

**UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION**

In the Matter of)	Docket Nos. 50-266 and 50-301
		NRC-2021-0021
NextEra Energy Point Beach, LLC)	
		March 23, 2021
(Point Beach Nuclear Plant, Units 1 and 2))	
)	

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DECLARATION OF MARK COOPER, PH. D.

Under penalty of perjury, I, Mark Cooper, declare as follows:

1. BACKGROUND

A. Biography

My name is Dr. Mark Cooper. I am a Senior Fellow for Economic Analysis at the Institute for Energy and the Environment at Vermont Law School. I hold a Ph.D. from Yale University. I am also Director of Research at the Consumer Federation of America, where I served for two decades as Director of Energy. I have testified over 400 times on energy and telecommunications issues at federal and state regulatory and legislative bodies in over forty jurisdictions in the U.S. and Canada. My *curriculum vitae* is attached to this Declaration as MNC-1.

I was asked by Physicians for Social Responsibility-Wisconsin to review the application for a 20 year subsequent operating license extension for NextEra Energy Point Beach, LLC's Point Beach Nuclear Plant, Units 1 and 2. Unit 1 would be extended from 2030 to 2050, and Unit 2 would be extended from 2033 to 2053. What follows are my observations and conclusions, offered to a reasonable degree of economic certainty based on my qualifications, experience and relevant information sources.

Although I have been analyzing the electricity sector in general and nuclear power, in particular, for over 35 years, in the past decade I have focused on the challenge of building a low cost, low carbon sector. In the first five years I focused on the construction of new nuclear reactors because the “nuclear renaissance” aspired to build dozens of huge, expensive reactors that, it was claimed, were extremely low carbon emitters that would anchor the electricity system for decades. I showed that new nuclear reactors were far from the least cost option around which to center a low carbon electricity sector by analyzing the economics of alternatives, efficiency and non-hydro renewable resources.

The “nuclear renaissance” evaporated, with billions of dollars wasted on abandoned plans and projects and is now reduced to a mere two reactors under construction and likely to be the most expensive source of electricity ever. For the past five years I have added a much more intensive analysis of how a 21st century low carbon electricity sector would be built and operated and have examined the role of aging reactors in the transition to that sector.

Attachment MNC-1 shows academic publications, testimony, and research reports I have authored in the past decade dealing with the electricity sector and the role of nuclear power in it, among the many topics I have analyzed and testified on over the years.

B. My Conclusion

With numerous articles, dozens of reports and pieces of testimony and a book, there is a mountain of material that could be reviewed. For the purpose of this analysis, I have included only updated versions of a few key general observations that represent the basic argument on and analysis of the transformation of the electricity system. General analyses apply to Wisconsin and all other states.

The bottom line is simple. Nuclear power is far too costly to include in a 21st century electricity system based on efficiency, distributed and renewable resources that deliver lower cost

and much less pollution while effectively decarbonizing the sector. Where I make a specific observation about Wisconsin, I include a data point for Wisconsin and one of the states I have looked at in detail, California, Illinois and New York. Every one of those analyses involved the extension of nuclear reactors beyond their economic life.

Adding Wisconsin to the list is a “no brainer.” Compared to these other states, Wisconsin is underperforming in efficiency and renewables. Under the purchased power agreement,¹ I estimate that compared to 21st century alternatives, ratepayers will bear unnecessary charges of about \$5 billion.

Of particular note is my recent book on the electricity sector (*The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Power Sector*).² In that book, I concluded a chapter entitled “The Nuclear War Against the Future” with the following observation on the role (or lack thereof) of nuclear power:

Once the direction of a least-cost route to a decarbonized economy is set by the superiority of renewables, it becomes impossible for nuclear power to participate in the ultimate portfolio. The idea of pursuing an “all-of-the-above” scenario runs afoul of the fundamental differences between the 20th-century baseload fossil fuel approach and 21st-century renewable energy approach. The two technologies simply do not mix well because nuclear is not flexible. The vigorous attack on renewables launched by advocates of nuclear power in an effort to secure favorable treatment of aging reactors is testimony to the incompatibility between the two...

This analysis leads to three interrelated recommendations for policymakers.

- Policy should move to quickly adopt the necessary institutional and physical infrastructure changes needed to transform the electricity system into the 21st-century approach.
- Policy should not subsidize nuclear reactors, old or new. In the long term, their large size and inflexible operation makes them a burden, not a benefit in the 21st-century system.

¹ Point Beach Nuclear Plant Power Purchase Agreement Between FPL Energy Point Beach, LLC and Wisconsin Electric Power Company, dated as of December 19, 2006, A-1.

² *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Power Sector*, Praeger, 2017.

- Nuclear's technological characteristics combined with the industry's political efforts to undermine the development of the 21st-century system makes nuclear a part of the problem, not the solution.³

In the four years since I reached those conclusions, the evidence supporting them has continued to mount in crucial aspects. The cost of alternatives has continued to plummet, while the cost of nuclear power has continued to rise. Confidence in the ability to manage a grid based on alternatives, distributed energy, and intense management and matching of supply and demand to meet needs has been demonstrated and has continued to grow at the conceptual and practical levels. Lower cost alternatives are increasingly available and their ability to reliably meet demand has been demonstrated.

Given this basic economic evidence of the prospective superiority of the alternatives, the great threat of maintaining the output of nuclear reactors is the obstacle they present to the development of the alternative. The longer they continue their massive, inflexible output with uneconomic subsidies, such as the Point Beach Purchased Power Agreement and/or unjustified preference in dispatch, the more difficult it is for the alternatives to take root and achieve their potential.

Nuclear power has always been uneconomic, more costly than the alternatives with which it is competing. However, the current problem of nuclear power is different and much greater. In the past, it was the least attractive of the alternatives, not only the most costly, but also the least flexible of the central station technologies. Nevertheless, it was part of the existing system. Today, it is not only too costly, but it is an obstacle to the development of a lower cost, more flexible 21st century system.

C. Testimony Outline

³ *Id.*, pp. 201-202

My testimony is organized as follows. In Section 2, I present an overview of the argument, addressing three issues: 1) the nature of the ongoing technological revolution in the electricity sector, 2) the threat and challenge that nuclear power poses to the transformation of the sector, and 3) the important policies that regulators involved in, or affected by, the decision to extend the license of Point Beach nuclear power station should implement to promote the transformation. In the remainder of this testimony I present the evidence that leads me to the conclusion.

In Section 3, I update the analysis of the cost of alternatives, which is the launchpad for consideration of whether Point Beach should be allowed to continue to operate. This discussion shows that the continued operation of Point Beach, not to mention an extension of its commercial operation, is unjustified.

In Section 4, I address the question of whether the 21st century approach to organizing the electricity sector that relies on alternative generation, demand reduction, and intense management of supply and demand can deliver reliable power. I begin with this focus on the alternative 21st century electricity system for the simple reason that it is necessary to correct the affliction from which the Licensee suffers, which I call “baseload myopia.” I conclude that the lead time necessary to ensure the operation of a 21st century system is more than adequate between now and 2030 (for Point Beach Unit 1) and 2033 (for Point Beach Unit 2), not to mention the two decades of operation during the license extension. Finally, I explain why nuclear power should play no role in the least cost, low-carbon, low-pollution, future electricity system.

In Section 5, I described the problems with nuclear power in general and small modular reactors in particular. Here I actually agree with the licensee, that building new nuclear reactors of any size is absurd as an economic proposition, as well as a carbon reduction strategy. I

explain why the large block of inflexible power that nuclear demands is a major obstacle to building the alternative system. The license extension creates a strategic overhang that the licensee will exploit in an effort to prevent its asset from being displaced.

2. THE TRANSITION TO A 21ST CENTURY ELECTRICITY SYSTEM

A. The Technological Revolution in the Electricity Sector

The potential transformation of the electricity system has been created by a technological revolution that has occurred over the past three decades. This revolution has resulted in a dramatic decline in the cost of alternative resources, a sustained decline in cost equal to decline in cost of any vital input in the history of the main technologies in past industrial revolutions. As shown in Attachment MNC-2, which is an update of the first figure I included in my recent book on the electricity sector, the costs of solar and batteries are projected to decline about 5 percent per year in the 30 years from 2000 to 2030. The cost of wind is estimated to decline by over 2 percent per year for the 50-years between 1980 and 2030. In contrast, the cost of nuclear power has increased by almost 3 percent per year over that same, 50-year period. Cost trends in the decade since the publication of the data on which the attachment is based reinforce and magnify those cost changes, as I discuss below.

While the cost of key generation resources (wind, solar and batteries) are important, there are also two key technological revolutions that have also taken place on the demand side. First and foremost the technologies of grid management, information, computer capacity, and advanced control technologies have made it possible to manage and integrate demand, matching it more closely with supply with much greater precision. This has directly lowered the costs of the system, but it has also yielded a transformation dividend, a reduction in the size of the system needed to meet demand. By replacing large units and dynamically managing the grid to better match supply and demand, a dividend of 15% or more is widely recognized and achieved.

It is also clear that the cost of efficiency, the use of technologies to lower energy consumption and therefore the cost of operating energy-consuming durable goods, has remained low for decades and there is every indication that the cost of efficiency is not rising. In fact, the same type of technological revolution has affected demand reduction, with the economically attractive opportunities expanding as new technologies convert what was known as “technical potential” into “economically attractive.”

As shown in Attachment MNC-2, an updated version of the first table of my book, the link between electricity consumption and economic growth has been broken. In contrast to the three decades after World War II (1950-1980) where electricity consumption per dollar of per capita GDP grew by almost 3 percent, the figure was flat between 1980 and 1995, and declined by 1.2 percent per year between 1995 and 2015. Between 2015 and 2019, it declined by 3% per year, in spite of very strong growth in GDP/capita.

B. The Threat of Nuclear Power to the Transformation of the Electricity Sector

Having described the potential of the alternatives, I will turn to the problem of nuclear power and the threat to the transformation it represents. The issue is not simply backing out coal and petroleum from our economy. The 21st century energy sector requires decentralized facilities that can be managed to dynamically match supply and demand, a shift away from central station facilities altogether. My research also shows that nuclear power is the antithesis of what is needed. Nuclear plants are the largest and least flexible of the current generation units. They are, and have always been, extremely expensive to build. As they age, they have become more costly to operate than the renewable resources entering the market. They are heavy users of water and raise numerous public health and environmental issues.

Promises that a new generation of “small modular” nuclear technologies will do better are doubtful at best. They will be much more expensive than the alternatives already available

and take decades to deploy. Their costs will likely create pressures to demand priority in dispatch, which frustrates flexibility. They leave serious doubts about security and pollution. Thus, nuclear power should be held to strict economic standards, without any subsidies. If it cannot compete on cost, it cannot be part of the 21st century energy sector.

C. Regulators Must Promote the Transformation by Blunting the Nuclear Threat

The Nuclear Regulatory Commission can play a key role in nullifying the threat of nuclear power by denying the license extension. It should reject the baseload power myopia from which the licensee suffers because it is obviously in the economic interest of the licensee to claim that only baseload power should be considered. However, it is not in the interest of the regulator, who is supposed to represent the public interest.

Ironically, the licensee is half right in this instance. It makes absolutely no sense to build new nuclear reactors, as discussed below. Large central station reactors, two of which are under construction in the U.S. and dozens of which have failed, are costly and difficult, taking a decade or more to build.

From the point of view of the transformation to a 21st century electricity sector, small modular reactors do not change things much and represent the same challenges.

- Small modular reactors have never been built in the U.S. and have experienced a classic doubling of costs projection before they get off the drawing board.
- They are likely to undergo even larger cost increases, if they ever go into construction.
- The idea of building 21 of them to replace the capacity of Point Beach is absurd.
- The decade or more it would take to build the fleet to replace Point Beach 1 and 2 will mean a great deal of reduction in emissions will be foregone.

However, while building new nuclear baseload is absurd, that is only the first step. Other options for replacing the aging reactors at Point Beach should be considered. At a minimum, the NRC should find the application deficient because it fails to consider the full range of

alternatives. If the utility refuses to accept the challenge of considering genuine alternatives that undoubtedly will be much less costly than operating two small, old reactors, or of building a fleet of new ones, the NRC should reject the license extension because it has no basis for licensing technologies that are grossly uneconomic and antithetical to the operation of an efficient, modern electricity system.

The state regulator has a role to play, too. The existing grossly expensive Point Beach Purchased Power Agreement that imposes billions of dollars of excess costs on Point Beach ratepayers is unconscionable. At a minimum state regulators should make it clear that no such above-market power purchase contract will be signed in the future. Moreover, the regulator should consider how to mitigate the impact of the current purchased power agreement. Above all, if the regulator has the obligation under state law to ensure consumers get the benefit of least cost power, that should trump any utility signed contract. Economic dispatch should take precedence.

3. THE ECONOMIC ADVANTAGE OF THE ALTERNATIVES

A. Supply-Side Costs

I begin the analysis with an update of the long-run cost of acquiring resources to meet demand. We should begin with the long run costs because that is where the system will end up. Short-run costs matter too, especially if they differ dramatically from long-run costs. If such a difference exists, then a trade-off must be made between short-run and long-run costs. It turns out that with respect to electricity resources at present, there is no difference and no need to make a trade off.

The economic dynamics of the electricity sector at the start of the 21st century have put immense pressure on nuclear power and central station generation in the United States and globally, pressure that ultimately falls on aging reactors. As Attachment MNC-4 shows, with

respect to long-run costs, at present the three main resources on which the 21st century electricity system relies – efficiency, onshore wind, and utility photovoltaics – are projected to be considerably lower in cost than central station generation, even without taking the reduction of pollution and carbon emission into account.

I use Lazard here,¹ as I have done since their first publication of levelized costs, a decade ago for a number of reasons.

- First and foremost, Lazard’s projections have tracked the actual development of costs over the past decade much more closely than others.
- From the outset, Lazard’s analysis included efficiency.
- Lazard’s was among the first of the comprehensive analyses to note the strong downward trend in the cost of solar and to begin arguing that solar was cost-competitive for peak power in some major markets.
- The analysis always included estimates for coal with carbon capture and storage, and later added an estimate for the cost of natural gas with carbon capture and storage.
- The analysis includes regional estimates for resources whose economics vary by location.
- The more recent analysis adds important storage technologies, utility-scale solar with storage, and utility-scale battery storage. It also presents a cost trend for storage that is similar to the trends from other renewable and distributed sources.
- The analysis always included natural gas peaking capacity costs and, in a recent analysis, added a cross-national comparison of peaking technologies that might displace gas as the peaker resource.
- The analysis has also recently added comparisons of carbon abatement costs, as the determination to deal with climate change has grown.
- Most recently, Lazard has made the case that new build alternatives are less costly than the operating (marginal) cost of traditional, central station facilities.

Therefore, selecting resources that minimize long-term costs are the same as resources selected to minimize short term costs.

I have added two sets of externality costs to Lazard’s estimates, the cost associated with non-carbon pollution and carbon emissions valued at \$30 per ton (which is the midpoint of the range used by Lazard in an analysis that shows that a price on carbon would “increase the LCOE

¹ Lazard, *Lazard’s Levelized Cost of Energy Analysis – Version 14.0*, October 2020,

[levelized cost of electricity] for certain conventional generation technologies above those of onshore wind and utility-scale solar.”² In fact, even without externalities, efficiency is the least cost option and wind and solar are much less costly than coal and nuclear, while they are competitive with gas combined cycle. The superiority of the key alternatives is strengthened when one considers a cost of carbon attributed to nuclear due to its extremely long construction period.

Beyond adding in the cost of externalities which makes the alternatives more attractive, there is a second factor implicit in Lazard’s analysis that leads to an underestimation of the cost of traditional central station technologies. As is the case with almost all cost estimates, Lazard uses a high capacity factor for all three of the traditional technologies, which is well above the actual average observed in the U.S. As a result, costs are underestimated. The lower capacity factor reflects reality. In the case of nuclear, the lifecycle experience of nuclear new builds that takes a decade to work the bugs out, lowers the lifetime load factor by 10 percent. In the case of coal and gas, the entry of renewables causes some facilities using conventional fuels to not be utilized.

Much the same conclusion emerges from the short-term analysis shown in the lower graph of attachment MNC-4. Lazard compares the full cost of new build wind or solar to the marginal cost of existing conventional generation. This is a very demanding comparison, since it is a comparison of all-in costs for alternatives to marginal costs for central station technologies. Nevertheless, the conclusion Lazard reaches is that “certain renewable energy generation technologies have an LCOE [levelized cost of electricity] that is competitive with the market cost of existing conventional generation.

² Id., p. 7.

To give a sense of a comparison that is “apples-to-apples,” marginal for both types of resources, I have included the estimate of the operating cost provided in the long-run analysis. Needless to say, renewables are very attractive. I have also included the cost of operating aging reactors as expressed in recent subsidy proceedings, at only their cost of operation. Necessary capital costs would increase their total near-term cost by almost 50%. I also note external costs, which should be included in the short term analysis, since there are emissions.

The point is that the short-term comparisons are not at odds with the long-term results. Since the alternatives are least cost in the long term and competitive in the short term there is no tradeoff necessary. The alternatives are preferable.

B. Demand-Side Savings

In the resource analysis I have included efficiency as the least cost resource. Estimates of the large potential for efficiency have been consistent for three decades, as shown in the upper graph of Attachment MNC-5. In the lower graph of Attachment MNC-5, the forward looking cost is about \$.03/kWh, below the backward looking cost.¹ The reason for the stable and slightly declining cost is learning by doing, economies of scale, and improving technology. There is also a significant reduction in electricity demand that occurs from the effect of shifting to decentralized technologies that better match supply and demand, which I call the transformation dividend. Thus, efficiency is cost competitive with the other alternatives and makes a substantial contribution to meeting need.

I have prepared a detailed analysis of the potential for efficiency and renewables to meet the need in analysis of New York, Illinois and California.² Given the performance and

¹ See Mark Cooper, *Energy Efficiency Performance Standards: Driving Consumer and Energy Savings in California*, California Energy Commission's Energy Academy, February 20, 2014, pp. 30-31, and the underlying studies.

² On New York see, Mark Cooper, *The Green New Deal, Nuclear Power and Other Potholes to avoid on the Road to a Progressive, Capitalist, Least Cost, Low Carbon, Clean, Electricity Sector*, April, 2019, pp. 31-37; On California and Illinois see, Cooper, *the Political Economy*

endowment of Wisconsin to exploit these various resources, I am confident that those conclusions apply here, as Attachment MNC-6 shows. The upper graph shows that each of the three states I have examined in detail rank higher on energy efficiency programs than Wisconsin. The right side of the table and the table and the graph show that Wisconsin is lagging and that all of the states can do much better.

4. OPERATING RELIABLE ALTERNATIVE SYSTEMS TO MEET DEMAND

Baseload myopia has been rejected on the basis of cost. Can it be salvaged by the claim that it is the only means of meeting the need for power at an affordable cost? The answer is an emphatic NO! The tools to meet demand with low cost, low carbon, low pollution resources are more than adequate and becoming increasingly available.

A. Integration Cost

Recalling the cost advantage that renewables enjoy today, and the even larger cost advantage that they are expected to enjoy in the mid-term, these factors make the 21st-century electricity system based on alternatives the least-cost approach in a low-carbon environment by a wide margin. The finding that the cost of the integration of distributed supply and actively managed demand are quite small enjoys a strong consensus in the literature.¹ It is reflected in the DOE analysis *Wind Vision*, which provides a simple explanation. The DOE *Wind Vision* analysis argues that “wind generation variability has a minimal and manageable impact on grid reliability and related costs.”² DOE believes that operational challenges that could arise with much higher levels of wind penetration can be easily overcome by expanding the use of techniques that have

of Electricity, pp. 169-201.

¹ Hannele Holttinen, *Design and Operation of Power Systems with Large Amounts of Wind Power*, Final Report, IEA Wind Task 25, 2009; Jing Wu et al., “Integrating Solar PV (Photovoltaics) in Utility System Operations: Analytical Framework and Arizona Case Study,” *Energy* 85 (2015); Jason Rauch, “Price and Risk Reduction Opportunities in the New England Electricity Generation Portfolio,” *Electricity Journal* 27 (2014).

² U.S. Department of Energy, *Wind Vision*, xxiii.

been found effective in the past. “Such challenges can be mitigated by various means including increased system flexibility, greater electric system coordination, faster dispatch schedules, improved forecasting, demand response, greater power plant cycling, and—in some cases—storage options.”¹ These highlight the impact and necessity of changes to the grid,² and the prospect of achieving reliability that equals or exceeds current levels with the alternative approach is increasingly seen as quite good.³

¹ U.S. Department of Energy, *Wind Vision*, xlii.

² For academic studies on system integration generally see, for example, Xi Lu *et al.*, “Optimal Integration of Offshore Wind Power for a Steadier, Environmentally Friendlier, Supply of Electricity in China,” *Energy Policy* 62 (2013): 131–138; P. Veena *et al.*, “Review of Grid Integration Schemes for Renewable Power Generation System,” *Renewable and Sustainable Energy Reviews* 34 (2014); N. Phuangpornpitak and S. Tia, “Opportunities and Challenges of Integrating Renewable Energy in Smart Grid System,” *Energy Procedia* 34 (2013); M. S. Jamel, A. Abd Rahman, and A. H. Shamsuddin, “Advances in the Integration of Solar Thermal Energy with Conventional and Non-Conventional Power Plants,” *Renewable and Sustainable Energy Reviews* 20 (2013); J. P. Chaves-Avila, R. A. Hakvoort, and A. Ramos, “The Impact of European Balancing Rules on Wind Power Economics and on Short-Term Bidding Strategies,” *Energy Policy* 68 (2014). On resource diversity, see for example, Tascikaraoglu, A., and M. Uzunoglu, “A Review of Combined Approaches for Prediction of Short-Term Wind Speed and Power,” *Renewable and Sustainable Energy Reviews* 34 (2014), Wolf D. Grossmann, Iris Grosssman, and Karl W. Seining, “Solar Electricity Generation Across Large Geographic Areas, Part II: A Pan-American Energy System Based on Solar,” *Renewable and Sustainable Energy Reviews* 32 (2014).

³ See for example, Martin I. Hoffert, “Farewell to Fossil Fuels?” *Science* 329 (2010); Bettencourt, Trancik, and Kaur, “Determinants of Pace”; Dalibor Petković *et al.*, “Adaptive Neuro-Fuzzy Maximal Power Extraction of Wind Turbine with Continuously Variable Transmission,” *Energy* 64 (2014); Toshiyuki Sueyoshi and Mika Goto, “Photovoltaic Power Stations in Germany and the United States: A Comparative Study by Data Envelopment Analysis,” *Energy Economics* 42 (2014); Ksenia Chmutina and Chris I. Goodier, “Alternative Future Energy Pathways: Assessment of the Potential of Innovative Decentralised Energy Systems in the UK,” *Energy Policy* 66 (2014); Trieu Mai *et al.*, “Envisioning a Renewable Electricity Future for the United States,” *Energy* 65 (2014); Katerina Tatiana Marques Santiago, Fernando Menezes Campello de Souza, and Diego de Carvalho Bezerra, “A Strong Argument for Using Non-Commodities to Generate Electricity,” *Energy Economics* 43 (2014); Erik Paul Johnson, “The Cost of Carbon Dioxide Abatement from State Renewable Portfolio Standards,” *Resource and Energy Economics* 36 (2014): 332–350; and Zheng and Daniel M. Kammen, “Innovation-Focused Roadmap.” There are a growing number of scenario analyses at the global level (Jacobson and Delucchi, “Technologies”; Jacobson *et al.*, “Examining the Feasibility of Converting New York State’s All-Purpose Energy Infrastructure to One Using Wind, Water and Sunlight,” *Energy Policy* 57 (2013); Delucchi and Jacobson, “Reliability”; Budischak *et al.*, “Cost-Minimized Combinations of Wind Power, Solar Power, and Electrochemical Storage, Powering the Grid up to 99.9% of the Time,” *Journal of Power*

In the early years of the transition, costs rise slightly because new generation resources are being deployed. The increasing cost of electricity is primarily the result of the need to replace aging and polluting generation with low-carbon alternatives, but “Wind generation variability has a minimal and manageable impact on grid reliability and related costs.”¹ The potential for extremely rapid balancing, innovative battery technologies, and microgrids, which address the core problem of reliability in the digital age, have only begun to be appreciated.² In sum, careful analysis shows that reliability is a nonissue; the conflict is about the future of the technoeconomic structure of the electricity sector in the 21st century.

The DOE explicitly laid out the process in the case of transmission.³ The *Wind Vision* analysis argues that transmission costs are constantly being incurred by the electricity system. In the early years, those costs are reallocated from supporting central station generation (which is shrinking) to supporting new renewable resources. There is only a slight net increase in transmission investment. As time goes on and the share of renewables grows, transmission costs increase. However, they are complementary to the deployment of renewables, whose capital and operating costs have been declining and are much lower than the nonrenewable, low-carbon alternatives.

B. System Values

The U.S. Energy Information Administration (EIA) recognized the increasing complexity of selecting generation resources as very different technologies began to compete for investment resources. It summarized the approach to system value at a workshop in 2013, where it argued

Sources 225 (2013); Mark A. Delucchi and Mark Z. Jacobson, “Meeting the World’s Energy Needs Entirely with Wind, Water, and Solar Power,” *Bulletin of the Atomic Scientists* 69 (2013); Cochran, Mai and Bazilian, “Renewable Energy Scenarios.”

¹ U.S. Department of Energy, *Wind Vision*, xv.

² Shrimali, Lynes and, Indvik, “Wind Energy Deployment,” 454, Allal M. Bouzid et al., “A Survey on Control of Electric Power Distributed Generation Systems for Micro Grid Applications,” *Renewable and Sustainable Energy Reviews* 44 (2015), 753.

³ U.S. Department of Energy, *Wind Vision*, xxxvi.

“that levelized cost of electricity (LCOE)...reflects both the capital and operating costs of deploying and running new utility-scale generation capacity... [but] the direct comparison of LCOE across technologies....is problematic and potentially misleading.”¹ The EIA analysis focused on a comparison of the marginal value to the system of individual resources and these calculations were added to its *Annual Energy Outlook*.²

Conceptually, a better assessment of economic competitiveness can be gained through consideration of avoided cost, a measure of what it would cost the grid to generate the electricity that is otherwise displaced by a new generation project, as well as its levelized cost. Avoided cost, which provides a proxy measure for the annual economic value of a candidate project, may be summed over its financial life and converted to a level annualized value that is divided by average annual output of the project to develop its “levelized” avoided cost of electricity (LACE). The LACE value may then be compared with the LCOE value.³

I call the difference between LCOE and LACE “inflexibility waste” to capture the key concept.⁴ The avoided cost is less than the levelized cost because resources are inflexible, i.e. unable to adapt their output to the needs of the system. The system cost would be lower if technologies that better fit system needs are used. Inflexibility waste can be lowered in two ways – reducing levelized cost or decreasing avoided costs (*i.e.*, a better fit between output and system needs).

After extensively discussing the EIA system value approach to improving comparisons between alternatives, analysts at two national laboratories (Lawrence Berkeley National Laboratory and Argonne), suggested an alternative approach that rested on system costs. The

¹ EIA, 2013, *Assessing the Economic Value of New Utility-Scale Electricity Generation Projects*, Workshop Discussion Paper: LCOE and LACE, July, p. 1.

² EIA, 2017, *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2017*, p.3

³ EIA, 2013, *Assessing the Economic Value of New Utility-Scale Electricity Generation Projects*, Workshop Discussion Paper: LCOE and LACE, July, p. 1.

⁴ Johnson, *et al.*, 2017, “A reduced-form approach for representing the impacts of wind and solar PV deployment on the structure and operation of the electricity system,” *Energy Economics* 64 estimate the system cost of ramping various resources as an “efficiency waste.” The concept of “inflexibility waste” would include that cost plus the cost of larger reserves made necessary by the need to be able to replace the largest unit on the grid..

levelized cost of energy was the starting point and the most important factor, as in the system value approach, but the adjustment made was not by subtracting avoided costs from LCOE, but by adding estimates of the unique system cost of individual technologies to the LCOE. The former is a top down approach, the latter is a bottom up approach and the authors caution against double counting by combining the two.

If properly defined, the ‘system cost’ of VRE [variable renewable electricity] (or any other resource) combined with the plant-level technology LCOE of VRE results in a ‘total system LCOE’, which can then be compared (with substantial caveats) to the ‘total system LCOE’ of any other technology to determine which resource has the lowest total system cost. An important point to make here is that this ‘system cost’ perspective is related to but distinct from the system value’ perspective described earlier. An analyst may choose to use the ‘system value’ perspective or the ‘system cost’ perspective, but it is important to avoid double counting. Moreover, as discussed in more depth later, all resources have ‘system costs’, and so an exclusive focus on VRE alone is inappropriate.¹

This approach was also advocated by a major research institution in Germany evaluating the aggressive transition to renewables being pursued in that nation.²

Attachment MNC-7 uses Lazard unsubsidized LCOE (from 2016) and also shows the operating and full costs of aging reactors developed earlier (\$6/kWh and \$9/kWh), rather than new nuclear reactors. The full cost is more appropriate.

To make a fair comparison between low carbon resources, I use the cost of natural gas combined cycle plants with 90% carbon capture. I have not included the cost of coal with 0% carbon capture because it is so far off the charts (50% higher than natural gas on LCOE) that it is not a contender and would distort the comparison between resources that should be considered for inclusion in the portfolio. Much the same is true of new nuclear, whose LCOE is more than twice gas, and whose carbon emissions are substantially higher than aging reactors because of

¹ Ryan, Wiser, Andrew Mills and Joachim Seel, 2017. *Impact of Variable Renewable Energy on Bulk Power System Assets, Pricing and Costs*, Argonne and Lawrence Berkeley National Laboratories, pp. 81-82.

² Agora, Energiwende, *The Integration Costs of Wind and Solar Power: an Overview of the Debate on the Effects of Adding Wind and Solar Photovoltaic into Power Systems*, 2015.

the long construction period and intensive carbon emissions of construction. The LCOE costs are adjusted for EIA's estimate of system value, so the figure shows avoided cost.

I also include energy efficiency with the current LCOE of \$35/MWh. I attribute system costs to efficiency equal to those for hydro, which is given a slight benefit in the EIA analysis.¹ Given all of the positive attributes of efficiency discussed above, this approach is likely to underestimate its benefit in terms of system costs.

The compelling conclusion of this analysis is quite clear, the renewables are preferable by far and all of the underlying trends reinforce these conclusions.² Renewable resource costs continue to fall, particularly for batteries, which would sharply increase their system value. Other advances in integration of renewables will also improve their value. In contrast, nuclear construction costs continue to rise.³

C. Tools to achieve Low Cost, Reliable Power

Attachments MNC-8 and MNC-9 show the many tools available to achieve low cost and reliable supply. I have included references to some of the extensive literature that supports the supply-side and demand-side tools. I treat storage as a demand-side strategy. This is unarguably true for distributed storage, although less so for dispatchable storage. Both are key to balancing

¹ This is consistent with Karier, Tom and John Fazio, 2017, "How hydropower enhances the capacity value of renewables and energy efficiency," *The Electricity Journal*, Vol. 30, Table 3 shows efficiency with much higher capacity values than natural gas. Johnson, 2017, *et al.* show gas with a 14% efficiency penalty. Resources available on-peak without ramping have capacity values of 1 and efficiency penalties of zero. All of these values suggest efficiency is a 1 on capacity and a zero on efficiency penalty.

² A study by researchers at the Columbia University Center on Global Energy Policy applied this approach to the underlying EIA LCOE, Keith J. Benes, and Caitlin Augustin, 2016. "Beyond LCOE: A simplified framework for assessing the full cost of electricity," *The Electricity Journal*, Vol. 29 (8). Since the earlier EIA costs were out of touch with reality, the analysis leads to erroneous conclusions, although the impact of other system costs points to the same conclusions as in the above analysis.

³ The disruption of the transformation is one of the most important harms of extending the life of central station facilities, note by Lovins, A. *Do Coal and Nuclear Deserve Above-Market Prices?*, *The Electricity Journal*, Vol. 30, Issue 6, July 2017, pp. 22-30.

load and supply. Attachments MNC-8 and MNC-9 give primarily academic and trade literature citations. When pressed, utilities give the same answers.

California held a proceeding that challenged parties to think about how high levels of renewables could be integrated into the grid. Utilities offered a host of approaches and my summary concluded there were at least ten general ways to handle the challenge.¹

1. Geographic diversity, particularly for wind, reduces extremes of generation, high or low output.
2. Technological diversity fosters a better fit with load.
3. Exploiting the best sites for renewable resources yields much larger economic value—three times the average.
4. Storage allows more energy to be captured and used when needed, both by reducing curtailment and by increasing demand (and therefore prices) during slack periods.
5. Demand shaping allows a better balance between supply and demand.
 - Demand reduction overall, and at the peak, through both reduction and load shifting.
 - Avoided capital cost in generation, transmission, and distribution.
 - Efficiency through reduction of line losses, reduced congestions, and transmission reinforcement.
 - Ancillary services by providing reserve support for energy, standby, and balancing.
6. Flexibility is a key attribute, achieved by
 - sub-hourly scheduling to reduce the magnitude and impact of forecasting error,
 - “quick start” generation, or
 - a portfolio approach that uses a mix of generation assets that can reduce the need for flexibility of individual assets.
7. Increasing regional coordination to create a large potential export market for excess energy.
8. Implementing a long-term, sustainable solution to address over-generation before the issue becomes more challenging with
 - promising technologies like storage (solar thermal with energy storage, pumped storage, other forms of energy storage including battery storage, electric vehicle charging, thermal energy storage) and
 - flexible loads that can increase energy demand during daylight hours (advanced demand response and flexible loads).
9. Optimizing the thermal generation fleet under high RPS [renewable portfolio standard].
10. A wide range of opportunities is opening up that can eliminate the wall between supply and demand behind which the 20th-century baseload model was built. Doing so re-

¹ Cooper, Green New Deal, *ibid*.

lies on the interrelationship of battery powered vehicles and the smart grid, the Internet of things, and having multiple roles for solar power.

The utility study identifies four “least regrets opportunities,” and a number of opportunities for “research and development for technologies to address over-generation.”¹ The transformation dividend is present in the utility analysis, which is equal to 10 percent of the capacity in the “unmitigated” PV system, and 15 percent of the capacity in the “mitigated” PV system.² This is consistent with the general finding of a transformation benefit.

I include these lengthy exhibits not only to show how much thinking has already gone into deployment of a new system, but also to underscore a simple fact. The Point Beach licensee refused to consider these remarkable developments because of its baseload myopia, which is unacceptable. If it wants to challenge the ability of the alternative system to meet need on a reliable basis, it can do so, although experience shows it will fail. It simply cannot ignore these developments, nor should the regulators at the federal and state levels.

5. NUCLEAR NIGHTMARES

A. The Fundamental Conflict

¹ E3, 2015. *Higher Renewables Portfolio Standard, E3. Investigating a Higher Renewables Portfolio Standard in California*. Energy and Environmental Economics, Inc., January, 2015. The four “least regrets” opportunities identified in this study include: “1. Increase regional coordination, 2. Pursue a diverse portfolio of renewable resources, 3. Implement a long-term, sustainable solution to address overgeneration before the issue becomes more challenging, 4. Implement distributed generation solutions.” Additional measures are from Mills and Wiser, *Strategies for Mitigating*, put costs in the \$5-\$10/MWh range; Andrew Mills and Ryan Wiser, *Implications of Wide-Area Geographic Diversity for Short-Term Variability of Solar Power*, Lawrence Berkeley National Laboratory, 2010.

² Jim Lazar, Teaching the “Duck” to Fly, Regulatory Assistance Project, January 2014; Steve Nadel, Conquering the Evening Peak, ACEEE, 2014. Mills AD, Wiser RH. 2015, Strategies to mitigate declines in the economic value of wind and solar at high penetration in California. *Applied Energy* 147:269--278; E3, 2015. *Higher Renewables Portfolio Standard, E3. “Investigating a Higher Renewables Portfolio Standard in California,”* Energy and Environmental Economics, Inc., January, 2015; Staff White Paper, NYSERDA Energy Efficiency and Renewable Energy Potential Study of New York State, puts the figure at 10%.

The economic conflict of interest between nuclear power and the lower-cost, low-carbon alternatives is not limited to the cost of nuclear power. It is reinforced by fundamental differences between central station power and distributed resources, both in terms of technological competence and institutional requirements. Lovins elaborated earlier on these deep-seated sources of conflict, making it clear that a truce that tries to accommodate both sides is neither very likely, nor good policy.¹

In short, this clash is inevitable and has given rise to a frontal assault by nuclear advocates on alternative resources and the institutions that support them. Responsible policymakers should reject the “all of the above” argument because the severely restricted market created by the forced presence of nuclear power will strangle the ability of non-hydro renewables to expand, which is likely to drive the market clearing price down, as resources compete for a smaller market. The nuclear carve out forces renewables to compete with much lower priced gas. If there had been no nuclear carve out, renewables could have competed for and won this load in an orderly fashion, avoiding another “crisis” at the termination of the

¹ Amory B. Lovins and Rocky Mountain Institute, *Reinventing Fire: Bold Business Solutions for the New Energy Era* (Boulder, CO: Rocky Mountain Institute, 2011), 216, “‘All of the above’ scenarios are . . . undesirable for several reasons. . . . First, central thermal plants are too inflexible to play well with variable renewables, and their market prices and profits drop as renewables gain market share. Second, if resources can compete fairly at all scales, some and perhaps much, of the transmission built for a centralized vision of the future grid could quickly become superfluous. Third, big, slow, lumpy costly investments can erode utilities and other provider’s financial stability, while small, fast granular investments can enhance it. Competition between those two kinds of investments can turn people trying to recover the former investments into foes of the latter—and threaten big-plant owners’ financial stability. Fourth, renewable, and especially distributed renewable, futures require very different regulatory structures and business models. Finally, supply costs aren’t independent of the scale of deployment, so PV systems installed in Germany in 2010 cost about 56–67 percent less than comparable U.S. systems, despite access to the same modules and other technologies at the same global prices.”

current subsidy, a “crisis” that the industry will inevitably invoke to demand another round of subsidies.¹

B. Small Modular Reactors Do Not Solve the Problem

Small modular reactors are the latest in a long line of technologies that the advocates of nuclear power hope will be provide answers to the many problems that have afflicted their industry. Hyped as the dream solution, they turn into a nightmare. Small modular reactors that have been on the drawing board for at least a decade exhibit all of the characteristics of failure. Like the “nuclear renaissance” before it, the initial estimates of cost have doubled before they go into construction and cost overruns really only begin when construction does. While they can find companies to back them and governments to support them, and academics to explain the theory of why they should work, the one thing they cannot do is deliver low cost power.

While they claim to be safer than large units, they achieve that goal not by solving safety problems, but by being excused from safety rules (like exclusion zones). While they are low in carbon emissions during operation, they suffer from the problem that, even if the production of small units will be possible in the future, they will arrive long after the battle against climate change is lost. While they are small, they still need “must run” status and large numbers of units shipped in order to lower their cost. Small modular reactors are likely to be between three and five times as costly as the already available technologies to build a low cost, low carbon, low pollution electricity sector. As Ramana recently put it,

¹ Lovins, *Do coal and nuclear, ibid.*.. rebuts the argument for nuclear subsidies showing that “All 14 current rationales for mandating or subsidizing uncompetitive coal and nuclear plants lack technical merit or would favor competitors instead. Subsidizing distressed nuclear plants typically saves less carbon than closing them and reinvesting their saved operating cost into severalfold-cheaper efficiency. Carbon prices, not plant subsidies, best recognize decarbonizing attributes. Grid reliability needs careful integration of diverse, distributed demand-side and renewable resources, using competitive market processes and resilient architectures, but does not require ‘baseload’ plants.

The estimated costs of the NuScale reactor design have been consistently going up. Just in the last five years, the estimated construction cost has gone up from around \$3 billion in 2015 to \$6.1 billion in 2020. Because the NuScale design might have to be modified to resolve the problems flagged by the Nuclear Regulatory Commission, there could be further cost increases even before construction starts. There is a long history of dramatic cost increases when paper designs are first constructed.¹

Attachment MNC-10 describes the SMR cost problem. It updates my 2014 analysis by including two recent estimates. I have included the current estimate for the only active small modular reactors project. The high cost of nuclear power is apparent and there is nothing in the small modular reactor technology that suggests it will result in a cost revolution for nuclear. Using the math of the vendor, the first cost estimate was put at \$0.055/kWh, so the current estimate is about twice that before construction cost overruns. In other words, it is at least 3 times as costly as the bundle of alternatives (efficiency, wind and solar) and likely to be even more if construction takes place. The economic failure of SMR technology should be the end of nuclear power, since a low-cost, low-carbon, low-pollution electricity system, in which it can play no role, should be in place before any of these reactors are constructed.

C. Subsidizing Aging Reactors is Also the Wrong Approach

The final chapter of the nuclear nightmare is the one on which the Point Beach Licensee would like the NRC to bet. Since the Licensee accepts the fact that it makes no sense to try to build new nuclear reactors to replace Point Beach, it concludes that it is best to extend its license for twenty years. Unfortunately for nuclear advocates, extending the lives of old reactors makes no more sense than new builds. The economic subsidy necessary to keep these aging reactors on line is massive.

¹ M. V. Ramana, 2020, *Eyes Wide Shut: Problems with the Utah Associated Municipal Power Systems Proposal to Construct NuScale Small Modular Nuclear Reactors*, Oregon Physicians for Social Responsibility, September.

Attachment MNC – 11 makes this point. It overlays the “guaranteed” price for power from the Point Beach purchased power agreement on a recent analysis I did of the operating cost of aging reactors. I include the earlier analysis, since we do not know the operating cost of Point Beach, but it fits well within the range I had earlier estimated. The obvious implication of the analysis is that the purchased power agreement is totally uneconomic. In 2020, the price is \$20/MWh higher than the bundle of alternatives analyzed above. The overcharge mounts steadily to almost \$100/MWh through 2030. The average excess is \$55/MWh. The cumulative excess cost imposed on ratepayers is almost \$5 billion for the period ending in 2030, which works out to over \$3,000 per electricity customer, or \$300 per year. .

With \$5 billion and the remaining time between the early-2030s expirations of Point Beach Units 1 and 2, the net expected power generation from the plant during that period could be completely obviated by construction of renewables and implementation of efficiency. Given current cost of alternatives, the output of Point Beach would cost ratepayers over twice as much as a least cost, low carbon, low pollution approach. Thus, the purchased power agreement for Point Beach imposes enormous excess costs on Point Beach ratepayers and is unconscionable. By 2030 and 2033, but for the PPA, efficiency and renewable energy sources could have expanded and displaced this myopic baseload power plant. By 2030, Point Beach Units 1 and 2 will be completely redundant and obsolescent.

March 23, 2021

Date



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Senior Fellow for Economic Analysis, Institute for Energy and the Environment, Vermont Law School 2009-present

Associated Fellow, Columbia Institute on Tele-Information, 2003-2016

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Fellow, Silicon Flatirons, University of Colorado, 2009-2014

Fellow, Stanford Center on Internet and Society, 2000-2010

Principle Investigator, Consumer Energy Council of America, Electricity Forum, 1985-1994

Director of Energy, Consumer Federation of America, 1984-1986

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Consultant, Office of Policy Planning and Evaluation, Food and Nutrition Service, United States Department of Agriculture, 1981-1984

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Technical Manager, Economic Analysis and Social Experimentation Division, Applied Management Sciences, 1979

Research Associate, American Research Center in Egypt, 1976-1977

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Lecturer, Washington College of Law, American University, Spring, 1984 - 1986, Seminar in Public Utility Regulation

Guest Lecturer, University of Maryland, 1981-82, Energy and the Consumer, American University, 1982, Energy Policy Analysis

Assistant Professor, Northeastern University, Department of Sociology, 1978-1979, Sociology of Business and Industry, Political Economy of Underdevelopment, Introductory Sociology, Contemporary Sociological Theory; College of Business Administration, 1979, Business and Society

Assistant Instructor, Yale University, Department of Sociology, 1977, Class, Status and Power

Teaching Assistant, Yale University, Department of Sociology, 1975-1976, Methods of Sociological Research, The Individual and Society

Instructor, University of Maryland, Department of Sociology, 1974, Social Change and Modernization, Ethnic Minorities

Instructor, U.S. Army Interrogator/Linguist Training School, Fort Hood, Texas, 1970-1971

PROFESSIONAL ACTIVITIES:

Member, Advisory Committee on Appliance Efficiency Standards, U.S. Department of Energy, 1996 - 1998

Member, Energy Conservation Advisory Panel, Office of Technology Assessment, 1990-1991

Fellow, Council on Economic Regulation, 1989-1990

Member, Increased Competition in the Electric Power Industry Advisory Panel, Office of Technology Assessment, 1989

Participant, National Regulatory Conference, The Duty to Serve in a Changing Regulatory Environment, William and Mary, May 26, 1988

Member, Subcommittee on Finance, Tennessee Valley Authority Advisory Panel of the Southern States Energy Board, 1986-1987

Member, Electric Utility Generation Technology Advisory Panel, Office of Technology Assessment, 1984 - 1985

Member, Natural Gas Availability Advisor Panel, Office of Technology Assessment, 1983-1984
 Participant, Workshop on Energy and the Consumer, University of Virginia, November 1983
 Participant, Workshop on Unconventional Natural Gas, Office of Technology Assessment, July 1983
 Participant, Seminar on Alaskan Oil Exports, Congressional Research Service, June 1983
 Member, Thermal Insulation Subcommittee, National Institute of Building Sciences, 1981-1982
 Round Table Discussion Leader, The Energy Situation: An Open Field For Sociological Analysis, 51st Annual Meeting of the Eastern Sociological Society, New York, March, 1981
 Member, Building Energy Performance Standards Project Committee, Implementation Regulations Subcommittee, National Institute of Building Sciences, 1980-1981
 Participant, Summer Study on Energy Efficient Buildings, American Council for an Energy Efficient Economy, August 1980
 Member, University Committee on International Student Policy, Northeastern University, 1978-1979
 Chairman, Session on Dissent and Societal Reaction, 45th Annual Meeting of the Eastern Sociological Society, April, 1975
 Member, Papers Committee, 45th Annual Meeting of the Eastern Sociological Society, 1975
 Student Representative, Programs, Curricula and Courses Committee, Division of Behavioral and Social Sciences, University of Maryland, 1973-1974
 President, Graduate Student Organization, Department of Sociology, University of Maryland, 1973-1974

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Ester Peterson Award for Consumer Service, 2010
 American Sociological Association, Travel Grant, Uppsala, Sweden, 1978
 Fulbright-Hayes Doctoral Research Abroad Fellowship, Egypt, 1976-1977
 Council on West European Studies Fellowship, University of Grenoble, France, 1975
 Yale University Fellowship, 1974-1978
 Alpha Kappa Delta, Sociological Honorary Society, 1973
 Phi Delta Kappa, International Honorary Society, 1973
 Graduate Student Paper Award, District of Columbia Sociological Society, 1973
 Science Fiction Short Story Award, University of Maryland, 1973
 Maxwell D. Taylor Award for Academic Excellence, Arabic, United States Defense Language Institute, 1971
 Theodore Goodman Memorial Award for Creative Writing, City College of New York, 1968
 New York State Regents Scholarship, 1963-1968
 National Merit Scholarship, Honorable Mention, 1963

PUBLICATIONS:

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"Affidavit of Mark N. Cooper on Behalf of the Consumer Federation of America," before the Public Utilities Commission of the State of California, Rulemaking on the Commission's Own Motion to Govern Open Access to Bottleneck Services and Establish a Framework for Network Architecture Development of Dominant Carrier Networks, Investigation on the Commission's Own Motion Into Open Access and Network Architecture Development of Dominant Carrier Networks, Order Instituting Rulemaking on the Commission's Own Motion Into Competition for Local Exchange Service, Order Instituting, R. 93-04-003, I.93-04-002, R. 95-04-043, R.85-04-044. June 1998.

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"Direct Testimony of Mark Cooper on Behalf of Residential Consumers," In the matter of the Investigation on the Commission's own motion into any and all matters relating to access charge reform including, but not limited to high cost or Universal Service funding mechanisms relative to telephone and telecommunications services within the state of Indiana pursuant to IC-8-1-2-51, 58, 59, 69; 8-1-2.6 Et Sec., and other related state statutes, as well as the Federal Telecommunications Act of 1996 (47 U.S.C.) Sec. 151, Et. Sec., before the Indiana Utility Regulatory Commission, April 14, 1998

"Affidavit of Mark N. Cooper on Behalf of the Texas Office of Public Utility Counsel," In the matter of Application of SBC. Communications Inc., Southwestern Bell Telephone Company Service Inc., d/b/a Southwestern Bell Long Distance, for Provision of In-Region InterLATA Service Texas, Public Utility Commission of Texas, Project 16251, April 1, 1998

"Comments of The Consumer Federation of America," Re: Case 97-021 - In the Matter of Petition of New York Telephone Company for approve of its statement of generally accepted terms and conditions pursuant to Section 252 of the Telecommunications Act of 1996 and Draft Filing of Petition for InterLATA Entry pursuant to Section 271 of the Telecommunications Act of 1996, before the State of New York, Public Service Commission, March 23, 1998.

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“Policies to Promote Universal Service and Consumer Protection in the Transition to Competition in the Electric Utility Industry,” Regulatory Flexibility Committee, Indiana General Assembly, September 9, 1997

“Reply Testimony of Dr. Mark N. Cooper on Behalf of the Attorney General of Arkansas,” In the Matter of Rulemaking Proceeding to Establish Rules and Procedures Necessary to Implement the Arkansas Universal Service Fund, Arkansas Public Service Commission, Docket No. 97-041-R, July 21, 1997

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“Direct Testimony of Dr. Mark N. Cooper on Behalf of Kentucky Youth Advocate, Inc.,” In the Matter of Inquiry into Universal Service and Funding Issues, before the Public Service Commission Commonwealth of Kentucky, Administrative Case NO. 360, July 11, 1997

“Direct Testimony of Dr. Mark N. Cooper on Behalf of the Office of Public Utility Counsel, Application of Southwestern Bell Telephone Company for Non-Rate Affecting Changes in General Exchange Tariff, Section 23, Pursuant to PURA95 s.3.53 (D), before the Public Utility Commission of Texas, July 10, 1997

“Testimony of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons,” Application of Pennsylvania Power and Light Company for Approval of its Restructuring Plan Under Section 2806 of the Public Utility Code, Pennsylvania Public Utility Commission, Docket No. R-00973954, July 2, 1997

“Testimony of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons,” Application of PECO Company for Approval of its Restructuring Plan Under Section 2806 of the Public Utility Code, Pennsylvania Public Utility Commission, June 20, 1997

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“Statement of Dr Mark N. Cooper,” Project on Industry Restructuring, Public Utility Commission of Texas, Project No. 15000, May 28, 1996

“Direct Testimony of Dr. Mark N. Cooper Submitted on behalf of The American Association of Retired Persons, before the Public Service Commission, State of New York, In the Matter of Competitive Opportunities Case 94-E-0952 New York State Electric and Gas Co. 96-E-0891; Rochester Gas and Electric Corp. 96-E-0898 Consolidated Edison Company of New York, Inc. 96-E-0897

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“Direct Testimony of Dr. Mark N. Cooper, on Behalf of New York Citizens Utility Board, the Consumer Federation of America, the American Association of Retired Persons, Consumers Union, Mr. Mark Green, Ms. Catherine Abate, the Long Island Consumer Energy Project,” before the Public Service Commission, State of New York, Proceeding on Motion of the Commission as the Rates, Charges, Rules and Regulations of New York Telephone Company, NYNEX Corporation and Bell Atlantic Corporation for a Declaratory Ruling that the Commission Lacks Jurisdiction to Investigate and Approve a Proposed Merger Between NYNEX and a Subsidiary of Bell Atlantic, or, in the Alternative, for Approval of the Merger, Case 96-c-603, November 25, 1996

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“Responses of Dr. Mark N. Cooper on Behalf of the Attorney General of Oklahoma,” In the Matter of the Rulemaking by the Oklahoma Corporation Commission to Establish Rules and Regulations Concerning Universal Service, Cause NO. RM 96000015, May 29, 1996

“Statement of Dr. Mark N. Cooper on Behalf of the Attorney General of Oklahoma,” In the Matter of the Oklahoma Corporation Commission to Establish Rules and Regulations Concerning Pay Telephones, Cause NO. RM 96000013, May 1996

“Statement of Dr. Mark N. Cooper on Behalf of the Attorney General of Oklahoma,” In the Matter of An Inquiry by the Oklahoma Corporation Commission into Alternative Forms of Regulation Concerning Telecommunications Service, Cause NO. RM 950000404

“Statement of Dr. Mark N. Cooper to the System Benefits Workshop,” Project on Industry Restructuring, Project No. 15000, before the Public Utility Commission of Texas, May 28, 1996

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"Reply Comments and Proposed Rules of the Oklahoma Attorney General," Before the Corporation Commission of the State of Oklahoma, In the Matter of the Rulemaking of the Oklahoma Corporation Commission to Establish Rules and Regulations for Local Competition in the Telecommunications Market, Cause No. RM 950000019, October 25, 1995

"Remarks of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons to the Members of the Executive Committee," Indiana Utility Regulatory Commission, in the Matter of the Investigation on the Commission's Own Motion into Any and All Matters Relating to Local Telephone Exchange Competition Within the State of Indiana, Cause No. 39983, September 28, 1995

"Direct Testimony of Dr. Mark N. Cooper on Behalf of the Office of Public Utility Counsel," before the Public Utility Commission of Texas, Petition of MCI Telecommunications Corporation for an Investigation of the Practices of Southwestern Bell Telephone Company Regarding the 713 Numbering Plan Area and Request for a Cease and Desist Order Against Southwestern Bell Telephone Company, SOAH Docket No. 473-95-1003, September 22, 1995

"Rebuttal Testimony of Dr. Mark N. Cooper on Behalf of the Office of the Attorney General State of Arkansas," Before the Arkansas Public Service Commission, In the Matter of an Earnings Review of GTE Arkansas Incorporated, Docket NO. 94-301-U, August 29, 1995

"Direct Testimony of Dr. Mark N. Cooper on Behalf of the Office of Public Utility Counsel," before the Public Utility Commission of Texas, Petition of MCI Telecommunications Corporation for an Investigation of the Practices of Southwestern Bell Telephone Company Regarding the 214 Numbering Plan Area and Request for a Cease and Desist Order Against Southwestern Bell Telephone Company, Docket NO. 14447, August 28, 1995

"Direct Testimony of Mark N. Cooper On Behalf of the Office of the People's Counsel of the District of Columbia," Before the Public Service Commission of the District of Columbia, In the Matter of Investigation Into the Impact of the AT&T Divestiture and Decisions of the Federal Communications Commission on the Chesapeake and Potomac Telephone Company's Jurisdictional Rates, July 14, 1995

"Comments of Consumer Action and the Consumer Federation of America," Before the Public Utilities Commission of California, Order Instituting Rulemaking on the Commission's Own Motion into competition for Local Exchange Service, Docket Nos. R. 95-04-043 and I. 95-04-044, May 23, 1995

"Testimony of Dr. Mark N. Cooper on Behalf of the Arkansas Attorney General," before the Arkansas Public Service Commission, In the Matter of an Earnings Review of Southwestern Bell Telephone Company, Docket NO. 92-260-U, April 21, 1995

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"Direct Testimony and Exhibits of Dr. Mark N. Cooper on Behalf of the Division of consumer Advocacy," In the Matter of Public Utilities Commission Instituting a Proceeding on Communications, Including an Investigation of the Communications Infrastructure in Hawaii, docket No. 7701, March 24, 1995

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"Statement of Dr. Mark N. Cooper," DPUC Exploration of Universal Service Policy Options, Docket No. 94-07-08, November 30, 1994

"Statement of Dr. Mark N. Cooper," DPUC Investigation of Local Service Options, including Basic Telecommunications Service Policy Issues and the Definition of Basic Telecommunications Service, Docket No. 94-07-07, November 15, 1994

"Testimony of Dr. Mark N. Cooper on Behalf of Attorney General of the Commonwealth of Kentucky, Utility and Rate Intervention Division, before the Public Service Commission, Commonwealth of Kentucky, Case No. 94-121, August 29, 1994

"Testimony of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons," before the Public Utilities Commission of Ohio, In the Matter of the Application of the Ohio Bell Telephone Company for Approval of an Alternative Form of Regulation and In the Matter of the Complaint of the Office of Consumers' Counsel, v. Ohio Bell Telephone Company, Relative to the Alleged Unjust and Unreasonable Rates and Charges, Case Nos. 93-487-TP-ALT, 93-576-TP-CSS, May 5, 1994

"Reply Testimony of Dr. Mark N. Cooper on Behalf of the Attorney General of Arkansas," before the Arkansas Public Service Commission, in the Matter of the Consideration of Expanded Calling Scopes and the Appropriate NTS Allocation and Return on Investments for the Arkansas Carrier Common Line Pool, Docket No. 93125-U, May 4, 1994

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"Comments of Dr. Mark N. Cooper on Behalf of Consumers Union, Southwest Regional Office, before the Public Utility Commission of Texas, Request for Comments on the Method by which Local Exchange Services are Priced, Project No. 12771, April 18, 1994

"Comments of Dr. Mark N. Cooper on Behalf of the American Association of Retired Persons," Before the Tennessee Public Service Commission, Inquiry for Telecommunications Rule making Regarding Competition in the Local Exchange, Docket No. 94-00184, March 15, 1994

"Rebuttal Testimony of Dr. Mark N. Cooper on Behalf of the Virginia Citizens Consumer Council, Inc., before the State Corporation Commission at Richmond, Commonwealth of Virginia, In the Matter of Evaluating Investigating the Telephone Regulatory Case No. PUC930036 Methods Pursuant to Virginia Code S 56-235.5, March 15, 1994

"Testimony of Dr. Mark N. Cooper on Behalf of the Virginia Citizens Consumer Council, Inc., before the State Corporation Commission at Richmond, Commonwealth of Virginia, In the Matter of Evaluating Investigating the Telephone Regulatory Case No. PUC930036 Methods Pursuant to Virginia Code S 56-235.5, February 8, 1994

"Testimony of Dr. Mark N. Cooper on Behalf of The American Association of Retired Persons, Citizen Action Coalition, Indiana Retired Teachers Association, and United Senior Action, before the Indiana Utility Regulatory Commission, Cause No. 39705, December 17, 1993

"Testimony of Dr. Mark N. Cooper on Behalf of the Virginia Citizens Consumer Council, Inc.," before the State Corporation Commission at Richmond, Commonwealth of Virginia, In the Matter of Evaluating the Experimental Plan for Alternative Regulation of Virginia Telephone Companies, Case No. PUC920029, October 22, 1993

"Testimony of Dr. Mark N. Cooper on Behalf of the Attorney General," before the Arkansas Public Service Commission, In the Matter of An Earnings Review of Southwestern Bell Telephone Company, Docket No. 92-260-U, 93-114-C, August 5, 1993

"Rebuttal Testimony of Dr. Mark N. Cooper on Behalf of the Attorney General," before the Public Service Commission of the State of Missouri, The Staff of the Missouri Public Service Commission vs. Southwestern Bell Telephone and Telegraph Company, Case No. TO-93-192, April 30, 1993

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"Direct Testimony of Dr. Mark N. Cooper on Behalf of the People's Counsel," before the Florida Public Service Commission, Comprehensive Review of the Revenue Requirement and Rate Stabilization Plan of Southern Bell Telephone and Telegraph Company, Docket No. 900960-TL, November 16, 1992

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"Testimony of Dr. Mark N. Cooper On Behalf of the Consumer Advocate," before the Public Service Commission of South Carolina, Petition of the Consumer Advocate for the State of South Carolina to Modify Southern Bell's Call Trace Offering, Docket No. 92-018-C, August 5, 1992

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"Testimony of Dr. Mark N. Cooper on Behalf of the Consumer Federation of America," before the Corporation Commission of the State of Oklahoma, In the Matter of the Corporation Commission's Notice of Inquiry Regarding Telecommunications Standards in Oklahoma, Cause No. PUD 1185, February 28, 1992

"Testimony of Dr. Mark N. Cooper on Behalf of the Consumer Federation of America," before the Georgia Public Service Commission, In the Matter of A Southern Bell Telephone and Telegraph Company Cross-subsidy, Docket No. 3987-U, February 12, 1992

"Testimony of Dr. Mark N. Cooper on Behalf of the Consumer Federation of America," before the Arkansas Public Service Commission, in the Matter of an Inquiry into Alternative Rate of Return Regulation for Local Exchange Companies, Docket No. 91-204-U, February 10, 1992

"Statement on Behalf of the Consumer Federation of America on HB 1076," before the Missouri General Assembly, January 29, 1992

"Testimony on behalf of the American Association of Retired Persons and the Consumer Federation of America," before the Legislative P.C. 391 Study Committee of the Public Service Commission of Tennessee, January 13, 1992

"Direct Testimony on Behalf of the "Consumer Advocate," Public Service Commission State of South Carolina, In the Matter of the Application of Southern Bell Telephone and Telegraph Company for Approval of Revision to its General Subscribers Service Tariff (Caller ID), Docket No. 89-638-C, December 23, 1991

"Comments of the Consumer Federation of America on Proposed Telecommunications Regulation in New Jersey (S36-17/A-5063)," New Jersey State Senate, December 10, 1991

"Comments of the Consumer Federation of America," Before the Public Service Commission, State of Maryland, In the Matter of a Generic Inquiry by the Commission Into the Plans of the Chesapeake and Potomac Telephone Company of Maryland to Modernize the Telecommunications Infrastructure, Case No. 8388, November 7, 1991

"On Behalf of the Office of Consumers Counsel," before the Public Utilities Commission of Ohio, In the Matter of the Application of the Ohio Bell Telephone Company to Revise its Exchange and Network Services Tariff, P.U.C.O. No. 1, to Establish Regulations, Rates, and Charges for Advanced Customer Calling Services in Section 8. The New Feature Associated with the New Service is Caller ID, Case No. 90-467-TP-ATA; In the Matter of the Application of the Ohio Bell Telephone Company to Revise its Exchange and Network Service Tariff, P.U.C.O. No 1, to Establish Regulations, Rates and Charges for Advanced Customer Calling Services in Section 8., The New Feature Associated with the New Service is Automatic Callback, Case No. 90-471-TP-ATA, September 3, 1991

"On Behalf of the American Association of Retired Persons," Before the Senate Select Telecommunications Infrastructure and Technology Committee, 119th Ohio General Assembly, July 3, 1991

"On Behalf of the Cook County State's Attorney," before the Illinois Commerce Commission, In Re: Proposed Establishment of a Custom Calling Service Referred to as Caller ID and Related Custom Service, Docket Nos. 90-0465 and 90-0466, March 29, 1991

"On Behalf of the Vermont Public Interest Research Group," before the Public Service Board In Re: Investigation of New England Telephone and Telegraph Company's Phonesmart Call Management Services, Docket No. 54-04, December 13, 1990

"On Behalf of the Office of Consumer Advocate," before the State of Iowa, Department of Commerce, Utilities Division, In Re: Caller ID and Related Custom Service, Docket No. INU-90-2, December 3, 1990

"On Behalf of the Office of Public Counsel," before the Florida Public Service Commission, In Re: Proposed Tariff Filings by Southern Bell Telephone and Telegraph Company When a Nonpublished Number Can be Disclosed and Introducing Caller ID to Touchstar Service, Docket No. 891194-TI, September 26, 1990

"On Behalf of the Office of Public Advocate," before the Public Service Commission, State of Delaware, In the Matter of: The Application of the Diamond State Telephone Company for Approval of Rules and Rates for a New Service Known as Caller*ID, PSC Docket No. 90-6T, September 17, 1990

"On Behalf of the Maryland People's Counsel," before The Public Service Commission of Maryland, In the Matter of Provision of Caller Identification Service by the Chesapeake and Potomac Company of Maryland, Case No. 8283, August 31, 1990

"On Behalf of the Office of Attorney General," before the Commonwealth of Kentucky, Public Service Commission, In the Matter of the Tariff Filing of GTE South Incorporated to Establish Custom Local Area Signaling Service, Case No. 90-096, August 14, 1990

"On Behalf of the Consumers' Utility Counsel," before the Georgia Public Service Commission Re: Southern Bell Telephone Company's Proposed Tariff Revisions for Authority to Introduce Caller ID, Docket No. 3924-U, May 7, 1990

"Testimony of Dr. Mark N. Cooper on Caller Identification" before the Committee on Constitutional and Administrative Law, House of Delegates, Annapolis, Maryland, February 22, 1990

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"On Behalf of Manitoba Anti-poverty Organization, the Manitoba Society of Seniors and the Consumers Association of Canada (Manitoba)" before the Public Utilities Board in the Matter of the Request of Manitoba Telephone System for a General Rate Review, February 16, 1989

"On Behalf of the Ohio Consumers Counsel, In the Matter of the Application of GTE MTO Inc. for Authority to Increase and Adjust its Rates and Charges and to Change Regulations and Practices Affecting the Same, Case No. 87-1307-TP- Air," before the Public Utility Commission of Ohio, May 8, 1988

"On Behalf of the Evelyn Soloman, Proceeding on Motion of the Commission as to the Rates, Charges and Regulations of Niagara Mohawk Power Corporation, Case Nos. 29670 and 29671," before the State of New York Public Service Commission, February 16, 1988

"An Economic Perspective - The Status of Competition in the Telecommunications Industry and Its Impact on Taxation Policy," Before the Joint Subcommittee on the Taxation of The Telecommunications Industry, December 8, 1987

"On Behalf of the Office of Consumer Counsel, State of Washington," In the Matter of the Petition of AT&T Communications of Pacific Northwest, Inc. for Classification as a Competitive Telecommunications Company, March 24, 1987

"On Behalf of Manitoba Anti-poverty Organization and the Manitoba Society of Seniors," before the Public Utilities Board in the Matter of the Request of Manitoba Telephone System for a General Rate Review, March 16, 1987

"On Behalf of the Office of Consumers' Counsel, State of Ohio," In the Matter of the Application of the Ohio Bell Telephone Company for Authority to Amend Certain of its Intrastate Tariffs to Increase and Adjust the Rates and Charges and to Change its Regulations and Practices Affecting the Same, Case No. 84-1435-TP-AIR, April 6, 1986

"On Behalf of Manitoba Anti-poverty Organization and Manitoba Society of Seniors," before the Public Utilities Board in the Matter of the Request of Manitoba Telephone System for a General Rate Review, February 6, 1986

"On Behalf of Mississippi Legal Services Coalition, in the Matter of Notice by Mississippi Power and Light of Intent to Change Rates" Before the Mississippi Public Service Commission, April 15, 1985

"On Behalf of the Universal Service Alliance, in the Matter of the Application of New York Telephone Company for Changes in it Rates, Rules, and Regulations for Telephone Service, State of New York Public Service Commission, Case No. 28961, April 1, 1985

"On Behalf of North Carolina Legal Services, in the Matter of Application of Continental Telephone Company of North Carolina for an Adjustment of its Rates and Charges, Before the North Carolina Utilities Commission, Docket No. P-128, Sub 7, February 20, 1985

"On Behalf of the Consumer Advocate in re: Application of Southern Bell Telephone and Telegraph Company for Approval Increases in Certain of Its Intrastate Rates and Charges," Before the South Carolina Public Service Commission, Docket No. 84-308-c, October 25, 1984

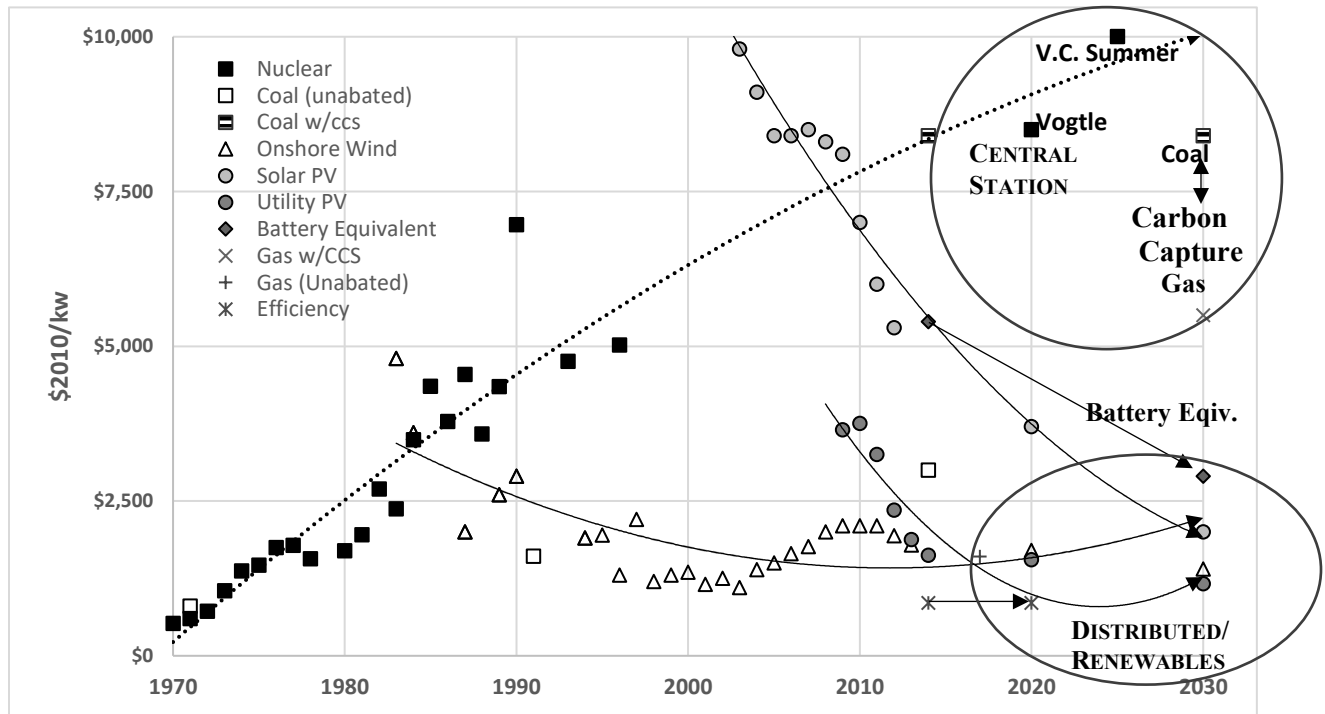
"On Behalf of the Office of the Consumers' Counsel in the Matter of the Commission Investigation into the Implementation of Lifeline Telephone Service by Local Exchange Companies," Before the Public Utilities Commission of Ohio, Case No. 84-734-TP-COI, September 10, 1984

"On Behalf of North Carolina Legal Services Resource Center in the Matter of Application Southern Bell Telephone and Telegraph Company for an Adjustment in its Rates and Charges Applicable to Intra-state Telephone Service in North Carolina," Before the North Carolina Utilities Commission, Docket No. P-55, Sub 834, September 4, 1984

"On Behalf of Mississippi Legal Services Coalition in the Matter of the Citation to Show Cause Why the Mississippi Power and Light Company and Middle South Energy Should not Adhere to the Representation Relied Upon by the Mississippi Public Service Commission in Determining the Need and Economic Justification for Additional Generating Capacity in the Form of A Rehearing on Certification of the Grand Gulf Nuclear Project," Before the Mississippi Public Service Commission, Docket No. U-4387, August 13, 1984

- "On Behalf of the Mississippi Legal Services Corporation Re: Notice of Intent to Change Rates of South Central Bell Telephone Company for Its Intrastate Telephone Service in Mississippi Effective January 1, 1984," before the Mississippi Public Service Commission, Docket No. U-4415, January 24, 1984
- "The Impact of Rising Energy Prices on the Low Income Population of the Nation, the South, and the Gulf Coast Region," before the Mississippi Public Service Commission, Docket No. U4224, November 1982
- "In the Matter of the Joint Investigation of the Public Service Commission and the Maryland Energy Office of the Implementation by Public Utility Companies Serving Maryland Residents of the Residential Conservation Service Plan," before the Public Service Commission of the State of Maryland, October 12, 1982
- "The Impact of Rising Utility Rates on the Budgets of Low Income Households in the Region of the United States Served by the Mississippi Power Company and South Central Bell Telephone Company," before the Chancery Court of Forrest County, Mississippi, October 6, 1982
- "The Impact of Rising Energy Prices on the Low Income Population of the Nation, the South and the Gulf Coast Region," before the Mississippi Public Service Commission, Docket No. U-4190, August 1982

ATTACHMENT MNC-2 PAST, PRESENT AND FUTURE COST OF NUCLEAR POWER V. ALTERNATIVES



Source: Updated and adapted from Mark Cooper, *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Sector* (Santa Barbara, Praeger, 2017), Figure 2.1 and accompanying text. (overnight cost for capital-intensive technologies, fuel-intensive technologies based on relative cost per kWh).

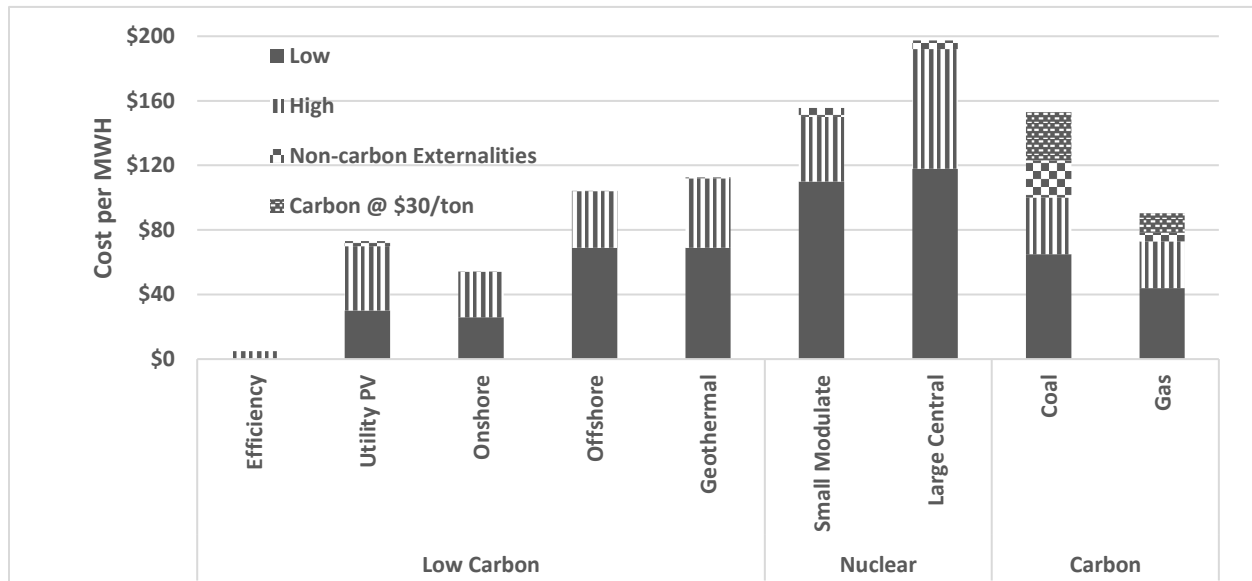
ATTACHMENT MNC-3 CHANGE IN U.S ELECTRICITY GENERATION (KWH) PER DOLLAR OF GDP (REAL)

Period	Annual % Change Electricity	GDP/capita	Electricity/GDP/capita
1950-1980	+6.4	+3.5	+2.89
1980-1995	+1.9	+2.2	-0.000
1995-2015	+0.1	+1.6	-0.012
2015-2019	+0.3	+3.5	-3.1

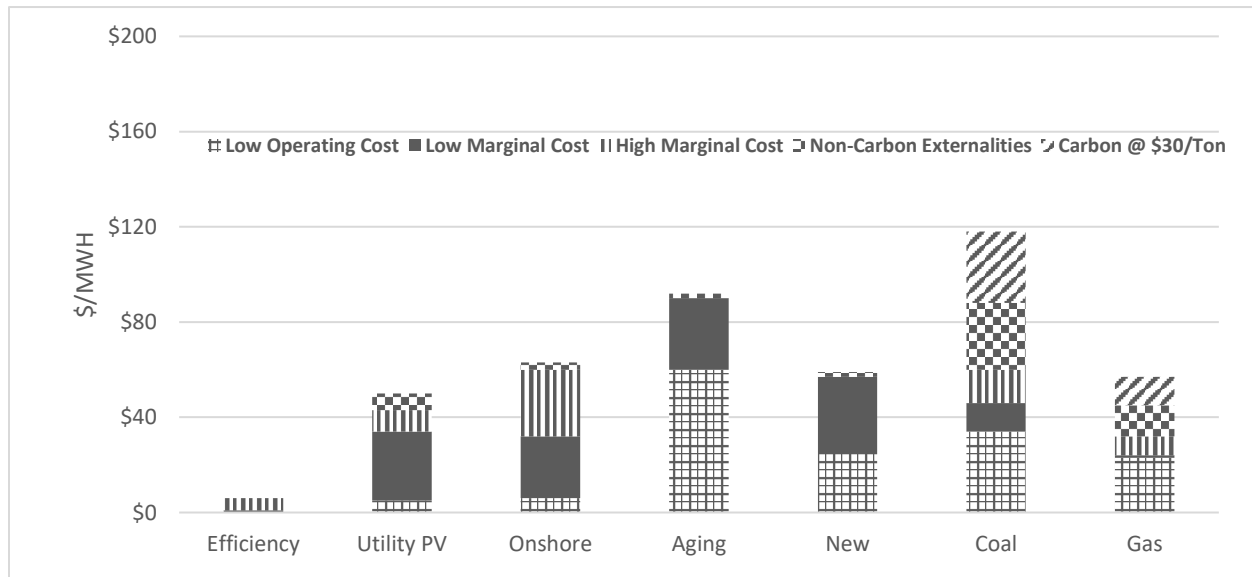
Source: U.S. Energy Information Administration, *Monthly Energy Review December 2015*, http://www.eia.gov/totalenergy/data/monthly/pdf/sec7_5.pdf; *US Real GDP by Year*, <http://www.multpl.com/us-gdp-inflation-adjusted/table>.

ATTACHMENT MNC-4: COST OF RESOURCES

Long Term Costs Per MWh



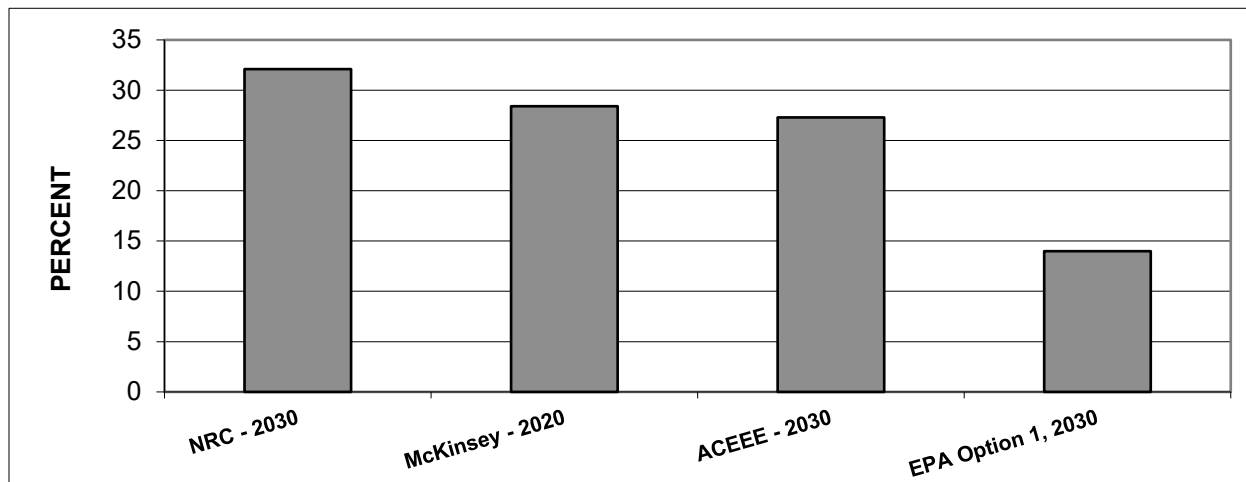
Short Term Costs Per MWh



Source: Lazard, *Lazard's Levelized Cost of Energy Analysis – Version 14.0*, October 2020, Long Terms Costs are from “Levelized Cost of Energy Key Assumptions. **Karkour, Selim, 2020**, Selim Karkour, et al., 2020, External-Cost Estimation of Electricity Generation in G20 Countries: Case Study Using a Global Life-Cycle Impact-Assessment Method,” *sustainability*, March 5. See also, Dallas Burtraw, et. al., 2012, *Power: An Inventory of Methodologies to Support Future Decision making in Comparing the Cost and Competitiveness of Electricity Generation Technologies*, Resources for the Future, June, Table 1. Short term costs are from LZARD, *Levelized Cost of Energy Comparison -- Renewable Energy Versus Marginal Cost of Selected Existing Conventional Generation*,” and *Levelized cost of Energy Components – Low End*,” for low operating costs.

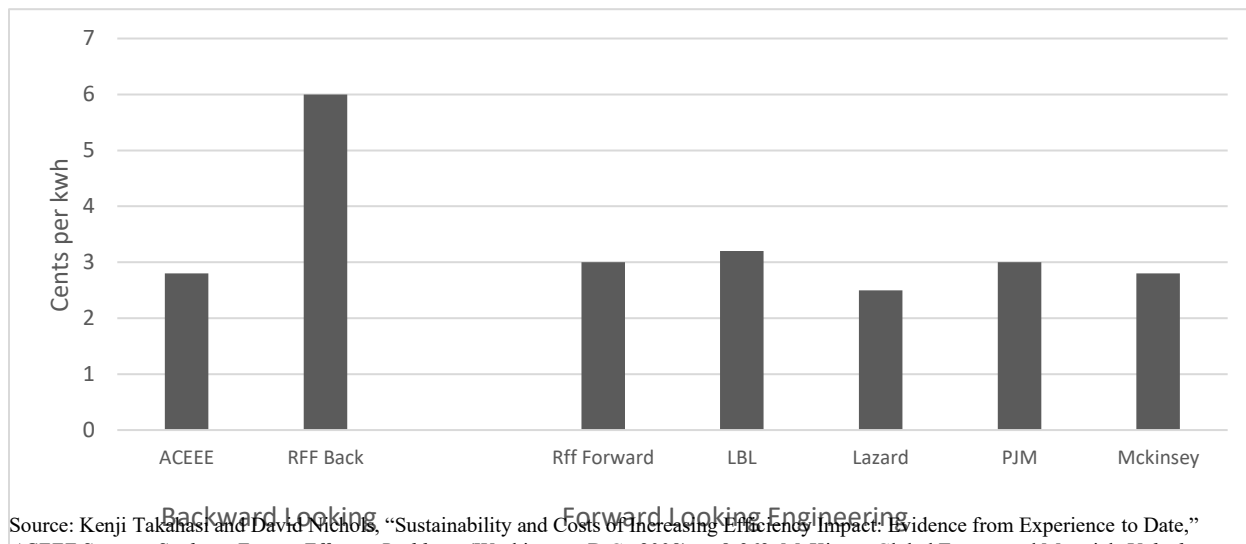
ATTACHMENT MNC-5 PLENTIFUL, LOW COST EFFICIENCY TO MEET FUTURE NEEDS

Efficiency Potential from Major National Studies Compared to EPA Option 1



Sources and Notes: See ,); National Research Council of the National Academies, *America's Energy Future: Technology and Transformation, Summary Edition* (Washington, D.C.: 2009). The NRC relies on a study by Lawrence Berkeley Laboratory for its assessment (Richard Brown, Sam Borgeson, Jon Koomey and Peter Biermayer, U.S. *Building-Sector Energy Efficiency Potential* (Lawrence Berkeley National Laboratory, September 2008). McKinsey Global Energy and Material, *Unlocking Energy Efficiency in the U.S. Economy* (McKinsey & Company, 2009; Gold, Rachel, Laura, et. al., *Energy Efficiency in the American Clean Energy and Security Act of 2009: Impact of Current Provisions and Opportunities to Enhance the Legislation*, American Council for an Energy Efficient Economy, September 2009); EPA, *Regulatory Impact Analysis*, 2004, Table 3-11.

The Cost of Saved Electricity



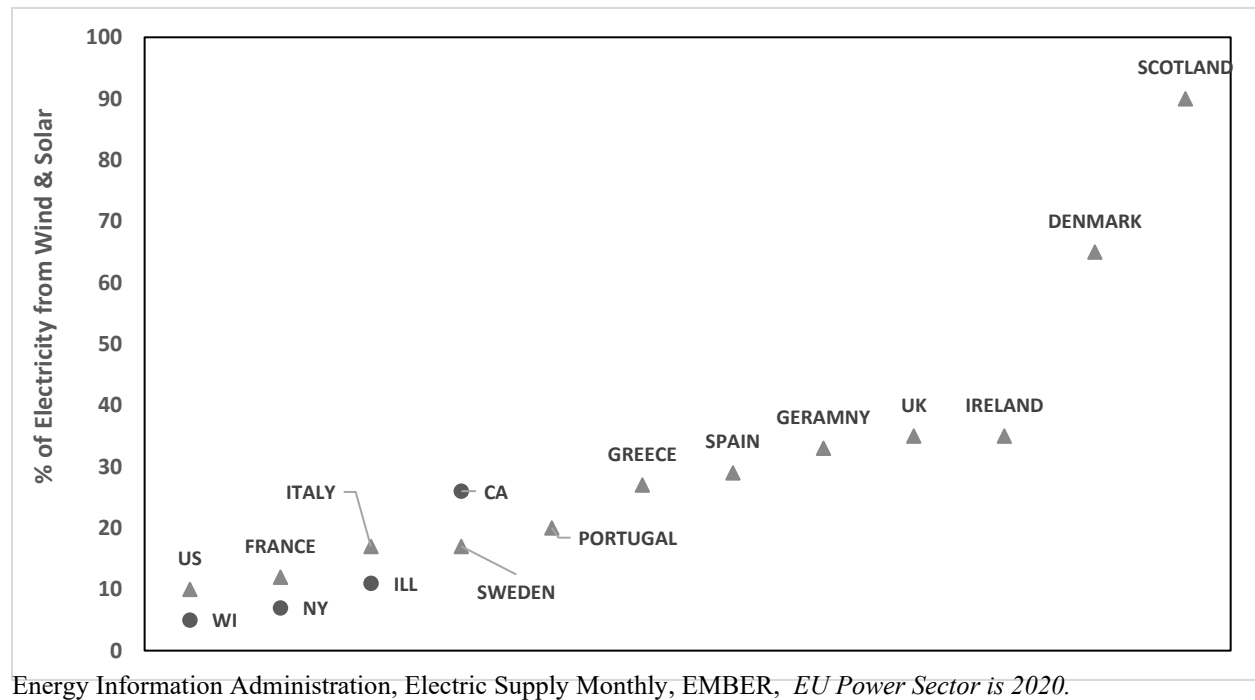
Source: Kenji Takahashi and David Nichols, "Sustainability and Costs of Increasing Efficiency Impact: Evidence from Experience to Date," *ACEEE Summer Study on Energy Efficient Buildings* (Washington, D.C., 2008), p. 8-363, McKinsey Global Energy and Material, *Unlocking Energy Efficiency in the U.S. Economy* (McKinsey & Company, 2009); National Research Council of the National Academies, *America's Energy Future: Technology and Transformation, Summary Edition* (Washington, D.C.: 2009). The NRC relies on a study by Lawrence Berkeley Laboratory for its assessment (Richard Brown, Sam Borgeson, Jon Koomey and Peter Biermayer, U.S. *Building-Sector Energy Efficiency Potential* (Lawrence Berkeley National Laboratory, September 2008).

ATTACHMENT MNC-6: PERFORMANCE ON ALTERNATIVE RESOURCES

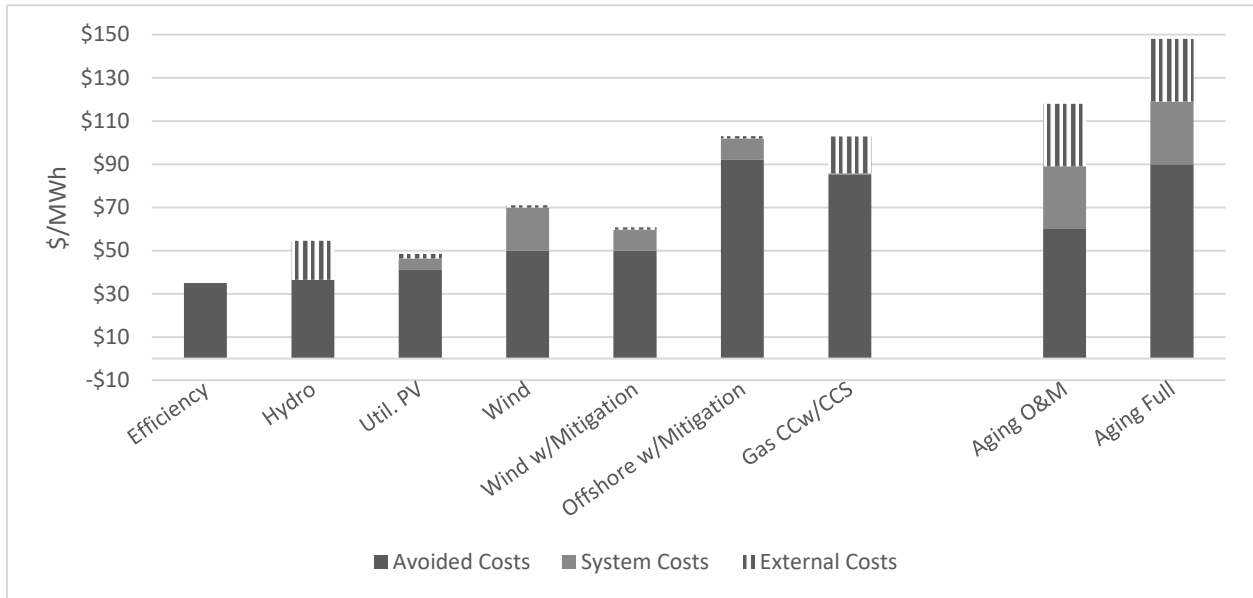
ACEEE Efficiency Scorecard 2020					NREL Wind and Solar Current Use		
	Overall Rank	Utility Rank	Utility Score	Achieves Savings % of Sales	Potential GWh/ Capita	Current Use GWh/ capita	Projects per million
California	1	4	16.0	1.74	4.5	.37	6.3
New York	5	5	13.5	1.29	10.2	.55	4.2
Illinois	15	9	21.0	1.44	9.2	1.26	5.8
Average	7	6	16.8	1.49	8.0	.73	5.4
Wisconsin	26	18	7.5	0.64	6.3	.86	2.2

Sources: Berg, Weston, et al., 2020, *The State Energy Efficiency Scorecard*, American Council for an Energy Efficient Economy, December. Wind and Solar potential from Anthony Lopez, et al., 2012, U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis NREL Technical Report NREL/TP-6A20-51946 July. Projects from, Solar and Wind Energy Research Database, visited March 22, 2021.

Penetration of Generation from Wind and Solar



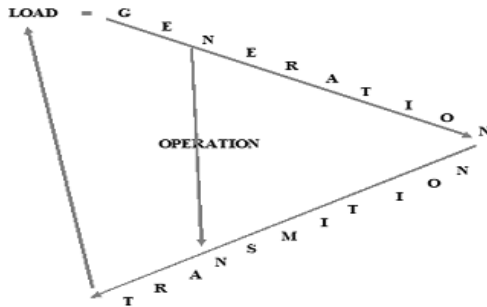
ATTACHMENT MNC-7: CURRENT ESTIMATES OF TOTAL SYSTEM COST



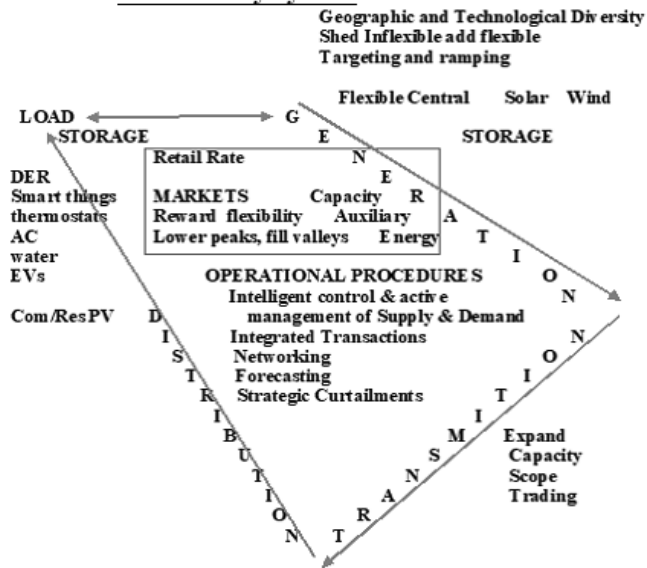
Source: EIA, 2018, *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2018*, February Tables 2 and 3, for the adjustment to levelized costs to account for the value of output, using capacity weighted averages where available and unsubsidized costs. Wisner, Ryan, Andrew Mills and Joachim Seel, 2015. *Impact of Variable Renewable Energy on Bulk Power System Assets, Pricing and Costs*, Argonne and Lawrence Berkeley National Laboratories, Chapter 5. Lazard, 2018. Lazard's Levelized Cost of Energy Analysis – Version 12.0 for LCOE, 10. For carbon costs, NRC, 2010, *The Hidden Cost of Electricity*, for non-carbon pollution costs of gas, with other resources expressed as a multiple of gas.

ATTACHMENT MNC-8: CREATING THE 21ST CENTURY ELECTRICITY SYSTEMS:

20th Century System



21st Century system



Fundamental Differences between Centuries and Systems

Characteristic	20 th Century	21 st Century
Goal	Redundancy (as resilience)	Flexibility (resilience is a result)
Operational objective	Increase capacity to follow load	Integrate & match supply and demand
Configuration, size	Island set by economies of generations	Interconnection set by value
Supply-Demand	Segregation	Integration
Demand driver	Dumb load	Smart Retailer
System cost recovery	High, lumpy and fixed	Variable targeted and local
Organization	Centralized	Distributed
Challenges	Increase capacity to follow load	Integrate & match supply and demand
Flash point	50 most expensive hours (>\$10,000)	50 least expensive hours (<\$0)
Market power	High	Low
Optimization Target	Meet peaks	Shave peaks, Fill valleys (shed & shift)
End users role	Passive	Active
Flow: Output	Hub & Spoke, linear	Networked, Dynamic & Transparent
Information	Aggregate	Transparent, local
Resources: Physical	Fuel, Cement and Boiling Water	Steel, Silicon and Intelligence
Intellectual	Engineering judgement	Communications, Advanced Control
Capital	High for base, low for peak	Moderate for both
Energy intensity	High, concentrated	Low, diffuse

**ATTACHMENT MNC - 9 : MEASURES TO MANAGE AN INTELLIGENT,
DECENTRALIZED ELECTRICITY SECTOR AND REDUCE PEAK LOAD**

Overall Effect¹

Lower Cost (including externalities, e.g., uncertainty, choice²)

Smaller Systems³ (especially the transformation dividend⁴)

Demand

Efficiency

Target efficiency to peak reduction

Aggressive demand response⁵

Manage devices (e.g., water heater loads to reduce peak.⁶

Smart controllers⁷

Shed inflexible baseload

Rates⁸

Target fixed-cost recovery to ramping hours

Time of use rates

Dispatchable storage⁹

Solar thermal electric with storage¹⁰

Utility storage in strategic locations¹¹

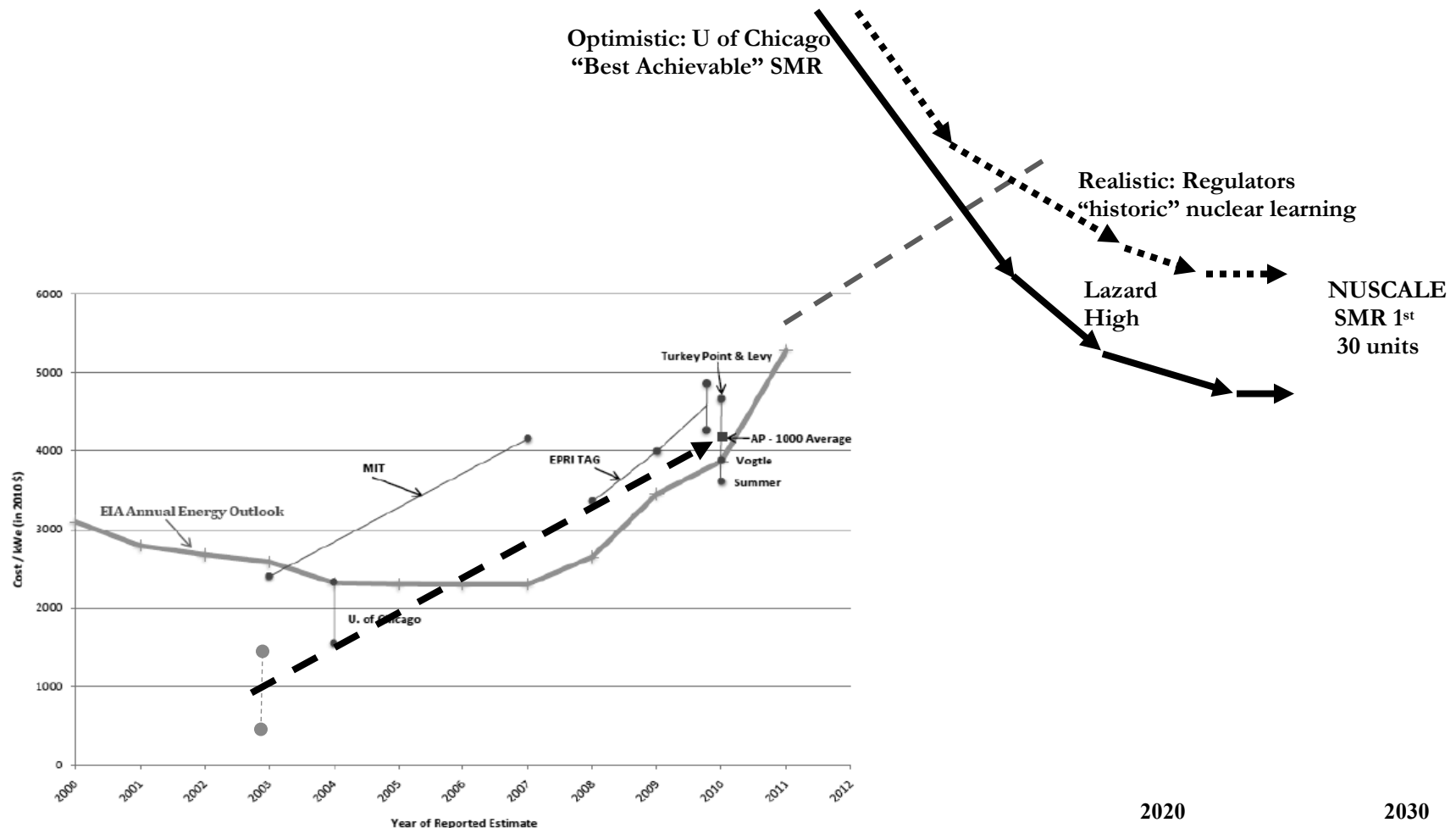
Distributed storage

Community & individual storage

Air conditioning water heating with storage

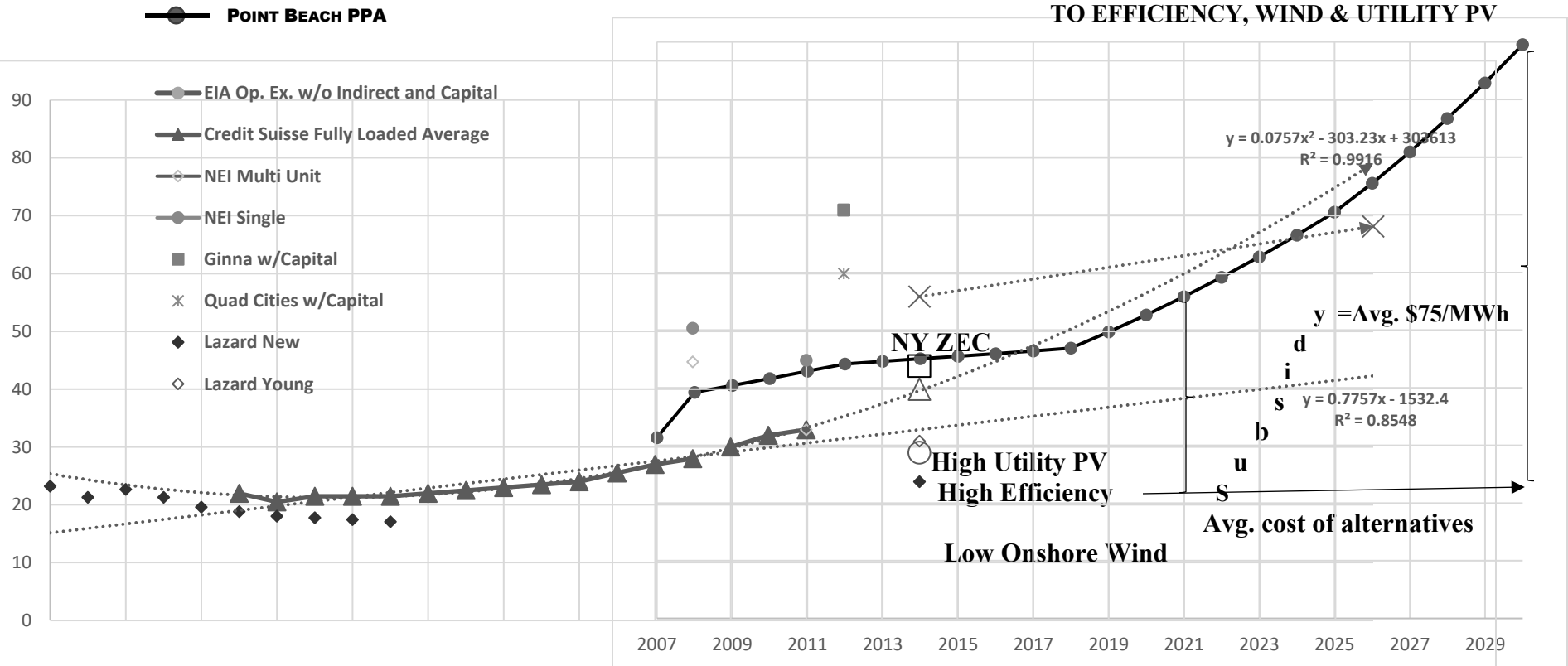
Electric vehicles¹²

ATTACHMENT MNC-10 - UNIVERSITY OF CHICAGO RECAP OF ENTHUSIAST/UTILITY ESTIMATES OF OVERNIGHT COST FOR NEW GW-SCALE NUCLEAR PLANTS AND SMRS



Sources: Mark Cooper, "Small modular reactors and the future of nuclear power in the United States," Energy Research & Social Science 3 (2014) 161; Rosner, Robert and Stephen Goldberg, 2011, *Small Modular Reactors – Potentially Key Contributors to Future Nuclear Power Generation in the U.S.*, Center for Strategic and International Studies, December 1; Rosner, Robert, et al., Analysis of GW-Scale Overnight Capital Costs, EPIC, University of Chicago, Technical Paper Nov. 2011. For the cost and other problems with the only active U.S. small modular Reactor see, h. V. Ramana, 2020, *Eyes Wide Shut: Problems with the Utah Associated Municipal Power Systems Proposal to Construct NuScale Small Modular Nuclear Reactors*, Oregon Physicians for Social Responsibility.

ATTACHMENT MNC-11 OPERATING AND TOTAL COST OF AGING REACTORS COMPARED TO EFFICIENCY, WIND & UTILITY PV



Sources: Eggers, Dan, Kevin Cole, and Matthew Davis. Nuclear . . . The Middle Age Dilemma? Facing Declining Performance, Higher Costs, Inevitable Mortality. Credit Suisse, 2013; Lazard. Lazard's Levelized Cost of Energy Analysis 12.0, November 2018, Nuclear Energy Institute, Nuclear Costs in Context, October, 2018; NEI Operating Cost (Nuclear Street News Team. "NEI Lays Out the State of Nuclear Power." Nuclearstreet.com. February 26, 2014); NEI Excludes Indirect (Nuclear Energy Institute, Operating Costs, <http://www.nei.org/Knowledge-Center/Nuclear-Statistics/Costs-Fuel-Operation-Waste-Disposal-Life-Cycle/US-Electricity-Production-Costs-and-Components>); Naureen S. Malik and Jim Poulson, "New York Reactors Survival Tests Pricey Nuclear," Bloomberg, January 5, 2015, p. 2. Quad Cities is based on a \$580 million subsidy (Steve Daniels, "Exelon Puts an Opening Price Tag on Nuclear Rescue: \$580 Million," Crains Chicago Business, September 24, 2014), converted to \$25/MWH for output at risk reactors. Illinois Commerce Commission, Illinois Power Agency, Illinois Environmental Protection Agency, Illinois Department Commerce and Economic Opportunity, 2015, Response to The Illinois General Assembly Concerning House Resolution 1146, January 5, real price increase to break even, plus \$11/MWH for capital. "Comments of Dr. Mark Cooper." In the Matter of Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units, Environmental Protection Agency, RIN 2060-AR33, November 24, 2015. Comments by Alliance For A Green Economy and Nuclear Information and Resource Service, Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard, Case 15-E-0302, April 22, 2016; RE: Case 15-E-0302- In the Matter of the Implementation of a Large-Scale Renewable Program and a Clean Energy Standard Re: Case 16-E-0270: Petition of Constellation Energy Nuclear Group, LLC; R.E. Ginna Nuclear Power Plant, LLC; and Nine Mile Point Nuclear Station, LLC to Initiate a Proceeding to Establish the Facility Costs for the R.E. Ginna and Nine Mile Point Nuclear Power Plants, July 22, 2016. Energy Information Administration, Electricity Annual, 2015, Table 8.4; Point Beach Nuclear Plant Power Purchase Agreement Between FPL Energy Point Beach, LLC and Wisconsin Electric Power Company, dated as of December 19, 2006, A-1.