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DISCIPLINED POLICY RESPONSES TO NUCLEAR RETIREMENTS

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CONTENTS

EXECUTIVE SUMMARY

A combination of market, policy and regulatory factors have converged to squeeze the finances of the U.S. nuclear generation fleet. Among a variety of organic and external factors, low-priced natural gas is the driving force of financial pressure.[1] A revolution in natural-gas extraction and generation technologies has dramatically shifted the competitive playing field.[2] External policy pressures—such as the Production Tax Credit (PTC) and Renewable Portfolio Standards (RPS) —also put downward pressure on nuclear revenues.

Increased cost pressure on nuclear plants largely stems from external regulatory factors, as the regulatory burden of the average nuclear plant now stands at $8.6 million annually.[3] Following the 2011 Fukushima Daiichi accident, increased safety-compliance costs have factored into the closure of several U.S. nuclear facilities.[4] However, it should be noted that, as post-Fukushima safety-related expenses decline, the nuclear industry expects capital expenditures to moderate from their 2014 peak back to levels last seen in 2007-2008.[5]

These forces have resulted in increased capital investment requirements, higher operating costs and reduced revenues in wholesale electricity markets for nuclear generators.[6] Cost and revenue pressures have rendered some nuclear plants unprofitable. Six reactors have closed in the past five years, while 19 others either have announced their intention to close or are "at-risk" of closure, as determined by ratings agencies and financial consultants.[7] Roughly 10 percent of the U.S. nuclear fleet has either already closed or is scheduled to close within the next 16 years.[8] Nuclear plants owned by independent power producers, or merchants, face greater risk of retirement given their exposure to market forces (i.e., they profit from market revenues, minus costs).

1 Rorke, 2016.

2 Hydraulic fracturing and horizontal drilling drove large production-cost decreases in natural-gas extraction, driving down the commodity price of natural gas. Meanwhile, natural gas, combined with cycle-generation technology, has witnessed marked advances that boosted plant efficiency. Combined with the low construction-cost risk of these plants and a very favorable financial environment (e.g., low interest rates and financial-engineering innovations), new market entrants using this technology add to market pressures on incumbents.

3 Batkins, 2016.

4 PJM Interconnection, "Resource Investment in Competitive Markets," May 5, 2016. http://www.pjm.com/-/media/documents/reports/20160505-resource-investmentin-competitive-markets-paper.ashx

5 Nuclear Energy Institute, "Nuclear Costs in Context," April 2016.

6 Coal generators have experienced similar effects.

7 Phillip Brown and Mark Holt, "Financial Challenges of Operating Nuclear Power Plants in the United States," Congressional Research Service, Dec. 14, 2016.

8 Rorke, 2016.

For this reason, announced or at-risk nuclear retirements tend to be concentrated in restructured electricity states, including Texas, Illinois, Ohio and most of the mid-Atlantic and Northeast. These states participate in organized, competitive wholesale electricity markets administered by regional transmission operators (RTOs) or independent system operators (ISOs). Plants owned by monopoly utilities are insulated from market forces to a large degree, as they pass wholesale market revenues and costs through to retail ratepayers. In 2015, *The Economist* correctly noted that "where markets are freer, it is harder for nuclear-power operators to make money, and too risky for them to build plants from scratch."[9]

Recent and anticipated nuclear retirements have prompted blowback from a variety of nuclear advocates. The reasons they argue against nuclear retirements include adverse effects on electric-system reliability, increased electricity costs, loss of fuel diversity, local economic impacts and increased air pollution, especially greenhouse-gas emissions. Claims of "incredibly detrimental" economic and environmental consequences have led to urgent calls for policies that prevent "premature" nuclear plant retirements.[10] Proponents have proposed or enacted various out-of-market, or "around market," policy interventions to support merchant nuclear plants.[11] These include subsidies, re-regulation and government takeover of private nuclear assets (i.e., nationalization).[12] Most notably, the New York Public Service Commission recently created a Zero Emissions Credits (ZECs) program that will subsidize three unprofitable nuclear plants for 12 years or more. This is part of a Clean Energy Standard to obtain half of New York's electricity from renewables, which will radically reshape its generation market.[13] Once the dust settles from legal challenges, ZEC may serve as a model for other states with unprofitable nuclear plants.[14] In December 2016, Exelon Corp. borrowed elements of the ZEC model in securing legislation that provides $235 million in annual subsidies for two unprofitable nuclear plants in Illinois.[15]

Nuclear retirements have not only invited interest in subsidies but spurred open discussions of re-regulation and against restructuring.[16] Discussions over vertical reintegration or re-regulation as a path to save unprofitable nuclear plants appear sincere and have staying power.[17] Ohio utilities openly discuss re-regulation and reintegration as part of a dispute over subsidies for unprofitable merchant coal and nuclear plants.[18] FirstEnergy Corp. announced plans to join American Electric Power Ohio (AEP) in lobbying the state Legislature to re-regulate generation assets.[19] In Michigan, utilities have cited Ohio's situation as a case against electricity competition and consumer choice, while pursuing legislation to eliminate it.[20] Like Ohio, Illinois policymakers have discussed re-regulation if nuclear subsidies fail.[21]

The market distortions posed by various interventions to preserve nuclear also have encouraged RTO/ISOs and their stakeholders to explore market-based alternatives. Nuclear subsidies in New York pushed the New York Independent System Operator (NYISO) and its stakeholders to be aggressive in exploring carbon pricing as an alternative.[22] A variety of disruptive state interventions to spur clean energy development and retention have encouraged ISO New England Inc. (ISO-NE) and its stakeholders also to examine carbon pricing, dedicated clean-energy markets or new market rules that accommodate state policy objectives.[23]

This report examines the merits of arguments to intervene to prevent nuclear retirements, as well as the consequences of doing so. It finds no justification for nuclear-specific interventions. The only legitimate concern that nuclear retirements are premature is that electricity markets do not fully account for the external "social cost" of pollution. Excluding

9 *The Economist*, "Half-death: The future of nuclear energy," Oct. 31, 2015. http://www.economist.com/news/international/21677243-nuclear-power-emits-no-greenhouse-gases-yet-it-struggling-rich-world-half-death

10 Donald R. Hoffman, "Presenting the Nuclear Narrative: Technical and Regulatory Issues Facing Nuclear Power Plants," ANS Special Committee on Nuclear in the State, June 2016. https://www.eiseverywhere.com/file_uploads/6dbdda911158b325ed6f7c550af95072_00-DonHoffman-PresentingtheNuclearNarrative_Revised.pdf

11 Raymond L. Gifford and Matthew S. Larson, "State Actions in Organized Markets: States Strive to 'Fix' Markets and Retain Base Load Generation," Wilkinson, Barker, Knauer LLP, September 2016. http://www.wbklaw.com/uploads/file/White%20Paper%20-%20Market%20Design%20Issues%20(September%202016).pdf

12 Energy Systems Strategic Assessment Institute, "Economic and Market Challenges Facing the U.S. Nuclear Commercial Fleet," Idaho National Laboratory, Center for Advanced Energy Studies, and Gateway for Accelerated Innovation in Nuclear, September 2016. https://gain.inl.gov/Shared%20Documents/Economics-Nuclear-Fleet.pdf

13 SNL Energy, "The New York Clean Energy Standard-A 360 View," Regulatory Research Associates, Aug. 23, 2016.

14 SNL Energy, 2016.

15 Peter Maloney, "Updated: Illinois Gov. Rauner signs Exelon nuclear legislation," Utility Dive, Dec. 7, 2016. http://www.utilitydive.com/news/updated-illinois-gov-rauner-signs-exelon-nuclear-legislation/431803/

16 Gifford and Larson, 2016.

17 Gifford and Larson, 2016.

18 Gifford and Larson, 2016.

19 Tom Knox, "FirstEnergy joining AEP push to pull back on open market in Ohio," *Dayton Business Journal,* Nov. 7, 2016. http://www.bizjournals.com/dayton/news/2016/11/07/firstenergy-joining-aep-push-to-pull-back-on-open.html?ana=RSS%26s=article_search

20 Andy Balaskovitz, "Michigan utility says Ohio 'bailouts' make case against deregulation," *Midwest Energy News*, April 12, 2016. http://midwestenergynews.com/2016/04/12/michigan-utility-says-ohio-bailouts-make-case-against-deregulation/

21 Based on personal conversations with elected Illinois officials in summer 2016.

22 E.g., see forthcoming Brattle Group white paper on CO_2 pricing in NYISO's energy market.

23 Mark Karl, "Initial ISO IMAPP Comments," ISO-NE, Sept. 14, 2016. https://www.iso-ne.com/static-assets/documents/2016/09/imapp_20160914_presentation_iso_initial_comments.pdf

external "social cost" considerations, nuclear retirements generally do not appear to be premature through a nominal economic lens.[24] Rather, they are consistent with the under-lying economics of baseload plants in the current market and regulatory environment.[25]

Electricity markets should not explicitly value fuel diversity (a proxy slogan for benefits already remunerated in markets) or local economic protection (transfer payments).[26] Rather, the core function of market design should remain to procure reliable electricity at the least cost. The RTO/ISO market constructs for reliability are imperfect, but do not appear specifically to disadvantage nuclear or other baseload assets.[27] To whatever extent market design fails to account for certain reliability attributes, that failure concerns reliability service procurement alone, not an inherent need to procure a certain type of fuel or technology. Any such failure should be corrected via market-design reforms, not out-of-market compensation. Furthermore, there is no evidence of an imminent threat to bulk reliability to justify interim subsidies.[28]

Some nuclear retirements—those that meet definitions of socially "premature" retirements—would not occur if markets fully internalized the social cost of pollution.[29] Nuclear retirements will generally increase conventional and greenhouse-gas emissions, except for emissions regulated under a binding emissions-trading program.[30] Socially premature nuclear retirements highlight the shortcomings of U.S. climate policy.[31] In the absence of consistent, market-based emissions-reduction policy, what has instead surfaced is ad hoc climate policy (e.g., sporadic subsidies for particular resources, including nuclear plants). This threatens to undermine competitive electricity markets severely and is generally inconsistent with sound economic policy. If an ad hoc system supersedes American capitalism's predictable rules-based system, the long-term economic damage will be grave.[32]

Nuclear subsidies, re-regulation or nationalization each represent industrial policy with, at best, temporary environmental co-benefits. Industrial policy is a high-cost, less-effective path to a cleaner energy future. Providing subsidies to clean energy is not equivalent to pricing externalities like air pollution. The underlying market failure is that pollution is underpriced, not that clean power is too expensive.[33] In theory, subsidies offer incentives to reduce emissions, but in practice, they often promote economically inefficient and environmentally unsound actions.[34] Counteracting subsidies for certain resources (e.g., renewables) with subsidies for others (e.g., nuclear) constitutes a policy race to the bottom. Introducing new subsidies deepens the political cycle of rent-seeking handouts. The future health of electricity markets depends on unwinding the existing subsidy regime.[35]

If subsidies are a foregone conclusion, they should be specific in purpose, minimal in duration and should be extended only where there is a valid market failure, all to reduce the likelihood of broader subsidy metastasis. Re-regulation and nationalization are economically damaging policy options that have no slimmer "diet" version to avoid severe market distortions. Electric industrial policy undermines market institutions during a politically vulnerable period and propels the uneconomical movement for government engineering of the electric fuel mix. Sacrificing policy quality for political expedience will come at high economic and political cost, with extensive long-term unintended consequences.[36]

24 "Premature," from an engineering perspective refers to where shutdown occurs with useful operating life remaining. This sense of the term is distinct from the relevant economic perspective. Retirements are economically premature if the costs of continued operation are less than the costs of replacement resources, assuming no change in demand.

25 The Brattle Group, "Response to U.S. Senators' Capacity Market Questions," open letter to the U.S. Government Accountability Office, May 5, 2016. http://www.brattle.com/system/publications/pdfs/000/005/283/original/Brattle_Open_Letter_to_GAO_-_Response_to_U.S._Senators%E2%80%99_Capacity_Market_Questions.pdf?1462477367

26 Mere transfer payments do not improve economic efficiency. Any policy intervention should occur to address legitimate market failures (e.g., barriers to labor retraining), if applicable.

27 No market-design flaws clearly discriminate against nuclear or other baseload resources in a manner that jeopardizes grid reliability. Investment trends in these markets indicate sufficient resources will exist to maintain reliability in light of nuclear retirements. The failure of some nuclear units to clear capacity markets indicates that reliability standards will be met more cost-effectively with replacement resources for unprofitable nuclear plants (largely new natural-gas generators).

28 Some cite MISO's projected generation shortfall as an imminent threat. However, MISO's limited tools to project resource adequacy multiple years in advance have led to false projections of resource shortages in the recent past. MISO's capacity market still must procure sufficient resources. A shortfall in resources would mean the supply offered into the market would have to be less than the procurement requirement. This has never occurred in any capacity market, because some market participants are always willing to provide capacity at some price.

29 The revenues obtained by nuclear plants would increase if electricity prices reflected the social cost of pollution. If these revenues were sufficient to keep some otherwise unprofitable plants financially solvent, then retiring these plants is socially premature.

30 Subsidizing a method of emissions reduction under a binding emissions-trading program simply shifts the means of emissions reductions (and distorts the emissions-allowance market) without reducing the total level of emissions.

31 Some nuclear-plant retirements are socially inefficient and would remain open under a robust price on carbon.

32 "How Donald Trump is changing the rules for American business," *The Economist*, Dec. 10, 2016. http://www.economist.com/news/leaders/21711314-president-elect-has-new-approach-dealing-corporate-america-it-not-all-good

33 Severin Borenstein, "The Private and Public Economics of Renewable Electricity Generation," Energy Institute at Haas, December 2011. https://ei.haas.berkeley.edu/research/papers/WP221.pdf

34 Robert N. Stavins, "Experience with Market-Based Environmental Policy Instruments," Resources for the Future, November 2001. http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-01-58.pdf

35 David Victor, "Energy and climate: Moving beyond symbolism," Brookings Institution, Oct. 18, 2016. https://www.brookings.edu/research/energy-and-climate-moving-beyond-symbolism/

36 For example, contentious, high-cost interventions intensify the political divide over climate policy.

Further sacrifices of market integrity will reverberate through the industry, chilling investment as costs escalate.[37]

The twin political motivations of economic growth and emissions mitigation should prompt policymakers to strengthen, not undermine, competitive electricity markets. Competitive electricity markets drive environmental improvements through improved fuel management, risk management, feedback effects of lowering emissions-reduction costs, facilitating organic growth in clean-energy demand and stimulating innovation. As such, out-of-market interventions that temporarily reduce emissions may compromise long-term emissions reductions by disrupting competitive market performance.[38]

Public policy should facilitate well-functioning marketplaces. Trimming regulatory costs could help the competitiveness of the nuclear industry.[39] Reforming wholesale electricity markets to improve price formation (prices do not currently reflect all costs) would enhance market performance. Reducing government engineering of the fuel mix similarly would bolster markets (e.g., reducing mandates and phasing-out deployment subsidies, which distort price signals). Such actions would increase market revenues for nuclear as a byproduct.

The most important message for policymakers is to stay disciplined. The notion that the economic and environmental consequences of nuclear retirements are "incredibly detrimental" is overblown. By contrast, the adverse consequences of out-of-market policies to prevent nuclear retirements are potentially severe. The economic case for government intervention remains limited to *efficient* correction of market failure. The unease of socially premature nuclear retirements should motivate political commitment for a market-based, long-term strategy that drives innovation, reduces emissions at least cost and bolsters reliability. This will benefit the U.S. economy the most and prove far more politically durable than ad hoc climate policy. It also would serve as a model the world is more likely to follow.

WHOLESALE ELECTRICITY MARKET DESIGN

Reliability and cost concerns of merchant nuclear retirements are necessarily questions of wholesale electricity market design. Extensive market failure in the electric industry necessitates the "visible hand" of market design to allow the "invisible hand" of the market to function. Market design sets the rules for how markets operate and participants interact. It provides incentives for competitive behavior and shapes the processes that guide market outcomes.

Some critics argue electricity markets have severe flaws that fail to recognize the unique value of nuclear – such as its dependability, price stability, environmental attributes and local economic development impacts (e.g., tax revenue, job creation and labor income).[40] This has led critics to levy broad assertions that structural problems in market design put well-operated nuclear plants at risk.[41] Others have made more specific charges that structural problems in wholesale electric energy and capacity markets pose a threat to grid reliability by insufficiently compensating baseload resources (i.e., resources with high year-round operational dependability).[42] Certain nuclear proponents have criticized specific RTO/ISOs, such as accusations of poor market design in NYISO.[43]

Evaluating market design begins with the central objective of achieving electric reliability at least cost. RTO/ISOs do not have an environmental mandate, but can reduce compliance costs with external environmental policies.[44] Fuel diversity and local economic development are not aims of market design, but questions have been raised questions about whether they warrant explicit market valuation.

Local economic development

Nuclear plants often are located in small towns, where they frequently comprise a large portion of the workforce and local tax base. An average nuclear plant creates 700 to 1,200 permanent jobs, $46 million in total labor income and $16-$20 million in state and local tax revenue.[45] Local economic disruption from a nuclear plant closure is not categorically different from the loss of any major employer, such as a large manufacturing facility. Out-of-market policies to keep unprofitable plants in operation reflect temporary transfer payments that suppress market prices.[46] This inhibits eco-

37 Such concerns prompted recent interest in enhanced emissions pricing in the Northeast as a more economical alternative.

38 Devin Hartman, "Environmental benefits of electricity policy reform," R Street Institute, January 2017. http://www.rstreet.org/policy-study/environmental-benefits-of-electricity-policy-reform/

39 Sam Batkins, "The Costs and Benefits of Nuclear Regulation," American Action Forum, Sept. 8, 2016. https://www.americanactionforum.org/research/costs-benefits-nuclear-regulation/

40 Hoffman, 2016.

41 Christine Todd Whitman, "Why Closing Nuclear Power Plants Is Short-Sighted," *Wall Street Journal*, Nov. 16, 2015. http://blogs.wsj.com/experts/2015/11/16/why-closing-nuclear-power-plants-is-short-sighted/

42 George David Banks, "Market Flaws and Distortions in Competitive Electricity Markets," *The American Consumer*, July 9, 2014. http://www.theamericanconsumer.org/2014/07/new-aci-consumergram-market-flaws-and-distortions-in-competitive-electricity-markets-preserving-grid-reliability-and-protecting-u-s-climate-goals/

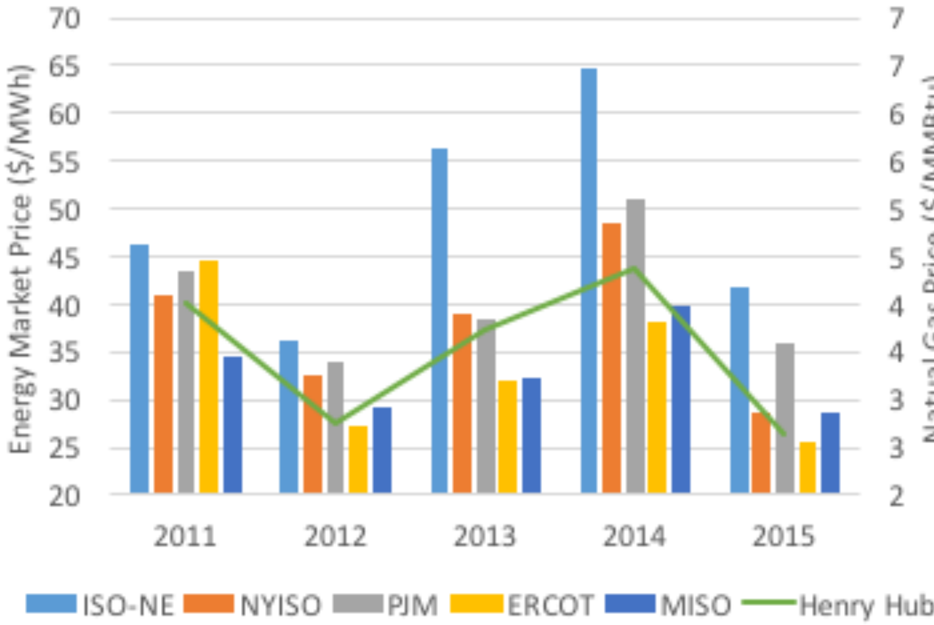
43 Nuclear Energy Institute, "Poor Market Design Propels Closure of another Plant-FitzPatrick," Nov. 5, 2015. http://www.nei.org/News-Media/News/News-Archives/Poor-Market-Design-Propels-Closure-of-Another-Plan

44 Devin Hartman "Wholesale Electricity Markets in the Technological Age," R Street Institute, August 2016. http://www.rstreet.org/wp-content/uploads/2016/08/67.pdf

45 Hoffman, 2016.

46 Brattle Group, "Response to U.S. Senators' Capacity Market Questions," 2016.

FIGURE I: WHOLESALE ELECTRICITY VERSUS NATURAL GAS PRICES



SOURCE: R Street chart derived from SNL Energy, NYMEX and CME Clearport data.

nomic dynamism, which depends on the unimpeded flow of capital and labor to facilitate their most productive uses. The "gale of creative destruction" relies on new firms leveraging an innovative process to replace incumbent firms within a specific industry.[47]

Structural unemployment from nuclear retirements does not warrant intervention to postpone retirements. Policy intervention, if necessary, should correct for labor-market failures (e.g., local illiquidity, information imperfections in capital markets that constrain access to job retraining) and perhaps to ease local economic shocks. This is not an economic justification for taxpayers or ratepayers to subsidize an expensive, temporary employment bridge, let alone to do so to the detriment of electricity-market performance.

Fuel diversity

Arguments for explicit valuation of fuel diversity tend to have two justifications: risk management and reliability. The first notes that fuel diversity has value as a hedge against volatility in electricity prices (i.e., risk management). Price volatility depends on the volatility of the physical output and input cost parameters of specific types of resources in specific locations. It does not correlate with a generic metric of fuel-mix diversity. For example, the comparatively high output variability of wind and solar and high fuel-price volatility of natural gas typically make generation portfolios with higher reliance on these fuel types experience more price volatility. The marginal cost of nuclear is comparatively very stable, thus nuclear generation in lieu of natural gas, wind or solar generation should reduce price volatility. This effect is very modest, however, as nuclear rarely sets the market-clearing price. Rather, natural gas is already the driving force of wholesale electricity prices. Thus, further reliance on natural gas in lieu of nuclear generation would have modest price hedging value, at best.

Some analysts argue that a diversified portfolio is the most cost-effective tool to manage inherent uncertainty in future fuel prices.[48] Merchant generation owners account for this in their portfolio holdings. Furthermore, merchants manage risk based on self-interest, resulting in better risk management than when risk is socialized (e.g., as with legislated resource mandates or under the monopoly utility model). Market failures under the competitive model will be seen only where there is a misalignment of private and social risk. This unsettled debate largely comes down to discrepancies in time horizons, as merchant owners use relatively high discount rates. This is a potential argument for time-adjustments to resource-adequacy constructs, but not for explicit valuation of resource diversity.

Wholesale electricity market participants employ hedging positions to protect against price volatility. Similarly, retail customers in restructured states can choose electric supply contracts that provide greater rate stability. Market partici-

47 Joseph Schumpeter, "Capitalism, Socialism and Democracy," Harper & Row, 1943.

48 IHS Energy, "The Value of US Power Supply Diversity," July 2014. http://www.energyxxi.org/sites/default/files/USPowerSupplyDiversityStudy.pdf

pants are best equipped to undertake hedges consistent with their individual cost-risk profiles, which vary substantially. Market design that explicitly seeks to reduce price volatility via fuel diversity would likely prove complex and require administrative judgment to substitute for that of heterogeneous market participants. This results in poor resource allocation.

The other argument for fuel diversity posits that a more diverse fuel mix is inherently more reliable, but this isn't necessarily the case.[49] As the market monitoring unit for PJM Interconnection LLC notes, "diversity is not a synonym for reliability."[50] Fuel diversity is often conflated with, and used as a proxy for, particular attributes that directly affect reliability. Attributes such as dependability, or specific capabilities like frequency response and operational flexibility (e.g., "ramp," or the ability to adjust generation output) are essential for reliability and often associated with particular fuel types to varying degrees. Markets must procure reliability attributes in the correct proportion, not necessarily a fuel type ratio, even if fuel type is associated with the attributes.[51] In this manner, well-designed markets achieve reliability without explicitly valuing fuel diversity.

The "fuel diversity as reliability" argument highlights a potential emerging hole in market design. Increased reliance on a shared fuel supply line at multiple power plants can lead to an amassing point of single failure, assuming no or limited alternative supply lines exist. For example, areas like New England—with few natural gas pipelines—are vulnerable to a single disruption in pipeline service that would affect multiple power plants. This can also apply to coal facilities, where railway delivery issues affect on-site coal inventories at multiple power plants on the same rail supply line.[52] Nuclear provides a reliability hedge against fuel-supply network constraints, but market design does not generally recognize this value. While the goal of market design should not be explicit valuation of fuel diversity, it should give consideration to the reliability attribute of shared fuel-delivery network effects.[53]

49 For example, a "well-diversified" generation portfolio consisting of five fuel types may not perform as reliably as a portfolio with three fuel types if the latter relies more on resources with superior performance capabilities. In this case, certain fuel types may have attributes that cause performance advantages (e.g., on-site fuel supply mitigates fuel shortages), but the attributes of that advantage are what should be pursued in market design, not the associated fuel type or any measure of fuel diversity.

50 Monitoring Analytics LLC, "Post-hearing reply brief of the independent market monitor for PJM," Feb. 26, 2016. http://www.monitoringanalytics.com/reports/Reports/2016/IMM_Post_Hearing_Reply_Brief_Case_No_14-1297-EL-SSO_20160226.pdf

51 PJM, 2016.

52 Federal Energy Regulatory Commission, "Coal Delivery Issues or Electric Generation," Dec. 18, 2014. https://www.ferc.gov/media/headlines/2014/2014-4/A-3-presentation-staff.pdf

53 For example, contingency definitions for reliability planning may need to recognize the impact of fuel delivery disruptions on multiple power plants.

Attempts to achieve fuel diversity explicitly likely would result in inefficient and discriminatory practices inconsistent with the Federal Power Act. The reliable performance of power generators varies across and within fuel types and often changes with fluctuating conditions. This would render any attempt to value fuel diversity explicitly very complex and would require extensive administrative judgment. Ultimately, the central aim of market design should remain to procure specific reliability attributes at the least cost.

Least-cost reliability

Wholesale grid reliability relies on resource adequacy, which is the state of having sufficient resources to meet maximum demand. Resource adequacy is nonexcludable, causing "bare" markets to underprovide the service.[54] To counteract this, RTO/ISOs employ scarcity pricing in energy markets. Midcontinent Independent System Operator (MISO), NYISO, PJM and ISO-NE also use capacity markets. These mechanisms ensure resource owners receive sufficient revenue to sustain resource investment for the system to obtain adequate resources. As of summer 2016, these mechanisms have led to RTO/ISOs maintaining adequate installed resources to meet reliability targets.[55] However, this does not guarantee that resources will operate dependably as expected at times of system stress.

Energy markets use short-term supply and demand to form prices that reflect the location-based marginal value of bulk energy. This facilitates the least-cost use of resources to maintain operating grid reliability. Expectations of future energy-market prices drive investment behavior.

The Electric Reliability Council of Texas (ERCOT) relies exclusively on energy markets to achieve resource adequacy, which puts great weight on scarcity pricing. Scarcity pricing is a mechanism to send price signals that reflect real-time systemwide shortages in power reserves.[56] This approach relies exclusively on investor expectations of sufficient market revenue to maintain resource adequacy.

System shortages are rare, typically occurring when unusual weather drives exceptionally high demand or when generation availability is low. This results in infrequent scarcity pricing events where some resources are unprofitable in most years but gain sufficient revenue during high shortage years to remain profitable over a multiyear period. Analysis suggests that, in 2015, ERCOT markets did not provide sufficient revenues to support existing nuclear or coal units, as

54 Hartman, 2016.

55 Federal Energy Regulatory Commission, "Summer 2016 Energy Market and Reliability Assessment," May 19, 2016. https://www.ferc.gov/market-oversight/reports-analyses/mkt-views/2016/05-19-16.pdf

56 Hartman, 2016.

well as any new entry from natural gas units.[57] ERCOT did not trigger scarcity in the summer of 2016, despite witnessing record peak demand, largely the result of high wind output. Loss of some coal and nuclear units could put ERCOT below its reliability target. However, new generation continues to come online in ERCOT, perhaps indicating that investors expect a rebound in future revenues.

In 2013, the Public Utilities Commission of Texas ordered ERCOT to implement scarcity-pricing reforms. The last step was implemented in June 2015. In 2015, the commission indicated an interest in reviewing the reforms.[58] It is difficult to evaluate whether further adjustments are warranted, given the brief duration of scarcity-pricing reforms.[59]

In contrast to reliance on a price instrument, which provides no guarantee of sufficient resource procurement, capacity markets procure a minimum quantity of capacity. This quantity is based on projected annual peak demand, plus a reserve margin. If a resource does not expect to receive enough revenues in the energy market to remain operational, it has the incentive to offer into the capacity market at a level that will provide it sufficient revenue to cover its costs. Resources whose offers are greater than the market price do not clear the market. The RTO/ISO relies on resources clearing the capacity market to perform when called upon. RTO/ISOs differ in the penalties for nonperformance. All three eastern RTO/ISOs (PJM, NYISO and ISO-NE) and MISO employ capacity markets to supplement energy markets.

MISO operates a short-term capacity market in a region where regulated monopoly utilities serve 96 percent of demand.[60] Resource procurement for regulated utilities occurs through state processes, not in response to capacity market signals.[61] As a result, utilities typically opt-out of MISO's capacity market or offer at zero. This leaves a small, residual capacity market to provide primarily for Illinois, the sole fully restructured state in MISO. Concerns over the lack of efficient and timely price signals in restructured areas has prompted MISO to propose major capacity-market design changes, which are currently under review by the Federal Energy Regulatory Commission (FERC).[62]

MISO's capacity market has multiple design flaws. One study concluded its current design is unlikely to support sufficient market-based investment to meet the needs of restructured areas.[63] Arguably the largest flaw is a single minimum-capacity requirement, effectively a vertical demand curve. This does not reflect the continuous value of incremental resource adequacy that a sloped demand curve would provide. As a result, price signals are volatile and difficult to predict, providing an inconsistent investment signal. At least some generation retirements and suspensions announced in 2016 in MISO can be attributed to inefficient capacity pricing.[64] This creates legitimate revenue concerns for all merchant generation in MISO, including its five remaining merchant nuclear plants. In addition to market-design concerns, deficiencies in utility procurement practices lead to undervaluation of merchant-owned resources, but enhanced "market tests" offer one option to better achieve this.[65]

NYISO also operates a short-term capacity market, but with a decidedly different design than MISO. According to NYISO's independent market monitor, the capacity market is fundamentally sound and has performed relatively well.[66] NYISO has always procured sufficient capacity to meet reliability requirements and retirement decisions generally have been efficient.[67] The primary incentive for generator performance rests with NYISO's real-time energy-market pricing. NYISO's energy market has provided sufficient performance incentive for the system to maintain reliability. For example, natural-gas fired generators conserved scarce natural gas by switching to fuel oil during 2014's "polar vortex."[68] Well-performing generators, such as nuclear, are rewarded for their dependability during such scarcity periods when prices spike.

ISO-NE and PJM recently enacted major overhauls of their long-term (three years forward) capacity markets to create robust capacity payments and penalties as the primary

57 Potomac Economics, "2015 State of the Market Report for the ERCOT Wholesale Electricity Markets," June 2016. https://www.potomaceconomics.com/uploads/ercot_documents/2015_ERCOT_State_of_the_Market_Report_-_FINAL_update_6.21_.16_.pdf

58 Kenneth W. Anderson, Jr., "Commission Proceeding to Ensure Resource Adequacy in Texas," PUCT Docket No. 40000, Oct. 7, 2015.

59 Potomac Economics, 2016.

60 Midcontinent Independent System Operator, "Market Vision Stakeholder Feedback," 2014. https://www.misoenergy.org/Library/Repository/Meeting%20Material/Stakeholder/MSC/2014/20140401/20140401%20MSC%20Item%2005a%20Stakeholder%20Market%20Roadmap%20Feedback.pdf

61 Kathleen Spees, Samuel A. Newell and Roger Lueken, "Enhancing the Efficiency of Resource Adequacy Planning and Procurements in the Midcontinent ISO Footprint: Options for MISO, Utilities, and States," prepared for NRG, November 2015. http://www.brattle.com/system/publications/pdfs/000/005/221/original/Enhancing_the_Efficiency_of_Resource_Adequacy_Planning_and_Procurements_in_the_MISO_Footprint_Newell_Spees_1115.pdf?1448034421

62 Marcy Crane, "MISO proposes forward capacity auction for competitive retail areas," SNL Energy, Nov. 2, 2016. https://www.snl.com/web/client?auth=inherit#news/article?id=38235280&KeyProductLinkType=2

63 Spees, et al., 2015.

64 Potomac Economics, "2015 State of the Market Report for the MISO Electricity Markets," June 2016. https://www.potomaceconomics.com/uploads/midwest_reports/2015_SOM_Main_Body_Final_Rev.pdf

65 Spees, et al., 2015.

66 David B. Patton, "NYISO Capacity Markets: Function, Performance, and Future," Joint Technical Conference on New York Markets and Infrastructure, Docket No. AD14-18-000, Nov. 5, 2014.

67 Patton, 2014.

68 David B. Patton, Pallas Lee VanSchaick and Jie Chen, "2014 State of the Market Report for the New York ISO Markets," May 2015. http://www.nyiso.com/public/webdocs/markets_operations/documents/Studies_and_Reports/Reports/Market_Monitoring_Unit_Reports/2014/NYISO2014SOMReport__5-13-2015_Final.pdf

drivers of resource performance. These reforms, known as "capacity performance" in PJM and "pay-for-performance" in ISO-NE, came in the wake of the polar vortex weather events that led to high generation-outage rates, prompting calls to improve incentives for generator performance.[69] The markets now heavily advantage resources with year-round dependability, such as nuclear, coal and natural gas-fired generators with dependable fuel supply. At the same time, it further disadvantaged resources with seasonal fluctuations in performance, including renewables and demand response. The nuclear industry supported the reforms, concluding that nuclear plants would benefit from performance payments.[70]

Market design takeaways

The suggestion that certain resources should receive special compensation for dependable performance or fuel-diversity benefits lacks economic merit. Reliability benefits are remunerated through existing market structures. Quality market design ensures sufficient incentive for dependable resource investment and operation within an electricity market.[71]

The dependability of nuclear has advantaged its revenue stream in existing resource-adequacy constructs, namely with a high likelihood of capturing scarcity-pricing rents and/or receiving a high capacity rating in capacity markets.[72] With the exception of merchant nuclear in MISO, the entire merchant nuclear fleet appears to operate in markets that provide sufficient price signals for resource dependability. It remains too early to tell whether ERCOT's scarcity-pricing reforms provide adequate compensation to existing generation.[73] The PJM and ISO-NE capacity markets likely overcompensate dependability outside the summer season, causing inflated demand and revenues for resources like nuclear.

The market-design flaws in MISO, and any potential shortcomings in ERCOT, are not unique to nuclear. Corrective action should take the form of fixing these flaws, which are currently under evaluation. They do not present a case for nuclear-tailored out-of-market policy support. Furthermore, there is no evidence of an imminent threat to reliability that would justify interim subsidies.[74]

Various distortions artificially suppress prices in energy markets, where nuclear units obtain the majority of their revenues.[75] Certain policies, like the federal PTC and state RPS, distort price formation. Grid operators can suppress prices by manually intervening when they perceive energy markets have failed to procure resources to maintain system reliability.[76] The nuclear industry and other market participants have diagnosed structural problems that inhibit energy-market prices from reflecting all aspects of generators' marginal costs, thus depressing those prices.[77] FERC has an ongoing energy price formation initiative that seeks to remedy these issues.[78]

Even with depressed energy market prices, the increased financial pressure on nuclear and other existing units puts upward pressure on capacity-market prices.[79] With the exception of ERCOT, the combination of well-designed energy and capacity markets should create sufficient incentives to maintain resource adequacy, despite energy-market distortions. Still, advancing price-formation reforms should enhance competitive market performance in a manner that should boost nuclear revenues in energy markets.

Single point-of-failure analysis on shared fuel infrastructure is worth evaluating, especially in ISO-NE, which is highly dependent on a small number of natural-gas pipelines to fuel much of its generation fleet.[80] It is unclear whether or how market design may account for this, as resource adequacy mechanisms generally evaluate thermal generation (e.g., fossil and nuclear) resources individually, not in regard to coincident synergies with other system resources.[81] Any changes

69 Some evidence suggests energy-market prices alone were high enough to encourage sufficient performance-improving investments in generators.

70 Jonas Monast, Kate Konschnik, Ari Peskoe, Sarah Adair, Christina Reichert and David Hoppock, "Illuminating the Energy Policy Agenda: Electricity Sector Issues Facing the Next Administration," Duke University, 2016. http://nicholasinstitute.duke.edu/publications

71 Market prices should reflect the reliability value of resources when and where they are needed. Proper price formation will ensure sufficient revenue exists to cover costs to achieve resource adequacy.

72 Resources receive capacity-value ratings, where a certain percentage of their output qualifies to receive capacity compensation based on the resource's historical performance. Fossil and nuclear plants tend to have a high capacity-value rating, which denotes the dependability of baseload nuclear resources is already valued in capacity market design.

73 Mark Watson, "Consultant's warning of ERCOT blackout potential disputed," SNL Energy, Sept. 21, 2016. https://www.snl.com/InteractiveX/article.aspx?CDID=A-37786909-12063&KPLT=4

74 Some cite MISO's projected generation shortfall as an imminent threat. However, MISO's limited tools to project resource adequacy multiple years in advance has led to false projections of resource shortages in the past. Given the predominantly vertically integrated structure of MISO states, any shortfall likely would be limited to a fraction of the small proportion of MISO demand that is reliant exclusively on market signals.

75 Banks, 2014.

76 Hartman, 2016.

77 Edison Electric Institute, Electric Power Supply Association, Natural Gas Supply Association, Nuclear Energy Institute, and America's Natural Gas Alliance, Letter to FERC Chairman and Commissioners, March 6, 2015. http://www.ngsa.org/download/filings_testimony/2015_filings/FYI-Joint%20price%20formation%20principles%20NGSA%20EPSA%20EEI%20ANGA%20NEI.pdf

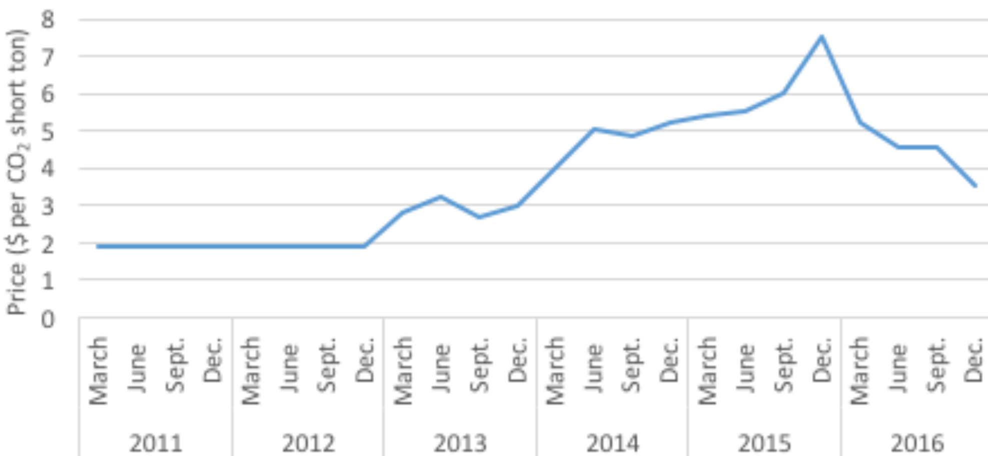
78 Federal Energy Regulatory Commission, https://www.ferc.gov/industries/electric/indus-act/rto/energy-priceformation.asp, accessed Nov. 2, 2016.

79 "Types of Organized Electricity Markets," R Street Institute, August 2016. http://www.rstreet.org/wp-content/uploads/2016/08/electricity5.pdf

80 Other RTO/ISOs examined here have at least fairly robust natural-gas pipeline networks.

81 Renewables capacity accreditation processes may offer analytical insights. Variances in wind and solar output at individual facilities have a correlation with output from in-kind resources as a result of a shared fuel source (i.e., solar radiation and wind).

FIGURE 2: RGGI AUCTION-CLEARING PRICES



SOURCE: R Street chart derived from data from the RGGI Inc.[1]

1. Regional Greenhouse Gas Initiative, Auction Results. https://www.rggi.org/market/co2_auctions/results

would likely advantage any resource that did not rely exclusively on a high dependency pipeline. This includes nuclear, dual fuel capability (on-site oil backup to natural gas), hydroelectric, coal, demand-side resources, wind, solar and others. This does not present an economically sound argument for out-of-market support for nuclear, in particular.

Nuclear unit retirements do not appear to result from faulty market design in the eastern RTO/ISOs. Rather, they are consistent with the underlying economics of baseload plants in the current market and regulatory environment.[82] Excluding external "social cost" considerations, nuclear retirements generally are not premature.[83]

CLIMATE POLICY

Domestic climate-change policy is in a state of flux, with nuclear caught in the middle. Nuclear retirements will have ripple effects on existing carbon markets and other initiatives to reduce emissions.[84] Concerns over increases in carbon emissions from nuclear replacements have spurred extensive calls from industry, environmental groups and public officials to save unprofitable nuclear plants. Others caution that such concerns are overblown, or that the medicine to save nuclear is harsher than the disease.

Premature retirements

Nuclear plant retirements are socially premature if they would remain profitable in a market that accurately reflected the social cost of pollution.[85] Policies to internalize the external cost of climate-altering emissions, including carbon dioxide, vary by region and state.[86] The most relevant for nuclear is the Regional Greenhouse Gas Initiative (RGGI), a mandatory emission-trading program to reduce greenhouse-gas emissions in Connecticut, Maine, Delaware, Maryland, Massachusetts, New Hampshire, Rhode Island, Vermont and New York.[87] This encompasses many merchant nuclear plants in ISO-NE, NYISO and PJM.

Under the new cap implemented in 2014, RGGI prices have fluctuated between $4 and $7.5 per short ton. This is well below the social cost of carbon estimates used by the U.S. Environmental Protection Agency (EPA). The optimal social cost determination is highly contentious and very sensitive to factors like discount rate, with EPA's 2015 estimate ranging from $11 to $56 per metric ton for a 5 percent and 2.5 percent rate, respectively.[88]

Nuclear plants vary in costs but most are low enough to make existing nuclear a relatively low-cost emissions-reduction option. For example, retaining existing nuclear in upstate

82 Brattle Group, "Response to U.S. Senators' Capacity Market Questions," 2016.

83 "Premature" from an engineering perspective, where shutdown occurs with useful operating life remaining, is distinct from the relevant economic perspective. Retirements are economically premature if the costs of continued operation are less than the costs of replacement, assuming no change in demand.

84 Gifford and Larson, 2016.

85 The revenues obtained by nuclear plants would increase if electricity prices reflected the social cost of pollution. If these revenues were sufficient to keep some otherwise unprofitable plants financially solvent, then retiring these plants is socially premature.

86 Greenhouse gases are the most common form of climate-forcing emissions but other substances—such as black carbon—also are noteworthy.

87 A new cap of 91 million short tons was implemented in 2014. This declines 2.5 percent each year from 2015 to 2020.

88 U.S. Environmental Protection Agency, "The Social Cost of Carbon: Estimating the Benefits of Reducing Greenhouse Gas Emissions," Dec. 22, 2016. https://www.epa.gov/climatechange/social-cost-carbon

New York would cost between $20 and $43 per ton.[89] Similarly, retaining a single-unit nuclear plant in ISO-NE costs about $20 per ton.[90] Depending on the value of the social cost of carbon, this suggests some nuclear retirements may be socially premature (i.e., if the social cost of carbon exceeds the carbon cost that would retain nuclear).

Socially premature nuclear retirements indicate that domestic environmental policies are not economically sound. In RGGI states, one option is to lower the emissions cap such that emissions prices better reflect prevailing estimates of the social cost of carbon. Outside RGGI, merchant nuclear plants face less-friendly prospects for emissions pricing.

Near-term emissions impacts

Existing nuclear plants provide more than 60 percent of domestic carbon-free power.[91] Some clean-energy advocates claim that renewables and energy efficiency can cost-effectively offset lost nuclear generation. Such an experiment—known as Energiewende, translated as "energy transition"—was initiated in Germany in 2010, focused on out-of-market renewable energy and energy-efficiency support. After the 2011 Fukushima accident, the German government decided to phase-out nuclear by 2022.[92] The result has been dramatic increases in energy costs and modest emissions increases, as the loss of nuclear has contributed to increased coal use.[93] Energiewende is unsustainable in its current form, with reforms needed to maintain the vitality of the German economy.[94]

In the absence of broad emissions-reduction policies, various parties have raised valid concerns that nuclear retirements will undermine short-term climate-emissions goals.[95] Economic modeling suggests that increased natural-gas generation will fill much of the nuclear void.[96] In regions with large coal capacity, nuclear retirements may cause coal generation to increase temporarily.[97] One recent study found that a 1,000 megawatt (MW) nuclear retirement (about the size of a typical nuclear reactor) would cause an increase in CO_2 emissions of 4.1 to 6.7 million tons per year, given the variances in regional electric-fuel mixes.[98]

Imposing new policies under a binding emissions-trading program would affect the market price of allowances without changing emissions levels.[99] Thus, policy intervention to retain nuclear will increase RGGI allowances and decrease market prices. This undercuts the signal to reduce emissions through other means, resulting in nuclear retention displacing emissions reductions elsewhere. Since many restructured states already participate in RGGI, this is what's likely to happen within ISO-NE, NYISO and some of PJM. One study concluded that New York's Clean Energy Standard will have a "barely discernible impact" on global emissions, with reductions possibly offset by an increase in emissions from other RGGI states.[100] Holding all else constant, nuclear retention will not reduce emissions in RGGI states if RGGI remains binding (i.e., reduces emissions below business-as-usual, setting a positive price on carbon allowances). Whether RGGI remains binding depends largely on adjustments to the RGGI cap, market dynamics and other carbon-reduction policies, namely the aggressive renewables and energy-efficiency policies in the Northeast.

Emissions pricing versus subsidies

Retaining many unprofitable nuclear plants is a relatively low-cost emissions-reduction method.[101] This frequently translates into the inaccurate conclusion that any form of policy intervention to retain nuclear comes at low cost. The full cost of nuclear retention depends on the underlying economics, as well as the method of intervention.

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89 David B. Patton, Pallas Lee VanSchaick and Jie Chen, "2015 State of the Market Report for the New York ISO Markets," May 2016. http://www.nyiso.com/public/webdocs/markets_operations/documents/Studies_and_Reports/Reports/Market_Monitoring_Unit_Reports/2015/NYISO%202015%20SOM%20Report_5-23-2016-CORRECTED.pdf

90 David B. Patton, Pallas Lee VanSchaick and Jie Chen, "2015 Assessment of the ISO New England Electricity Markets," June 2016. https://www.iso-ne.com/static-assets/documents/2016/06/isone_2015_emm_report_final_6_14_16.pdf

91 Monast et al., 2016.

92 Phillip Brown, "European Union Wind and Solar Electricity Policies: Overview and Considerations," Congressional Research Service, Aug. 7, 2013. https://www.fas.org/sgp/crs/row/R43176.pdf

93 The sudden shutdown of nuclear units in Japan had a similar effect.

94 IHS Global, "A More Competitive Energiewende: Securing Germany's Global Competitiveness in a New Energy World," March 2014. https://www.vci.de/vci/downloads-vci/media-weitere-downloads/dokumente/2014-03-ihs-report-a-more-competitive-energiewende-english.pdf

95 E.g., see Samuel Brinton and Josh Freed, "When Nuclear Ends: How Nuclear Retirements Might Undermine Clean Power Plan Progress," Third Way, August 2015. http://www.thirdway.org/report/when-nuclear-ends-how-nuclear-retirements-might-undermineclean-power-plan-progress

96 Lucas Davis and Catherine Hausman, "Market Impacts of a Nuclear Plant Closure," Energy Institute at Haas, May 2015. https://ei.haas.berkeley.edu/research/papers/WP248.pdf

97 Jeffrey Tomich, "Do at-risk Exelon reactors matter for Ill. compliance?," ClimateWire, June 20, 2016; Illinois Commerce Commission, et al. "Potential Nuclear Power Plant Closings in Illinois: Impacts and Market-Based Solutions," Response to the Illinois General Assembly Concerning House Resolution 1146, 119, Jan. 5, 2015.

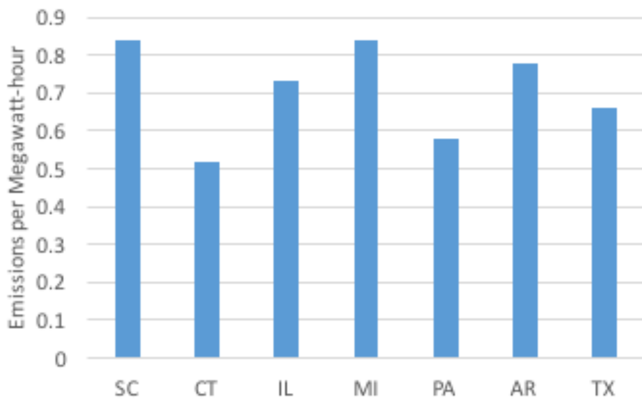
98 Metin Celebi, Marc Chupka, Frank Graves, Dean Murphy and Ioanna Karkatsouli, "Nuclear Retirement Effects on CO2 Emissions," The Brattle Group, December 2016. http://www.brattle.com/system/publications/pdfs/000/005/385/original/Brattle_Nuclear-Carbon_Whitepaper_-_Dec2016.pdf?1482159096

99 Carolyn Fischer, Richard G. Newell and Louis Preonas, "Environmental and Technology Policy Options in the Electricity Sector," Resources for the Future, December 2013. http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-13-20.pdf

100 Ken Girardin and Annette Brocks, "Green Overload: New York State's Ratepayer-Zapping Renewable Energy Mandate," Empire Center, 2016. http://www.empirecenter.org/wp-content/uploads/2016/09/GreenOverload.pdf

101 See e.g., Celebi et al., 2016.

FIGURE 3: CARBON DIOXIDE IMPACT OF 1,000 MW RETIREMENT IN SELECTED STATES



SOURCE: R Street chart derived from data from the Brattle Group.[1]

1. Celebi et al., 2016.

Pricing environmental externalities (e.g., air pollution) is the most economically efficient policy, but policymakers often find the approach politically impractical.[102] The focus then shifts to whether alternative policy interventions would provide more benefit than harm. Some parties consider production subsidies more politically palatable and a suitable alternative. For example, a U.S. Department of Energy task force recently concluded that electricity markets must recognize zero-carbon generation, based on the social cost of carbon emissions avoided, by either assessing an emission charge or, alternatively, extending a production payment of about $0.027 per kilowatt-hour on carbon-free generation.[103]

The portrayal of subsidies for clean energy as nearly equivalent to pricing pollution externalities is very problematic, as the underlying market failure is underpricing of pollution, not overpricing of clean energy.[104] In theory, subsidies, as a mirror image of taxes, can provide incentives to reduce emissions. In practice, they often promote economically inefficient and environmentally unsound actions.[105] Subsidies artificially depress power prices, leading to overconsumption and disincentives for energy efficiency.[106]

Production subsidies are also vulnerable to extensive government failure. This stems both from ulterior government motives and from honest faults in subsidy calculations that result from incomplete information.[107] For example, the ability of clean-energy sources to reduce emissions varies with time and location. Pollution pricing accounts for that variance but technology-specific subsidies do not.[108] The carbon emissions avoided by retaining nuclear varies markedly across and within RTO/ISOs, which handicaps the ability to determine a subsidy that reflects the dynamic value of zero-emissions resources.

Recent subsidies for three nuclear plants in New York and two in Illinois reveal major disparities between subsidies and emissions pricing. Policymakers used the federal government's social cost of carbon estimate to determine the subsidy value. This approach has economic advantages relative to an arbitrary method, but it will allocate resources less efficiently than emissions pricing applied at the same social-cost level. Subsidies result in at least five types of economic inefficiencies that emissions pricing avoids:

- Subsidies create a public financial burden. The DOE task force recommendation would cost $213 million for a 1,000 MW reactor,[109] which would easily reach billions of dollars in subsidies across the full at-risk nuclear fleet. By comparison, emissions pricing creates no such burden, with costs incurred in proportion to the social cost of emissions by responsible parties.

- Subsidies inaccurately compensate for low-emissions attributes. Subsidy revenue for low-emissions resources differs from increased market revenues that result from emissions pricing. Emissions pricing raises revenues consistent with the marginal emissions costs of the electric system. This value is very dynamic (grid conditions can change rapidly) and granular across time by location. The administrative estimates that determine subsidies fail to capture this dynamism.

- Subsidies encourage poor economic behavior by nuclear owners. Production subsidies lower the effective costs of operation, which provides incentive for owners to offer into electricity markets below their true marginal cost. This can artificially suppress market-clearing prices and distort market signals for resource investment.

- Government picks different winners than markets. Emissions pricing is technology-neutral and induces least-cost emissions reductions through a combination of actions that may differ from nuclear retention (e.g., replace coal with natural gas, replace fossil generators with renewables, energy efficiency). In NYISO, one estimate suggests the least-cost option

102 Borenstein, 2011.

103 Secretary of Energy Advisory Board, Task Force on the Future of Nuclear Power, Department of Energy, Draft Report, 2016. http://energy.gov/sites/prod/files/2016/09/f33/SEAB%20Nuclear%20Power%20Task%20Force%20Draft%20Report%20%28final%29.pdf

104 Borenstein, 2011.

105 Stavins, 2001.

106 Borenstein, 2011.

107 Hartman, 2016.

108 Borenstein, 2011.

109 Secretary of Energy Advisory Board, 2016.

to reduce emissions incrementally is to replace inefficient generation with a new combined-cycle natural-gas-fired generator on Long Island.[110] The independent market monitor for NYISO notes the result underscores the importance of using a technology-neutral approach to carbon reductions.[111] Nuclear subsidization merely selects one politically preferred method of emissions reductions, which misallocates resources and raises the cost of emissions reductions. In New York, the application of subsidies was not even consistent within the nuclear technology class; only three of four nuclear generators received subsidies.

- Subsidies elevate political risk for investors. Commitment to emissions pricing, and rejection of out-of-market interventions, contributes to a healthy, stable investment climate. Upholding market institutions belies investor confidence. Subsidies and other market-contradicting policies undermine investor confidence, which can lead to artificial increases in capital costs and inefficient capital expenditures (see next section).

Subsidies have an adverse economic and political interplay with emissions pricing. Clean-energy subsidies are unlikely to enhance social welfare when enacted alongside sufficient emissions pricing.[112] Aggregate emissions levels remain constant when applying subsidies under a binding emissions-trading scheme. Subsidization also creates an incentive for rent-maintenance behavior that could undermine any attempt to use nuclear subsidies as a transitional policy to efficient emissions pricing.

If the pursuit of subsidies is a foregone conclusion, policymakers should take care to pursue subsidies that achieve the most cost-effective emissions reductions with the least-adverse impacts on electricity markets. Recent economic analyses have explored various auction mechanisms to allocate subsidies for carbon-emissions reductions.[113] Conditional subsidies may also improve effectiveness, such as provisions to phase-out subsidies upon implementation of emissions-pricing policies, or ensuring additional emissions reductions in RGGI states (e.g., altering the cap to account for nuclear retention). Predicating subsidies on specific conditions may avoid broader subsidy pursuits, reduce investment risk and encourage substitution of superior policies.

110 David B. Patton, Pallas Lee VanSchaick and Jie Chen, "2015 State of the Market Report for the New York ISO Markets," May 2016.

111 Patton et al., May 2016.

112 Fischer, Newell and Preonas, 2013.

113 E.g., see Haoran He and Yefeng Chen, "Auction Mechanisms for Allocating Subsidies for Carbon Emissions Reduction," Environment for Development, March 2014. http://www.rff.org/files/sharepoint/WorkImages/Download/EfD-DP-14-06.pdf

For example, the New York Public Service Commission can modify or eliminate the ZEC if a national, NYISO or other program internalizes the value of zero-emission attributes.[114] This has contributed to NYISO and its stakeholders aggressively exploring carbon pricing as an alternative.[115]

Maintaining a long-term strategy

Effective climate policy is geared toward a stable decades-long strategy. This places exceptional importance on the quality of policies and institutions. The United States should serve as a policy model to follow and assist in driving down the costs of emissions abatement economically, which maximizes the likelihood of emissions reductions abroad. This requires technologies that are globally scalable and affordable.[116] Innovation plays a pivotal role, given the high cost of clean power generation.[117] In the long term, global climate progress is linked to the innovative performance of the electricity industry, which outperforms under a competitive model.

The rise of competitive electricity markets has had positive environmental implications and should serve as a domestic and global foundation to achieve a low-emissions future. Markets create pathways to low-cost emissions reductions. The competitive platform spurs innovation and facilitates transitions to breakthrough technologies far more effectively than the regulated-monopoly model.[118] These effects amplify when combined with emissions pricing, which is far more effective in competitive markets, where participants have incentives to follow price signals.[119]

The imperative to strengthen competitive electricity markets has run into political headwinds. Policymakers face great temptations to cave to ad hoc climate policy.[120] Sacrificing policy quality for political expedience will come at high economic and political cost, with extensive long-term unintended consequences.[121] Sporadic interventions may

114 Justin Gundlach and Romany Webb, "Carbon Pricing in New York ISO Markets," Columbia Public Law Research Paper, Nov. 28, 2016. https://ssrn.com/abstract=2876895

115 E.g., see forthcoming Brattle Group paper on CO_2 pricing in NYISO's energy market.

116 National Academies of Sciences, Engineering, and Medicine, "The Power of Change: Innovation for Development and Deployment of Increasingly Clean Electric Power Technologies," The National Academies Press, 2016.

117 National Academies of Sciences, Engineering, and Medicine, 2016.

118 Hartman, 2017.

119 Navigant Consulting, Inc., "Price Signals and Greenhouse Gas Reduction in the Electricity Sector," prepared for the COMPETE Coalition. http://www.competecoalition.com/files/Navigant%20Study%20FINAL.pdf

120 The patchwork of ad hoc sporadic subsidies for unprofitable technologies or artificial rejections of profitable ones.

121 Contentious, high-cost interventions intensify the political divide over climate policy.

temporarily reduce emissions but undermine competitive-market performance.[122] Nuclear bailouts are a prime example of such nearsighted thinking. In sacrificing the foundations of competitive markets, such interventions undercut long-term climate success.

IMPLICATIONS OF POLITICAL INTERVENTIONS

A fundamental assumption of competitive electricity markets is that market participants make operating and investment decisions based on market prices.[123] In particular, resource investments are driven by forward price expectations.[124] This makes the determinants of price formation critical to investor confidence and the efficiency of capital expenditures. When investors perceive political interference in price formation, it negatively impacts flows of capital to the sector.[125] Price distortions adversely affect market efficiency and sometimes reliability. The degree of impact depends on the structure, severity and duration of interventions. Once a state has abolished price regulation, interference in price formation breaches that state's commitment to reform the electricity sector on a free-market basis.[126]

Political interventions harm competitive relationships in at least two ways. First, the artificial retention of unprofitable power plants suppresses market prices, depressing revenues for competitors. Secondly, interventions inefficiently reallocate risk in the market by providing an income guarantee to one participant and shifting risk to the rest of the marketplace. The mere threat of intervention creates political risk that worsens creditworthiness and can inflate borrowing costs for competitors.[127]

Political interventions deter investment or require a significant risk premium for investment.[128] This mutes market signals for reliability. Reliability signals occur at the margin, where a relatively small change in quantity induces a large change in energy or capacity prices (i.e., the supply curve is very steep near the equilibrium point). Energy-only RTO/ISOs are especially vulnerable, as a large fraction of net revenues required to cover capital investments is produced in a very small number of hours each year.[129] This can create underinvestment by eliminating the financial viability of power investments, thus compromising resource adequacy. Capacity markets provide a reliability backstop for nominal (i.e., installed) capacity investment. However, suppressing energy market prices discourages investment that would otherwise improve resource performance (e.g., firming fuel supplies, weatherizing equipment). In this way, out-of-market policies deter reliability-enhancing behavior, even in RTO/ISOs with capacity markets.[130] While nominal capacity may remain the same, retaining capacity artificially will still oversupply the market, distorting capacity prices and investment decisions.

Subsidies

Subsidies are inconsistent with market principles, as they weaken price signals and create an uneven playing field among competitors.[131] Such payments for select resources oversupply the market and distort short- and long-term investment signals.[132] Even short- and medium-term interventions significantly affect the annual and long-term profitability of capacity investments.[133] For example, New York's ZEC program will profoundly disrupt NYISO electricity markets and result in a transfer of more than $600 million per year.[134] This has prompted a lawsuit from competitors, signifying the degree to which the program alters competitive relationships within NYISO.[135]

Some nuclear proponents argue that subsidies are necessary to counter subsidies for competing technologies that harm. The goal of market design is not to include counteracting existing subsidies via enhanced revenue to nonsubsidized sources.[136] As it is, designing and maintaining effective power

122 Ad hoc climate policy weakens competitive markets at a time they need strengthening to meet economic and environmental objectives. Caving to pressures for political expediency risks setting a legal and political precedent for expanded ad hoc climate policy.

123 William W. Hogan, "Electricity Market Design and Efficient Pricing: Applications for New England and Beyond," 2014. https://www.hks.harvard.edu/fs/whogan/Hogan_Pricing_062414r.pdf

124 Potomac Economics, "2015 State of the Market Report for the ERCOT Wholesale Electricity Markets," June 2016. https://www.potomaceconomics.com/uploads/ercot_documents/2015_ERCOT_State_of_the_Market_Report_-_FINAL_update_6.21_.16_.pdf

125 Anatole Boute, "Challenging the Re-regulation of Liberalized Electricity Prices under Investment Arbitration," Energy Law Journal, Vol. 32, 2011. http://www.felj.org/sites/default/files/docs/elj322/14-497-boute.pdf

126 Boute, 2011.

127 For a discussion on the impact of credit ratings on electric company borrowing costs, see Lynne Holt, "U.S. Electric Utility Creditworthiness—Why the Regulatory Framework Matters," Feb. 9, 2016. http://warrington.ufl.edu/centers/purc/purcdocs/papers/1602_Holt_Electric_Utility_Creditworthiness.pdf

128 Peter Cramton and Axel Ockenfels, "Economics and design of capacity markets for the power sector," May 30, 2011. ftp://www.cramton.umd.edu/papers2010-2014/cramton-ockenfels-economics-and-design-of-capacity-markets.pdf

129 Paul L. Joskow, "Competitive Electricity Markets and Investment in New Generating Capacity," The New Energy Paradigm, 2007.

130 The increase in non-performance penalties in ISO-NE and PJM quells this somewhat.

131 PJM, 2016.

132 Johannes P. Pfeifenberger, Samuel A. Newell and Kathleen Spees, "Energy and Capacity Markets: Tradeoffs in Reliability, Costs, and Risks," Harvard Electricity Policy Group, Feb. 27, 2014. http://www.brattle.com/system/publications/pdfs/000/004/986/original/Energy_and_Capacity_Markets_Pfeifenberger_Newell_Spees_HEPG_Feb_27_2014.pdf?1393528054

133 Cramton and Ockenfels, 2011.

134 Coalition for Competitive Electricity, et al., v. Audrey Zibelman, U.S. District Court for the Southern District of New York, Oct. 19, 2016. http://www.epsa.org/forms/uploadFiles/3D17B00000014.filename.ZEC_Complaint_File_Stamped_101916.pdf

135 Ibid.

136 PJM, 2016.

markets is extremely difficult with layers of distorting and counterdistorting subsidies.[137] Indeed, the future health of electricity markets depends on unwinding the existing subsidy regime.[138]

RTO/ISOs have to introduce new rules, such as those requiring minimum offer prices, to prevent subsidies from degrading price signals and potentially undermining reliability.[139] Recent nuclear subsidies have potential to disrupt markets profoundly, given the size of the resources and their propensity to influence capacity prices at the margin. This has contributed to efforts in PJM to examine further market-rule adjustments to limit the market distortions of subsidies.[140] Even in the absence of emissions pricing, supporting subsidies as a next-best approach does not translate into sound policy for requiring RTO/ISOs to administer the subsidy regime.[141] The harm of subsidies is growing, as they create a toxic mix of imperfect competition and regulation that work at cross-purposes.[142]

Any subsidy proposal must be subjected to a robust cost-benefit analysis. Evaluations of nuclear subsidies have tended to examine only direct financing costs to ratepayers or taxpayers. This ignores such indirect costs as increased investor risk, resource misallocation from price distortion and the propensity for government failure. If the use of subsidies is a foregone conclusion, they should be minimal in duration and conditioned upon valid market failure to reduce the likelihood of broader subsidy metastasis. Subsidy design must account for the protection of investors' market-pricing expectations.

Re-regulation and nationalization

Re-regulation and nationalization of merchant nuclear assets would fundamentally undermine market institutions and may adversely affect the performance of the fleet. These actions remove the incentives provided under competitive conditions to increase power plant efficiency, cut costs and innovate. Competitive forces motivated merchant nuclear owners to reduce the frequency and duration of plant outages, contributing to a 10 percent increase in operating efficiency.[143]

Re-regulation would stymie the health of competitive markets. Merchants are reluctant to invest when they anticipate re-regulation, as it prevents them from recovering their costs and earning a reasonable rate of return.[144] If fully implemented, re-regulation would backtrack to the economically inferior paradigm of monopoly-utility regulation.

The profound deficiencies of re-regulation and nationalization simply reflect the advantages of restructuring. Competitive wholesale electricity markets provide clear, transparent market signals, enhance efficiency and promote innovation.[145] Even when competitive rates rose sharply with natural-gas prices in the mid-2000s, clear heads recognized that the superficial appeal of re-regulation carried substantial risk of being ineffective and costlier in the long term.[146] Even then, Standard & Poor's noted that "the introduction of competition into generation resulted in greater efficiencies, lower heat rates, greater reliability, lower nonfuel operating costs, and in general, more widely adopted best practices."[147]

Since 2008, natural-gas prices have plummeted, benefiting restructured states the most.[148] Overall, competition has outperformed the regulated monopoly model on the basis of weighted-average electricity prices.[149] This portends well for the future benefits of retaining restructuring and speaks to the adverse consequences of reverting to re-regulation or nationalization.

Political precedent

Where American capitalism has flourished thanks to predictable application of rules, if an ad hoc system that super-

137 David Victor, "Energy and climate: Moving beyond symbolism," Brookings Institution, Oct. 18, 2016. https://www.brookings.edu/research/energy-and-climate-moving-beyond-symbolism/

138 Victor, 2016.

139 PJM, 2016.

140 Stu Bresler, "Potential Alternative Approach to Expanding the Minimum Offer Price Rule to Existing Resources," PJM Interconnection, Aug. 11, 2016. http://www.pjm.com/-/media/committees-groups/stakeholder-meetings/grid-2020-focus-on-public-policy-market-efficiency/meeting-materials/20160816-potential-alt-solution-to-the-min-offer-price-rule-for-existing-resources.ashx

141 William W. Hogan, "Electricity Markets and the Clean Power Plan," The Harvard Project on Climate Agreements October 2015. http://belfercenter.ksg.harvard.edu/files/dp79_hogan.pdf

142 John Moot, "Subsidies, Climate Change, Electric Markets and the FERC," *Energy Law Journal*, 35(2), 345–374, 2014. http://heinonlinebackup.com/hol-cgibin/get_pdf.cgi?handle=hein.journals/energy35&section=24

143 Lucas W. Davis and Catherine Wolfram, "Deregulation, Consolidation, and Efficiency: Evidence from U.S. Nuclear Power," National Bureau of Economic Research, August 2011. http://www.nber.org/papers/w17341.pdf

144 Boute, 2011.

145 Frank Huntowski, Aaron Patterson, and Michael Schnitzer, "Negative Electricity Prices and the Production Tax Credit," The NorthBridge Group, Sept. 14, 2012. https://www.hks.harvard.edu/hepg/Papers/2012/Negative_Electricity_Prices_and_the_Production_Tax_Credit_0912.pdf

146 J.P. Pfeifenberger, G.N. Basheda and A.C. Schumacher, "Restructuring Revisited: What we can learn from retail-rate increases in restructured and non-restructured states," Public Utilities Fortnightly, June 2007. http://www.brattle.com/system/publications/pdfs/000/003/999/original/RestructuringRevisited_Pfeif_PUF_2007.pdf?1378772091

147 Standard & Poor's "Re-Regulation of U.S. Electric Utilities: The Toothpaste Challenge," April 3, 2007.

148 Severin Borenstein and James Bushnell, "The U.S. Electricity Industry after 20 Years of Restructuring," Annu. Rev. Econ. 7 submitted, May 2015. https://ei.haas.berkeley.edu/research/papers/WP252.pdf

149 Philip R. O'Connor and Erin M. O'Connell-Diaz, "Evolution of the Revolution: The Sustained Success of Retail Electricity Competition," COMPETE Coalition, July 2015.

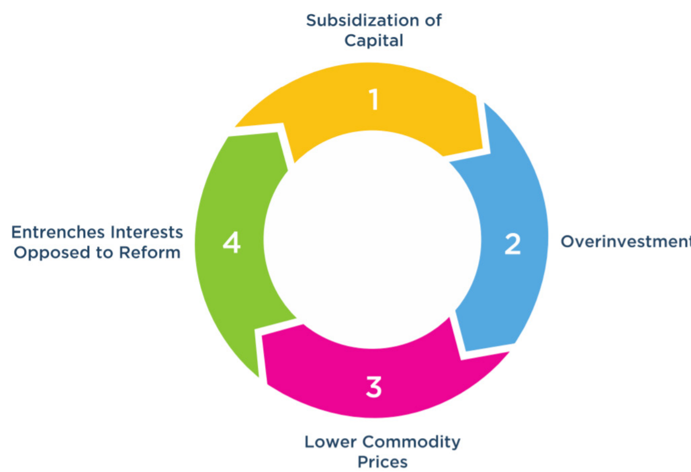
sedes this rules-based system, the long-term economic damage would be grave.[150] The legitimacy of electric investors' market-pricing expectations depends on the regulatory and contractual framework created by the state.[151] Ad hoc subsidies or, worse, re-regulation or nationalization, set a precedent that can fundamentally disrupt a stable investment framework. Limiting the grounds for price interference to cases of structural market malfunction (e.g., market power, imminent reliability threat) contains investment risk. But the unlimited right of public authorities to interfere in electricity markets fundamentally contradicts the principle underlying liberalization.[152] The rationales, conditions and policy instruments behind interventions therefore have a major impact on the degree of damage to investor confidence.

New York's rationale for nuclear subsidies goes beyond compensation for insufficient emissions pricing. The intervention revealed a clear intent for government to engineer the fuel mix. The New York Public Service Commission (PSC) stated that nuclear is needed in the short term and would ideally be replaced by renewable generation.[153] This fundamentally contradicts free-market principles and creates artificial investment risk in those resources that aren't politically preferred. The PSC also cited fuel diversity and fuel security as reasons to support nuclear subsidies.[154] The economic validity of these purported benefits is debatable, and the ability of central planners to achieve these aims efficiently via ad hoc interventions is exceptionally dubious. New York's ZEC framework has served as a model for other states with nuclear plants at risk of retirement, setting a precedent that extends far beyond out-of-market support for select nuclear plants.

Nuclear subsidization for the express purpose of preserving traditional baseload generation, fuel diversity or avoiding local economic disruption could politically justify subsidies for a variety of other retiring plants, especially coal. A subsidy spree expanded to coal would severely erode investor confidence and distort markets, while increasing emissions at the expense of taxpayers or ratepayers. In Ohio, for example, the PUCO-approved subsidies went to finance unprofitable coal and nuclear plants on the basis of perceived supply diversity and reliability benefits.[155] Such political slogans proved more convincing than the opinion of PJM's market monitor, which noted that "Ohio customers have nothing to gain from paying above market prices to preserve aging and obsolete assets."[156]

An examination of bailout policy history reveals that "early bailouts set a stage that makes subsequent requests for assistance more difficult to resist."[157] The low prices and overinvestment induced by subsidies may foster concentrated consumer and producer interests. Once entrenched, these interests naturally tend to resist having the subsidies removed, contributing to an ongoing cycle of subsidization.[158] Economists call this rent-maintenance behavior, where the benefiting industry seeks continued subsidization even after the initial subsidy rationale no longer exists. As evidence, the PTC was created more than 20 years ago to launch a nascent wind industry, yet this distortive subsidy still remains, even though the wind industry is now mature globally.[159]

FIGURE 4: ENTRENCHED CYCLE OF SUBSIDIZATION



SOURCE: PJM[1]

1. PJM, 2016.

The nuclear industry has lamented the PTC for wind resources, which drives down market revenues and undermines market performance. But countersubsidies for nuclear would merely exacerbate the effects on market performance and anchor a subsidy precedent, with damaging economic ramifications.

150 The Economist, 2016.

151 Boute, 2011.

152 Boute, 2011.

153 SNL Energy, "The New York Clean Energy Standard-A 360 View," Regulatory Research Associates, Aug. 23, 2016.

154 SNL Energy, 2016.

155 The Federal Energy Regulatory Commission rejected the decision, but PUCO approved a less substantial subsidy in October 2016.

156 Monitoring Analytics LLC, "Post-hearing reply brief of the independent market monitor for PJM," Feb. 26, 2016. http://www.monitoringanalytics.com/reports/Reports/2016/IMM_Post_Hearing_Reply_Brief_Case_No_14-1297-EL-SSO_20160226.pdf

157 Cheryl D. Block, "Overt and Covert Bailouts: Developing a Public Bailout Policy," Indiana Law Journal, Vol. 67, Fall 1992. http://www.repository.law.indiana.edu/cgi/viewcontent.cgi?article=1456&context=ilj

158 PJM Interconnection, "Resource Investment in Competitive Markets," May 5, 2016. http://www.pjm.com/~/media/documents/reports/20160505-resource-investmentin-competitive-markets-paper.ashx

159 Huntowski, Patterson and Schnitzer, 2012.

Given the planned phase-out of the PTC and investment tax credit, expanding subsidies to nuclear would torpedo a critical opportunity to reduce subsidies dramatically.

Surely, any broad momentum toward re-regulation and nationalization of generation assets would signify a profound risk to merchant investors. This, or the onset of widespread subsidization, could spur an investor-confidence contagion. Standard & Poor's notes that re-regulation "is a risky proposition that could threaten utility balance sheets, destroy value and impair credit ratings."[160] The ramifications would be dire for innovation and inflate producer and consumer costs. Artificially elevating project-finance costs would disrupt the entry of new resources—especially power plant-construction—keeping older and generally less-efficient resources operating longer. Such severe disruption to capital stock turnover would undermine economic and environmental objectives. Securing market integrity is imperative to the health of the electricity industry.

CONCLUSION

Organic market factors are the principle drivers of the financial challenges facing the U.S. merchant nuclear fleet. The swiftness and efficiency of merchant coal and nuclear retirements predominantly reflect that competitive wholesale electricity markets are performing as intended. That is, markets signal generation retirements and new resource entry when and where supply and demand indicate.[161] Nuclear-specific interventions to promote fuel diversity, local economic development and grid reliability lack economic merit.

Some nuclear retirements would not occur if markets fully internalized the social cost of pollution. However, the notion that the economic and environmental consequences of nuclear retirements are "incredibly detrimental" is overblown. By contrast, the adverse consequences of interventionist policies to prevent nuclear retirements are potentially severe. Such actions would undermine market institutions during a politically vulnerable period and propel the uneconomical movement for government engineering of the electric-fuel mix. Further sacrifice of market integrity will reverberate through the industry, chilling investment as costs escalate. In this case, the medicine of out-of-market interventions is worse than the underlying disease.

Romanticizing nuclear power for its historically affordable, reliable and emissions-free service has often found a receptive audience. But this tempting political narrative should not be mistakenly translated into misguided industrial policy.

Nuclear subsidies, re-regulation or nationalization constitute industrial policy with, at best, temporary environmental co-benefits. Industrial policy is a high-cost, less effective pathway to a cleaner energy future. If subsidies are a foregone conclusion, they should be specific in purpose, minimal in duration and should be extended only where there is a valid market failure, all to reduce the likelihood of broader subsidy metastasis. Re-regulation and nationalization are economically damaging policy options that have no slimmer "diet" version to avoid severe market distortions.

The twin political motivations of economic growth and emissions mitigation should prompt policymakers to strengthen competitive electricity markets. Electric competition drives environmental improvements through improved fuel management, risk management and, most importantly, innovation. The competitive electricity model has tremendous upside to usher in rapid technological change with profound economic and environmental benefits.[162]

Public policy should facilitate well-functioning marketplaces. Removing government engineering of the fuel mix is essential, and could largely benefit nuclear as a byproduct (e.g., reducing mandates and phasing out deployment subsidies for competing technologies). But counteracting subsidies for select resources with subsidies for others is a policy race to the bottom. Rather, bolstering competition by enhancing market rules that affect price formation may augment nuclear revenue streams.[163] Specific to nuclear, trimming regulatory costs could help the competitiveness of the nuclear industry.[164]

The most important message for policymakers is to stay disciplined. The economic case for government intervention remains limited to efficient correction of market failures. Failure to enact efficient emissions pricing does not warrant an abandonment of market principles. This was summarized appropriately by former Exelon Corp. Chairman and CEO John Rowe. Regarding three unprofitable Exelon Corp. nuclear plants in Illinois, Rowe stated: "in a world that's driven by unfriendly market prices and unfriendly public policy, you shut them down… it is the proper market-driven answer."[165]

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160 Standard & Poor's "The Credit Implications of U.S. Electric Utility Re-Regulation," April 12, 2007.

161 For example, ISO-NE's markets have driven the retirement of 4,200 MW of oil, coal and nuclear generation capacity since 2013. They also have attracted 3,000 MW of new natural gas generation to high demand areas that will come online over 2017-2019.

162 Hartman, 2017.

163 Energy Systems Strategic Assessment Institute, 2016.

164 Batkins, 2016.

165 Jeffrey Tomich, "Former Exelon CEO Rowe: Shutting down struggling nukes is 'the proper market-driven answer'," EnergyWire, July 27, 2015. http://www.eenews.net/stories/1060022403

The unease of socially premature nuclear retirements should motivate political commitment for a market-based, long-term strategy that drives innovation, reduces emissions at least cost and bolsters reliability. This will benefit the American economy the most and prove far more politically durable than ad hoc policy. It will also serve as a model the world is more likely to follow.

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