national benefits merit compensation.

- Economic closures of nuclear facilities, understandably, rattle the sector, and its considerable importance to the national economy and our global nuclear innovation leadership. The perception of sector instability – indeed, its reality – alters the long-term nuclear workforce – that is, whether students opt into nuclear education, nuclear employment and, more tangentially, our national interest in nuclear innovation.[18] Ultimately, U.S. global leadership in the sector may be adversely impacted. This global leadership is worth salvaging through targeted compensation.

IV. A Modest Proposal: Contracts for Difference

Compensatory mechanisms for merchant nuclear power plants can redress inadvertent electricity market signals and avoid the loss of the various public benefits that merchant nuclear confers. While a variety of mechanisms exist, in this section we propose that, at existing merchant nuclear power plants facing financial distress, the federal government put in place narrowly tailored contracts for differences (CfDs) as a bridge to avoid economic closures and to support future nuclear construction.[19]

What are CfDs? CfDs are well known, widely used financial mechanisms to correct inadvertent market shortcomings, e.g., the ''missing money'' problem. Here, we propose to use them to stabilize the prices received by targeted generation sources, i.e., merchant nuclear power plants, by paying the marginal price needed to preserve those generation sources. Under this approach, CfDs reduce the risks these generation sources

face for the life of the CfD contract. Through price stabilization, therefore, CfDs ensure that the targeted generation source receives a price for its power that supports continued operation and, possibly, future investment over the long term.

The mechanisms for CfDs are various and flexible, but almost universally contemplate controls to ensure that targeted goals are achieved, while minimizing the risk of windfall payments to merchant owners. Typically, for instance, a contract for differences is structured around a strike price. If the electricity market price is lower than the strike price, the generator receives payments to make up the difference between the strike price and the lower electricity market price. If the electricity market price is higher than the strike price, the generator makes payments of the difference between the strike price and the higher electricity market price. This approach, particularly levelized over time, ensures the necessary price stability and support that nuclear power plant owners currently require, but avoids windfall profits if (i.e., when) electricity market prices are higher. As a result, CfDs are more efficient (and therefore less costly) to taxpayers than flat production tax credits of the sort routinely used to encourage renewable generation.

Importantly, the legal basis for supporting merchant nuclear power plants exists and can be readily exercised. In enacting the Atomic Energy Act, Congress envisioned a complex future, one in which the Nuclear Regulatory Commission (NRC) could compensate a nuclear station owner for its operation under circumstances describe as ''a national emergency.'' Specifically, Section 108 of the Atomic Energy Act, 42 U.S.C. § 2137, states in material part: ''Whenever the Congress declares that a . . . national emergency exists . . . [t]he Commission is authorized . . ., if the Commission finds it necessary to the common defense and security, to order . . . the operation of any facility licensed under section 103 or 104, and is authorized . . . to operate such

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facility. Just compensation shall be paid for any damages caused . . . by the operation of any such facility.''

In other words, some assertion of rights by the NRC is contemplated where Congress has declared a national emergency or, consistent with subsequent law delegated that declaration power.[20] Declarations of emergency are not infrequent, can be narrowly tailored and readily implemented, subject to certain public processes. The ''national emergency'' can be variously defined, but we suggest that it be defined here as the needless loss of large-scale infrastructure that confers clear national security, economic (including global competitiveness), and environmental benefits. NRC orders for operation are contemplated and authorized, but NRC operation is not mandated; consequently, we suggest that NRC-authorized price supports fall within the spirit of Section 108 and are the preferred path. To further align with Section 108, assumptions of assumption of operation by NRC of nuclear power plants with in-place CfDs can be integrated as a condition to non-compliance with the in-place CfDs. Thus, under Section 108, the precept for Presidential authorization of NRC CfDs is facially consistent with existing law.

It may be already too late to help the Kewaunee and Vermont Yankee plants. However, other operating merchant nuclear power plants face economic pressures similar to those faced by Kewaunee and Vermont Yankee. Rather than lose these plants and their benefits, we suggest an efficient series of predictable steps, advanced by the President consistent with the Administration's efforts to advance the U.S. economy without recourse to an

arguably dysfunctional Congress:

- A prompt Presidential declaration of emergency and commitment to implement Section 108, *via* NRC or its delegate, through CfDs. Further, we suggest retroactive assistance that starts on the date of announcement of the program; this avoids further casualties in the event it takes months or years to put CfDs in place.[21]
- Publication of the form of CfDs for a minimum initial 10-year term (subject to one 10-year renewal to account for the customary license-renewal period and the fact that the U.S. Congress has failed to provide comprehensive energy planning for decades).
- An open call for submission to qualify for a CfD.
- Prompt negotiation of CfDs, and corresponding payment, to each qualifying nuclear power plant. In terms of funding, access to unused EPAct2005 – advanced nuclear Loan Guarantee Program funds ($18.5 billion, of which $6.5 billion has been issued and $1.8 billion has been conditionally committed, as well as the EPAct2005 $18-per-MWh production tax credit[22]) should be considered.

V. Conclusions

U.S. electricity markets, theoretically successful in reducing short-term costs to consumers, have failed to properly compensate merchant nuclear power plants that remain essential to grid stability and confer a host of other unremunerated public benefits. This article describes that perverse dynamic – one that the sector neither anticipated, nor reasonably could have foreseen. More importantly, this article proposes a resolution, consistent with existing law and sound economics, which leverages incremental electricity pricing support through CfDs to the extent necessary to avoid these needless early retirements.

As this article demonstrates, CfDs can be used to preserve important nuclear assets in a cost-effective manner – that is, at the lowest marginal cost to U.S. taxpayers. CfDs also can avoid the significant, long-term adverse impacts to national security, U.S. global competitiveness, the electric grid, regional economies, and the environment (even accounting for anti-nuclear sentiment) that needless nuclear retirements represent. In the final analysis, the only thing standing between early, permanent retirement of nuclear power plants with decades of remaining useful life is a relatively simple contract and an even simpler idea that squandering important national assets is short-sighted public policy and worse economic policy. We can, and must, do better.■

Endnotes:

1. See, e.g., Restoring U.S. Leadership in Nuclear Energy, A National Security Imperative, Center for Strategic & International Studies, report chaired by Lt. Gen. Scowcroft, M. Shattuck and M. Wallace (June 2013), p. x.

2. See, e.g., Optimized Capacity: Global Trends and Issues, World Nuclear Association (2012).

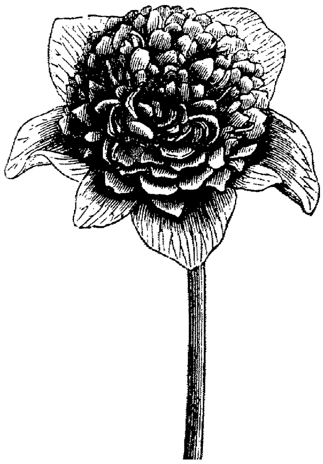
3. Id. at 10–12 (linking a strong civil nuclear industry with nonproliferation and other critical national security goals).

4. See, e.g., The Closing of Yankee Rowe Nuclear Power Plant: The Impact on a New England Community, UMass Amherst Landscape Architecture & Regional Planning Faculty Publication Series, J. Mullin and Z. Kotval (1997).

5. See, e.g., Annual Energy Outlook 2013 (with Projections to 2040), U.S. Energy Information Administration (2013), pp. 45, 47 and 89 (''CO_2 emissions from the electric power sector are affected by the share of nuclear power in the generation mix.'').

6. This article is focused on US electricity markets; similar issues are present in other countries.

7. See, e.g., Competitive Electricity Markets and Investment in New Generation Capacity, CEEPR/P. Joskow (2006) (''Evidence from the U.S. and some other countries indicates that organized wholesale markets for electrical energy and operating reserves do not provide adequate incentives to stimulate the proper quantity or mix of generating



capacity consistent with mandatory reliability criteria.''); Lessons From Liberalized Electricity Markets, OECD/IEA (2205), p. 17 (''Finally, when it comes to secure real-time system operation, markets so far have failed to provide a complete framework of incentives without jeopardizing system security. Government intervention is necessary and this has been carried out (rather effectively) through the establishment of truly independent system operators.''). Notably, this dynamic arises because, despite real advances in storage (the final frontier for electricity markets), electricity remains difficult and costly to store; since it must be available on demand and varies continuously, typical stocking, rationing and queuing systems are not available.

8. See Endnote 7; see also ''FERC capacity market discussions center on 'missing money,''' SNL (26 September 2013); ''Regulated Capacity Payments,'' Standing Group on Long-Term Co-Operation, EA OECD (June 2, 1999).

9. See, e.g., ''The trouble with capacity markets, L. Harrison, Wind Power Monthly (Nov. 1, 2013), available at http://www.windpowermonthly.com/article/1218191/trouble-capacity-markets (discussing debate over capacity shortfalls).

10. See, e.g., ''Negative Electricity Prices and the Production Tax Credit – Why wind producers can pay us to take their power – and why that is a bad thing,'' Huntowski, Patterson, and Schnitzer, The NorthBridge Group (Sept. 10, 2012).

11. See Endnote 7; see also Annual Energy Outlook 2013 (with Projections to 2040), U.S. Energy Information Administration (2013), pp. 13, 14–19 and 75 (''The short-term availability of federal incentives has helped to make renewable capacity attractive to investors and helped utilities meet state requirements or potential load growth in advance, (that is, buil[t] ahead of time to take advantage of the federal incentives.'').

12. See, e.g., Annual Energy Outlook 2013 (with Projections to 2040), U.S. Energy Information Administration (2013), p. 39, 41, 44 and 72 (''Over the past 20 years, natural gas has been the go-to fuel for new electricity generation capacity. From 1990 to 2011, natural gas-fired plants accounted for 77 percent of all generating capacity additions, and many of the plants added were very efficient combined-cycle plants.''); (''In recent years, natural gas has come into dispatch-level competition with coal . . . .'').

13. See, e.g., ''How Less Became More: Wind, Power and Unintended Consequences in the Colorado Energy Market,'' prepared for Independent Petroleum Association of Mountain States, Bentek Energy (16 April 2010); Annual Energy Outlook 2013 (with Projections to 2040), U.S. Energy Information Administration (2013), pp. 87 and 89 (reflecting increase in share of natural-gas-derived CO_2

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emissions, 2005 to 2040, and carbon policy implications).

14. The Closing of Yankee Rowe Nuclear Power Plant: The Impact on a New England Community, UMass Amherst Landscape Architecture & Regional Planning Faculty Publication Series, J. Mullin and Z. Kotval (1997).

15. See, e.g., ''Several Surprising Reliability Issues Emerged During Recent Cold Snap,'' SNL, (16 January 2014) (''PJM, which was forced to direct member utilities to implement a 5 percent voltage reduction for about an hour and deploy demand response resources, was particularly hard hit by forced outages. . . . Moreover, during one evening peak, 33.4 percent of its forced outages were due to gas curtailments, meaning that 4.8 percent of its installed capacity was suddenly unavailable.''); Annual Energy Outlook 2013 (with Projections to 2040), U.S. Energy Information Administration (2013), p. 48 (establishing impacts of nuclear retirements on retail electricity pricing, even in regions without nuclear retirements).

16. See, e.g., http://www.forbes.com/sites/kensilverstein/2013/01/29/pipeline-explosion-rattles-natural-gas-industry. Stating, as has been widely reported, ''[a]t present, 2.5 million miles of existing natural gas pipelines exist in the United States, according to the National Transportation Safety Board. Half of that was installed prior to 1970, meaning that the standards by which they have been built are not as strict as the more recently constructed lines. With the share of natural gas used to fuel power plants expected to keep rising, gas producers are saying that between 29,000 and 62,000 miles of new pipeline is needed over the next 25 years.''

17. The Closing of Yankee Rowe Nuclear Power Plant: The Impact on a New England Community, UMass Amherst Landscape Architecture & Regional Planning Faculty Publication Series, J. Mullin and Z. Kotval (1997).

18. Nuclear's Lost Generation, S. Westfall, Reuters Special report (November 2010).

19. The precise form of contract may depend on the electricity market in which the merchant nuclear plant is located.

20. See, e.g., ''Toward Comprehensive Reform of America's Energy Regime,'' P. Thronson, University of Michigan Journal of Law Reform, Vol. 46, No. 2 (2013), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2056822.

21. Less-preferable alternative options are forcing assumption of ownership by NRC (with leasebacks or comparable operating agreements) or that struggling nuclear power plants facing closure be placed into a low-cost suspended state (i.e., similar to a conventional generation plant in mothballs), where operating costs would be low and the time-clock on the NRC operating license would be suspended. The latter option may allow nuclear power plant owners to have another option short of permanent closure. This would be similar to the situation that exists for nuclear power plants under construction. Stopping costs by stopping construction, even for decades, has been allowed by the NRC for the Watts Bar and Bellefonte project construction restarts.

22. See, e.g., Annual Energy Outlook 2013 (with Projections to 2040), U.S. Energy Information Administration (2013), p. 45; and US DOE Loan Guarantee Office site at https://lpo.energy.gov/projects/georgia-power-company/

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