

**AVOIDING NUCLEAR AND FOSSIL FUEL POTHOLES,
A GREEN NEW DEAL
HAS A CLEAR PATH TO A CLEAN, LOW COST, LOW CARBON,
PROGRESSIVE, CAPITALIST ELECTRICITY SECTOR**

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EXECUTIVE SUMMARY

This paper uses a rigorous cost benefit approach to analyze the aspirations of the Green New Deal in the electricity sector and assess the role of central station facilities, particularly nuclear power, in meeting those goals. From a strictly economic and environmental point of view, the initial reaction of the main (House) sponsor of the Green New Deal to the question of nuclear power was exactly right. Nuclear is not part of the long-term solution and should be phased out as quickly as possible.

It makes no sense to subsidize central station facilities, nuclear power in particular, for two simple reasons. First, if you pay too much for something, in this cash decarbonization of the economy, you will buy less of it. Second, if you start a journey by heading in the wrong direction, you will raise the cost as correcting the mistake becomes more and more difficult. While the answer is simple, the analysis needed to reach it is, of necessity, more complex.

The first part of the paper lays out the case against subsidies for central station facilities, nuclear power in particular.

Aging reactors are uneconomic. With costs at least twice the cost of the main alternatives (wind, solar, efficiency, integrated, managed and stored in a dynamic grid that balances supply and demand), they cannot compete. New nuclear reactors are worse, at least three times more costly. The alternatives are also less costly than coal and competitive with gas. Allowing the alternatives to expand as rapidly as possible is the economically correct thing to do.

These resource economics conclusions hold without using a “cost of carbon” to tip the scales. The least cost future is a sector based on alternatives. Adding in a requirement to decarbonize the sector and the economy makes the fossil fuels twice as costly as the alternatives.

But that is not the only, or even the most important problem with subsidies for central station facilities. Environmentally, central station resources are an inferior choice. Neither coals, nor nuclear or even natural gas are zero emission. That is a euphemism. They all have larger carbon footprints than the alternatives. Even with carbon abatement, the fossil fuels emit more carbon and new reactors that take so long to build have a severe deficit. Moreover, 95% of the carbon reduction achieved in the U.S. in the past two decades has come for non-hydro renewables. Neither nuclear, nor coal, nor natural gas are “clean.” They have much higher emissions of other pollutant. than the alternatives.

But those are not only or most problems with subsidies for central station facilities, nuclear power in particular. The alternatives produce more jobs and more economic growth per kilowatt hour of output than central station facilities, twice as much as nuclear.

But those are not the only problem with subsidies for central station facilities, particularly nuclear power. The biggest problem of the subsidies for central station facilities is that they crowd out the alternatives. The current and key challenge to building the 21st century system is not cost, environmental impact, or economic development, it is laying the physical and institutional infrastructure to support a different approach to meeting the need for electricity. Distorting the market to keep aging reactors online shrinks the near-term size of the

market for alternatives, perpetuates the “must run” inflexible approach to load management and will delay the building of an alternative system.

The second part of the paper examines the ability of the alternatives to meet the need for electricity.

It starts by showing that the resource base for the alternative are more than adequate to supply reliable power. That is true today globally, in the United States and in New York State. The ability and advantage of the alternative approach to meet the need will grow over time, particularly as resources are shifted into that approach.

Using three dozen tools to build the alternative sector, an ever-increasing number of U. S. states and nations have achieved rapid and large penetration of renewables to deliver reliable, affordable power, levels of penetration that had been unheard of and deemed impossible just a decade ago. A technological revolution that has made building the 21st century electricity system possible.

The third part of the paper shows why the approach to the transformation of the electricity sector based on the progressive, capitalism, embodied in the Green New Deal and the Paris Agreement of 2015 implementing the United Nations Framework Convention for Climate Change of 1992, is the correct approach.

They have chosen the correct goals by demanding that public policy solve the dilemma of decarbonization and development based on a democratic, participatory path that recognizes the importance of subnational action and civic involvement.

The empirical literatures on energy efficiency and climate change demonstrate that a progressive, capitalism approach, which uses policies to remove barriers to entry, speed innovation, and mobilize local resources, will cut the cost of responding to climate change in half. Because the energy sector is riddled with imperfections, raising prices with heavy carbon taxes is the wrong policy because it increases the burden on consumers and the economy too much, too soon.

This paper also finds support for broader aspiration of the Green New Deal in two respects. First, the data clearly indicates that we can economically accelerate the deployment of alternative resources to move the end-point much closer to 2030 without nuclear power. Second, while there are much broader social goals to which the Green New Deal aspires, the transformation of the electricity sector is consistent with the direction of the broad change desired.

Thus, the key first step is to reject subsidies for central station general and get on with the transformation of the sector. A great deal is within the reach of the Green New Deal based on basic economics, markets that are well-regulated with “command-but-not-control” strategies, and well-targeted subsidies. Even if the Green New Deal does only what can be accomplished within these parameters of long-run, least cost, cleanest power, it will accomplish a great deal.

1. INTRODUCTION AND OUTLINE

THE GREEN NEW DEAL AND THE PUSH TO SUBSIDIZE NUCLEAR POWER AND FOSSIL FUELS

This paper argues that the debate over the Green New Deal in America is exactly what one should expect at this critical juncture in the electricity sector.¹ New technologies have emerged (distributed resources) that threaten to displace the techno-economic paradigm (central station generation) that has dominated the sector for a century. Economic superiority of the alternative is not enough to secure the transformation of the sector, however. A socio-institutional paradigm shift must also take place that supports the emerging new economic paradigm. It must become the “common sense” way of thinking about the sector.² The Green New Deal is exactly such an alternative.

At turning points like these in each of the previous industrial revolutions,³ the incumbents fight back. Knowing that their assets and skill sets do not fit well within the new economic model, they fear that they would be significantly devalued if the alternative model were to become dominant. Entrenched in the dominant structure, they have considerable political power which they use to try to stop, slow or redirect the expansion of the new technology. Intensifying the rigging of the economics of the sector against change and resisting the physical and institutional changes that the alternatives need can obscure the increasing economic disadvantage of central station facilities, significantly delaying and altering the future.

While the paper examines central station power broadly, it also uses the economics of aging nuclear reactors and the effort by the industry to secure subsidies to support them as a focal point. Nuclear power provides a useful focal point to illuminate the intense policy struggle that is unfolding because nuclear reactors epitomizes the 20th century approach as huge, central station resources with the least flexibility, longest lives and longest construction periods. They also claim to be low carbon emitters, certainly lowest among the dominant resources of the central station system. To strengthen their case, advocates of nuclear power claim that their low carbon, central station resources are the only viable path to decarbonizing the economy in the long term.⁴ Thus, the mantle of the defender of the central station system has fallen to nuclear power.⁵

In the short-term, however, they have been seeking subsidies for aging reactors, which can no longer compete with the lower cost alternatives.⁶ The intensive demand for subsidies magnifies the conflict between the old and the new systems. In a sense, analyzing the economics of aging reactors compared to alternatives is a key point in the broader debate about the path to a low carbon economy.⁷ The cutting edge of change can be seen best in the inability of aging reactors to cover their costs in contemporary electricity markets in three ways.

First, if aging reactors, with massive sunk costs already paid off, cannot compete, new reactors with much higher going forward costs certainly cannot. Second, the extension of the operation of aging reactors in the generation fleet beyond their economic lives perpetuates the strong tendency of central station, particularly nuclear power, to crowd out the alternatives.

Third, because the operating characteristics of aging reactors (inflexible, must run units) are antithetical to the (flexible, dynamic) operation of the 21st century alternative, keeping these

reactors online will slow the transition at a key moment when it is critically important to build an alternative physical and institutional infrastructure to support the emerging electricity system.

Fourth, more broadly, the effort to secure subsidies for central station generation should be rejected as a bad investment from every point of view because they are

- uneconomic in the short term and even less economic in the long term,
- not as low carbon,
- much dirtier than the alternatives,
- crowd out and delay the transition to a system based on the alternatives, and
- impede a vastly superior long run development of jobs and the local economy.

The suggestion that the Green New Deal duck the issue for now⁸ is very bad advice for three reasons.

- First, the economic and environmental analysis are extremely clear, so if the Green New Deal cannot get this decision right, prospects for subsequent decisions are dim.
- Second, subsidizing nuclear power violates a simple economic principle, if you pay too much for something (in this case decarbonization of the sector while continuing development) you will buy less of it.
- Third, extending the life of nuclear reactors beyond their economic viability, makes it harder to transition to the alternative electricity system that the Green New Deal envisions.

Here, too, I can simply summarize this conclusion. The best way to start a journey is not to go in the wrong direction; it wastes too much time and imposes substantial costs of changing directions. Subsidies for central station facilities, aging nuclear reactors in particular, are the wrong way to go.

THE GREEN PART OF THE GREEN NEW DEAL

The use of the term New Deal evokes the policies of the (arguably) most progressive era of American lawmaking. My recent book on the *Political Economy of Electricity*,⁹ subtitled *Progressive Capitalism and the Struggle to Build a Sustainable Power Sector*, has two central themes that address the debate over the Green New Deal head on.

Obviously, the implementation of the New Deal and the intent of the Green New Deal go well beyond these basic economic issues. They took (take) on broader social goals that might or might not – indeed, need not – be justified on simple direct economic ground. This paper takes no position on those other goals. However, it is important to know how far the straightforward economics of the choices the policy makes can go. The purpose is to show that simple economics can carry the Green New Deal a long way (even to 100%) toward reliance on alternatives and that subsidizing nuclear power and other central station resources is counterproductive from the point of view of achieving a least cost, low carbon clean electricity sector.¹⁰

Moreover, the immediate headlines about the Green New Deal scream with controversy from expected directions.¹¹ The link to nuclear power was raised immediately, both by those advocating for it and those opposed.¹² From the perspective of this paper, the main (House) sponsor's answer to the immediate question raised about nuclear was exactly right, "a Green New Deal would not include creating new nuclear plants... and ... the movement's goal is to 'transition off of nuclear and all fossil fuels as soon as possible'"¹³

Clearly, the idea of a Green New Deal flies in the face of the direction of policy in the U.S. under the Trump Administration. Over the past two years the U.S. reversed course on climate policy, gutting the Clean Power Plan and withdrawing from the Paris Agreement. Losing the participation of one of the largest carbon emitters is a blow to the effort to respond to climate change, but I have argued it could act to strengthen the commitment of the other participants, virtually all nations.¹⁴ It has also stimulated vigorous support and action in the U.S. at the subnational level, even before the Green New Deal became an active policy goal.

There is another sense in which the Green New Deal deserves central stage in this debate. Advocates of unfettered free markets – market fundamentalists in the terms of Nobel laureate Joseph Stiglitz¹⁵ – have been sent scrambling by the Trump administration. They call for both a "free market welfare state"¹⁶ and an aggressive policy to address climate change through policies to stimulate innovation and entrepreneurship,¹⁷ while conservative democrats gravitate toward a tax or piecemeal regulation,¹⁸ although their effectiveness is questionable, unless the burden is so high that it imposes immense pain on consumers and the economy.¹⁹

The bits and pieces of policy, sliding in the direction of more aggressive action, lace exactly what the New Deal provided for the economy three-quarters of a century ago and the Green New Deal seeks to do provide in the electricity sector. They seek to provide an indispensable overarching framework of progressive capitalism to guide the sector to a least-cost, low-carbon goal,²⁰ without which the individual policies fail to reinforce one another, are captured by antisocial purposes and yield disappointing results.

While the political support has grown for the alternative approach has grown, the analytic challenge continues. Demonstrating the feasibility of the green path to development with economic analysis and real-world data remains essential to convincing policymakers to guide the electricity sector in a green and progressive capitalist direction. Given the collapse of the nuclear renaissance in the U.S. under massive cost overruns at the two projects under construction,²¹ industry attention has shifted to aging reactors, with the largest U.S. nuclear utility pushing hard for subsidies in New York and Illinois. Does it make sense to subsidize and extend the life of the aging nuclear reactor fleet in the U.S.? In a sense, this is the most challenging question facing the choice of a progressive, capitalist solution to pollution problems in the 21st century.

Introducing a rigorous, least economic cost, least total social cost perspective to evaluate the options available has significant implications for the broader policy perspective. This perspective shows that the least cost options are utility scale on both the supply-side (wind, utility photovoltaics) and the demand side (efficiency, storage and demand management implemented in an integrated grid management approach). Depending on the richness of the available resources, other alternative sources of electricity may prove to be economic, but the bulk of the need will be met by the five resources listed above – wind, solar, storage, efficiency,

and demand management with grid integration. To the extent that subsidies are needed to accelerate the transition they should be consistent with the economic logic of those emerging, dominant resources.

OUTLINE

To arrive at this conclusion, the analysis begins in Part I by evaluating the comparative economic, environmental and employment impact of the key resources in the two electricity systems competing for dominance in the 21st century – central station v. alternatives.

Section 2 analyzes the long-term economics of the resources. Section 3 discusses the short-term distortions introduced by subsidizing uneconomic central station generation and the long-term crowding out of alternatives that results from reliance on these resources. Section 4 discusses the environmental (carbon and other pollutants) and employment footprints of resources, which are the primary externalities raised in the defense of central station subsidies.

Part II addresses key question about the ability of the alternative, 21st century approach to achieve the desired outcome of reliable, low-cost, clean electricity.

Section 5 examines the ability of alternatives to meet the need for electricity while lowering carbon emissions. Section 6 shows that nuclear and other central station subsidies have been much greater than the subsidies for renewables and that redirecting those subsidies to renewables would have a larger, payoff much more quickly. Section 7 shows that the task of integrating renewables is manageable and the cost is low, meaning that the total cost of the alternative system would be lower than continuing to rely on central station power.

Given the characteristics of the electricity system Part III shows that the Green New Deal and the Paris Agreement adopt progressive, capitalist policies that are well-suited to address the challenge of climate change.

Section 8 presents an evaluation of the Green New Deal and the Paris Agreement as progressive capitalist solution to the challenge of climate change in the context of massive literatures on energy efficiency and climate change. These strongly support the need for aggressive state actions to secure a least cost approach. Section 9 concludes with three concrete policy paths to follow. It shows that the simplistic, free market approach of “just tax carbon” is an inferior policy and outlines a strategy for making near-term choices to achieve long-term goals. Finally, it underscores how important it is to consider the unintended consequences of policies,

I adopt several general conventions in this analysis. In each section I discuss the broad trends observed throughout the industry, then I review the same issue at the state level. It goes without saying that intense criticism I develop for the state programs apply to any federal subsidy for aging nuclear reactors. The analysis of state programs gives the critique a specificity that is often lacking in big, federal policy debates. I begin each major section with a quote from the citizen groups challenge to the New York program,²² while I bring in the federal issues in a final footnote to each section. Rather than clutter the analysis with lengthy footnotes, I include about 500 references in the tables and provide these in a series of appendices.

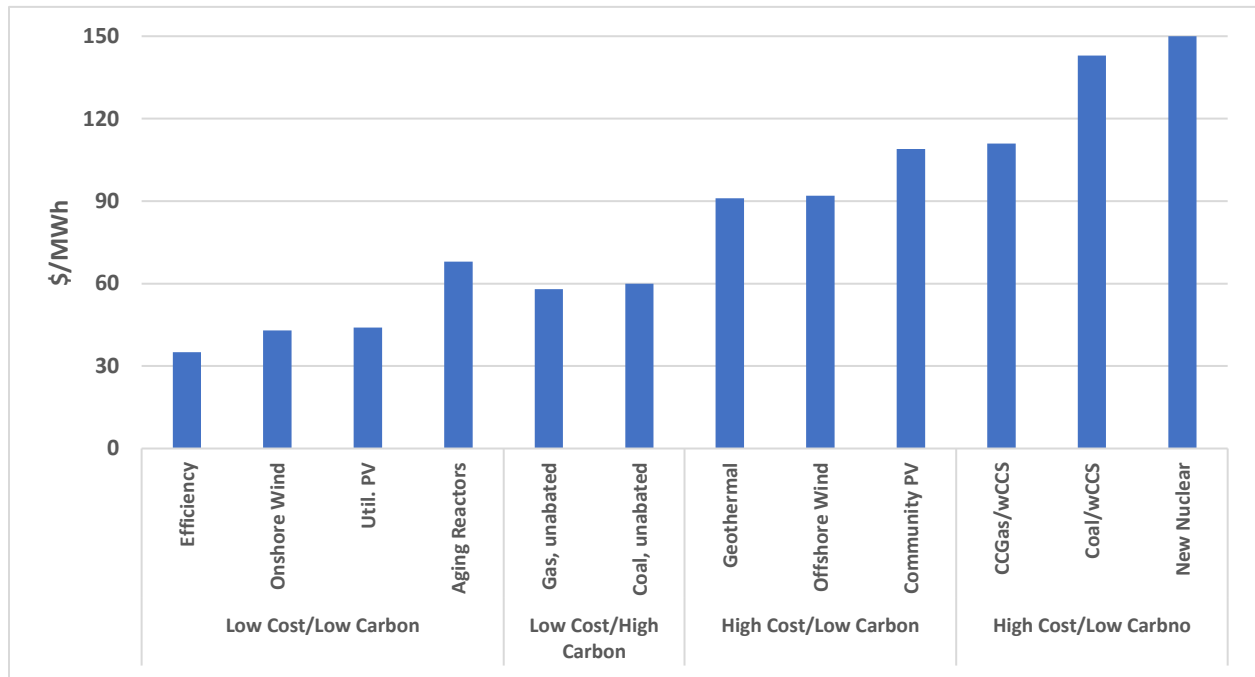
**PART I:
COMPARATIVE ECONMICS OF ALTERNATIVE 21ST CENTURY RESOURCES AND
CENTRAL STATION GENERATION**

2. CENTRAL STATION GENERATION IS UNECONOMIC²³

THE ALTERNATIVES ARE LOWER IN COST TODAY AND VERY LIKELY TO REMAIN SO

The economic dynamics of the electricity sector at the start of the 21st century has put immense pressure on nuclear power and central station generation in the United States and globally, pressure that ultimately falls on aging reactors. As Figure 2.1 shows, at resent the three main resources on which the 21st century electricity system relies – efficiency, onshore wind, and utility photovoltaics. – are cost competitive with central station generation, even slightly less costly, even without taking the reduction of carbon emission into account. This observation includes aging reactors at only their cost of operation, although necessary capital costs would increase their total near-term cost by almost 50%, as discussed below.

FIGURE 2.1: UNSUBSIDIZED LEVELIZED COST OF ELECTRICITY, \$/MWH



Source: Lazard’s Levelized Cost of Energy Analysis, Version 12.0, p.2. November 2018, except CCGasw/CCS, which adds the cost of CCS from Lazard 2014 (Version 8.0) analysis to the 2018 cost of Combined Cycle Gas and efficiency from Lazard 2015 (Version 9.0)

I use Lazard here, 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 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 added comparisons of carbon abatement costs, as the determination to deal with climate change has grown.

Factoring in carbon abatement and looking to the future (since carbon capture for fossil fuels and new nuclear reactors will take significant time), the advantage of the alternatives become even greater. Geothermal, offshore wind and community PV all are less costly than the central station facilities that can claim to be low carbon emitters. Simply put, the least cost resources now and for the foreseeable future are the alternatives.

HOW DID THIS HAPPEN?

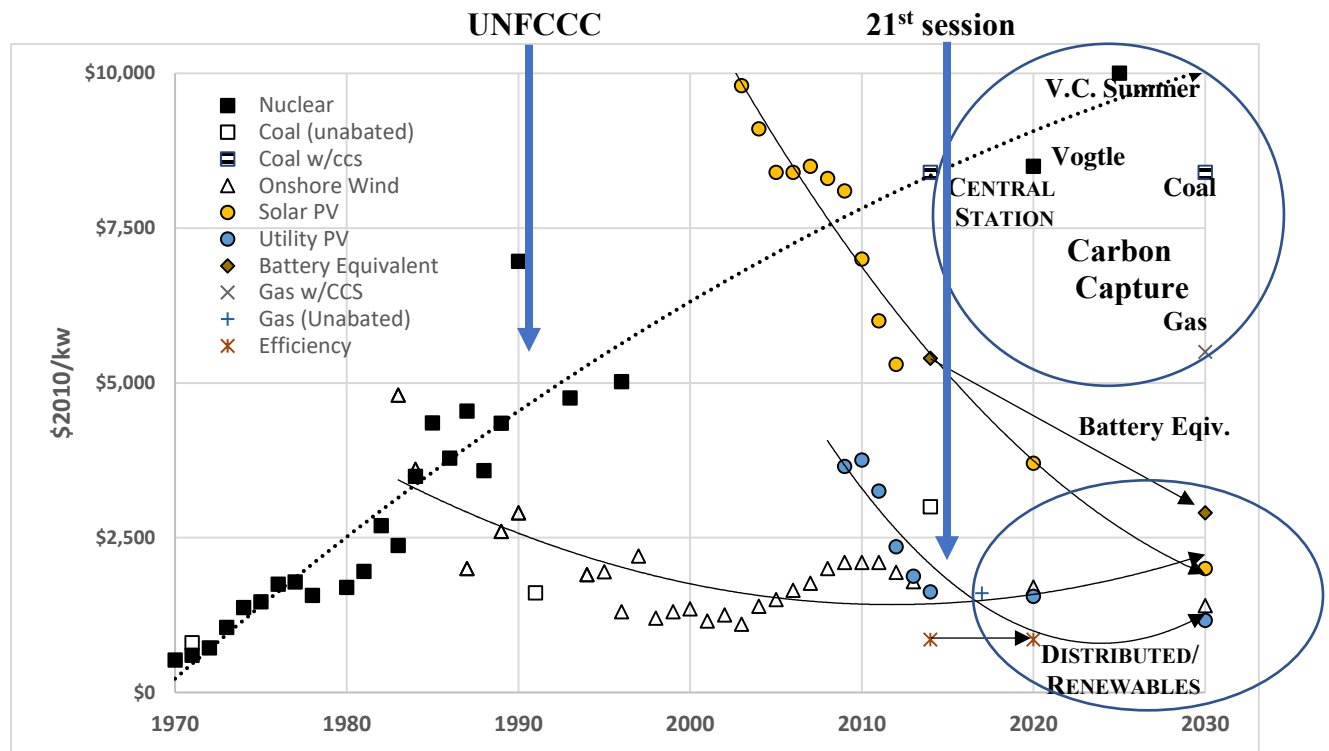
I have used the history and context of the Paris Agreement on climate change, marked by the technological changes in Figure 2.2, to frame the review of long run costs in the electricity sector.

First, the challenge is not climate change, but decarbonization and development. “In short, a massive increase in affordable, low-carbon electricity production is necessary to meet the twin challenges of development and decarbonization.”²⁴

Second, although the challenge was identified over a quarter of a century ago, “When the treaty underlying the Paris Agreement was negotiated in the early 1990s, it was impossible to pass through the horns of the dilemma.”²⁵

Third, “a technological revolution driven by progressive capitalism in the subsequent quarter century has made it possible to do so,”²⁶ as shown in the lower graph of Figure 2.2. The Paris Agreement is fully aware that the solution resides in the application and continuous expansion of the technological revolution. The dramatically declining cost of a key economic resource, driven by technological change is a hallmark of capitalist industrial revolutions.²⁷

FIGURE 2.2: A RENEWABLE REVOLUTION: ALTERNATIVES V. CENTRAL STATION COSTS



Source: See Appendix A, Long Term.

This view of the Paris Agreement as a response to climate change frames it as a pattern that has been repeated several times in the quarter millennium of capitalist industrial revolutions. “A new technology, nurtured by the state with early support and market creation policies, is now moving to dominance and in need of discipline to control its more destructive tendencies. It has produced the tools to sustain development and overcome the problems it has created, but a socio-institutional paradigm must be created to guide it.”²⁸

The supply curves I cite to make this point have one, overwhelming message, in addition to the fact that the technological revolution has made an economically viable response to carbon emissions possible in the electricity sector; nuclear power has no future in the low carbon, 21st century sector, not if economics is an important consideration. Every existing nuclear reactor and other central station facility must be replaced over the course of the first half of the 21st century and nuclear power simply cannot compete. I described the terrain of supply-side resource selection as follows.

When the United Nations Framework Convention on Climate Change was negotiated in 1991, prospects for building a low-carbon electricity sector—and therefore a low-carbon economy—were bleak.²⁹ However, the economic fundamentals of the supply-side options changed over the next two decades. A technological revolution in generation dramatically lowered the cost of some low-carbon technologies. It was built on a combination of public policies and support for research and development that set the direction of socially responsible economic growth and created markets.³⁰

Another technology that has exhibited sharply declining costs—a trend that is expected to continue—is storage. The central station approach used expensive, dirty, fossil-fueled peakers to meet demand surges on a daily basis. Since the raw materials were inexpensive and the externalities of pollution were ignored, it did not make economic sense to invest in storage technologies. Today storage receives a great deal of attention.

No discussion of technological change would be complete without mentioning information communications technologies (ICT). The potential for storage to transform the electricity system goes hand in hand with the ICT revolution and advanced control technologies. These revolutions are transforming the ability to manage a dynamic electricity system that integrates decentralized, variable clean renewable supply with demand. It also brings supply into closer coordination with demand, so the size of the system needed to meet demand can be substantially reduced as a result.³¹

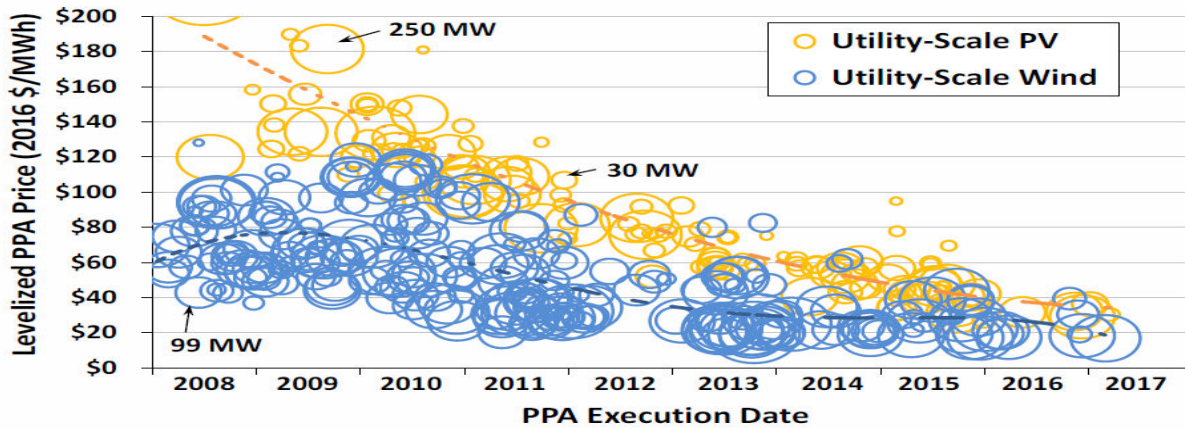
A final technological revolution is also taking place on the demand side. At the time of the 1991 negotiations, the link between economic growth and energy consumption was strong, as it had been throughout the history of the Industrial Revolution. Since then, new, more energy-efficient technologies in capital equipment and consumer durables first weakened, then severed the tie between energy consumption and economic growth. The link between electricity consumption and economic growth has not only been severed, it has been reversed.³²

This observation on efficiency in consumption underscores the central role of efficiency in the broader analysis. It reminds us of the central role that efficiency plays in a progressive capitalist economy. Efficiency is one of the main pillars on which a capitalist economy stands and progressive capitalism is successful because it corrects market imperfections to make the economy function better. The second pillar is progressive social policy that guides the pursuit of efficiency to social goals. Where market imperfections and externalities are involved, as in energy policy, the two pillars are perfectly compatible.

The reality of this technological revolution in the U.S. can be seen in the contracts signed for the two major renewables, wind and solar. These are described in a series of reports by and for the National Renewable Energy Laboratory, NREL, as shown in Figure 2.3. NREL describes the trend as follows:

Average wind PPAs have fallen from a high of over \$70/MWh in 2009 to around \$20/MWh in 2017, driven in part by installations in the interior of the country at high resource quality wind sites and technology advancements that improve performance. Utility-scale PV PPAs have also fallen dramatically, from nearly \$200/MWh in 2008 to under \$40/MWh in 2017. As the level of incentives has been relatively constant over this period, a major driver of these cost declines can be attributed to improvements in technology cost and performance.³³

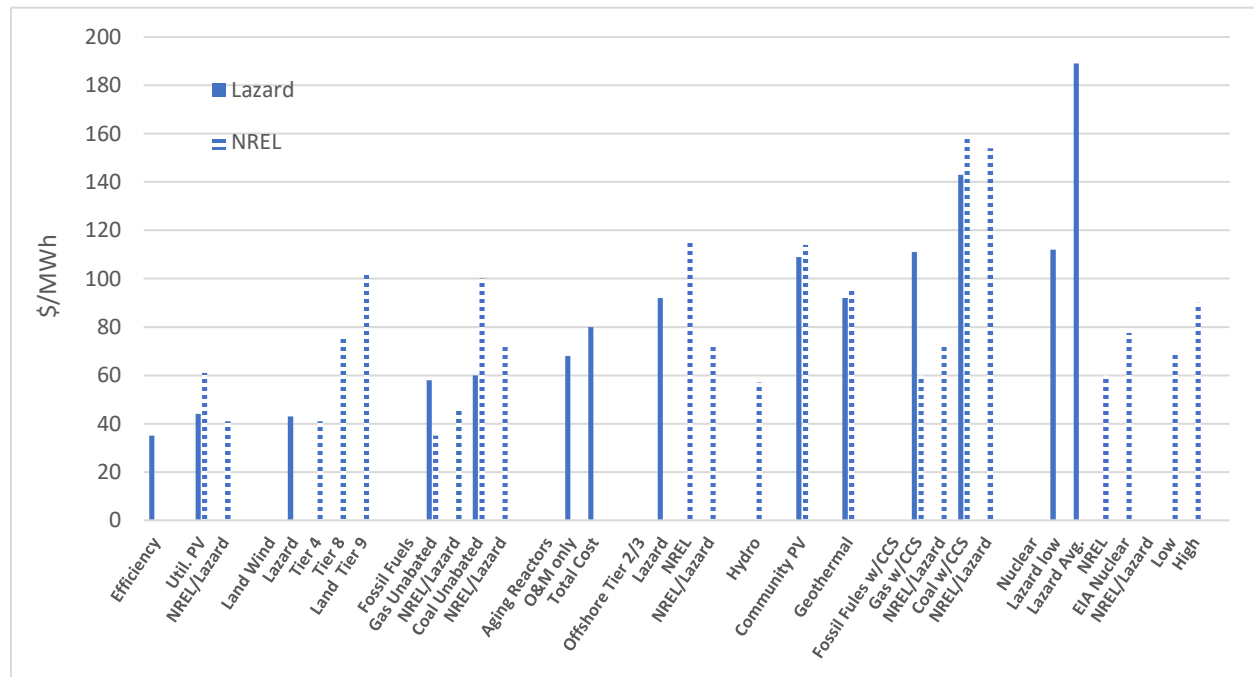
FIGURE 2.3: NREL RECENT COST TRENDS



Source: Wesley Cole, et al., *2017 Standard Scenarios Report: A U.S. Electricity Sector Outlook*, NREL/TP-6A20-68548, October 2017, p.19.

To project long term trends, I use the NREL model, but I ground the estimates in the Lazard costs. Figure 2.4 shows the estimates from the two sources. It is clear that there are differences, which can easily be reconciled.

FIGURE 2.4: CURRENT COST OF RESOURCES

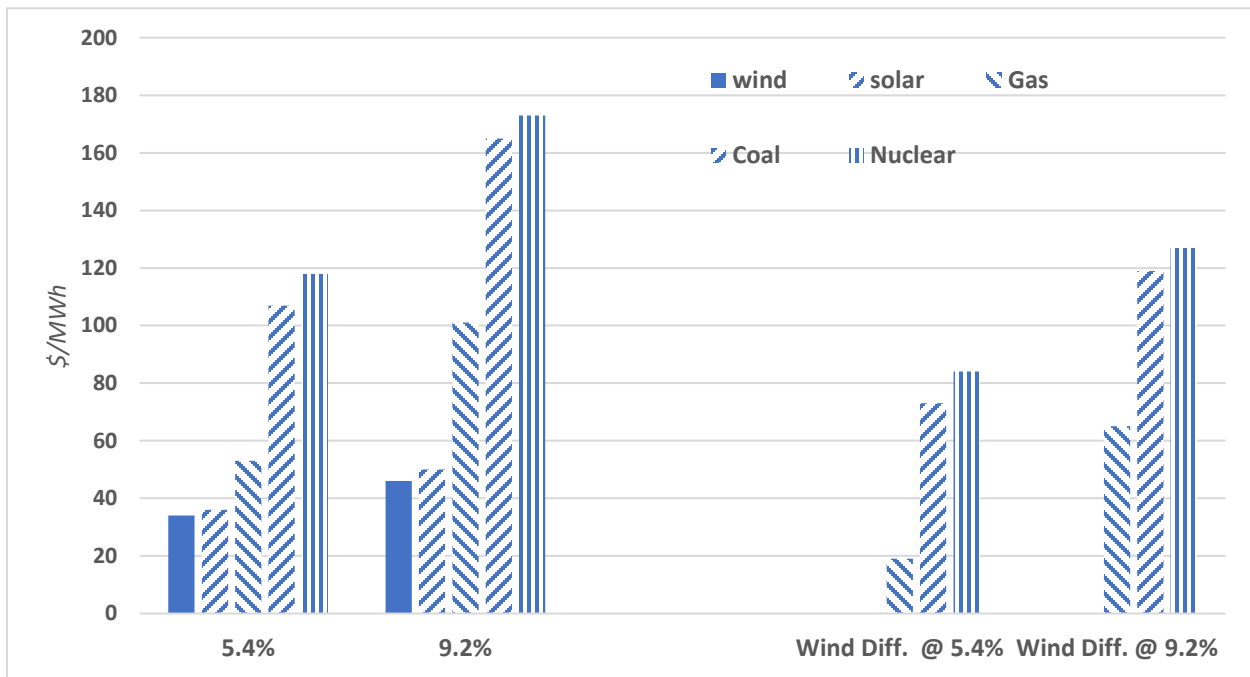


Source: NREL (National Renewable Energy Laboratory). 2018. 2018 Annual Technology Baseline. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/analysis/data_tech_baseline.html. Lazard's Levelized Cost of Energy Analysis, Version 12.0, p.2. November 2018, except CCGasw/CCS, which adds the cost of CCS from Lazard 2014 (Version 8.0) analysis to the 2018 cost of Combined Cycle Gas and efficiency from Lazard 2015 (Version 9.0). NREL/Lazard estimates are based on Lazard costs as inputs to the NREL model.

The difference result in part of its reliance on EIA estimates for central station facilities, particularly nuclear. EIA has been far off the mark – on the low side, for nuclear for over a decade. It now uses a cost that is half of Lazard, which fails to reflect the actual experience of nuclear plants that went into construction in the U.S., not to mention the historical experience. Figure 2.3 also includes several renewable resources that are less rich than the national average, but play an important role in New York, as discussed below.

NREL has higher cost of utility PV primarily because they assume a high current cost that drops quickly to the level of Lazard, so it does not affect the long-term projection. Wind is similar, when the resource being costed is taken into account. NREL uses lower costs for unabated and gas and higher costs for unabated and abated coal. The costs for nuclear are extremely low, for two reasons. As shown in Figure 2.5, using Lazard’s estimated cost of capital increases the cost projection somewhat.

FIGURE 2.5: IMPACT OF WEIGHTED AVERAGE COST OF CAPITAL ON THE COST ESTIMATES



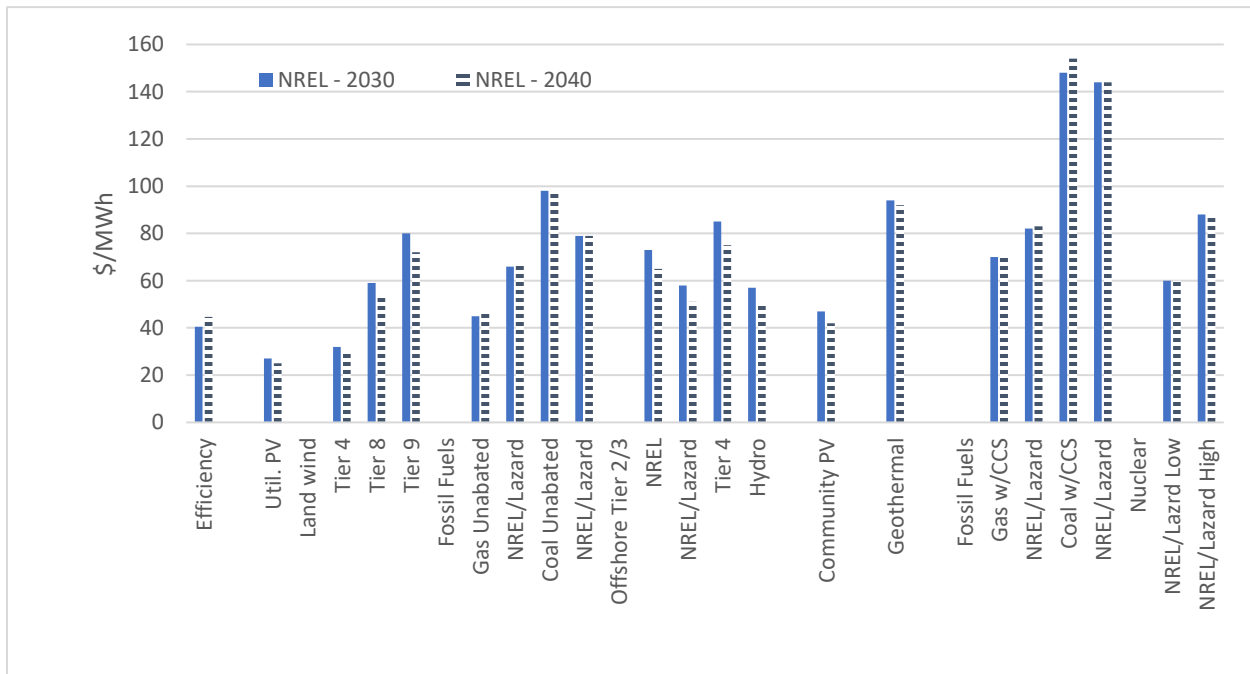
Source: Lazard’s Levelized Cost of Energy Analysis, Version 12.0, p. 5.

There is a second factor at work to create the differences. NEL uses a very low cost of capital. Lazard recognized this issue as analyzed it, as shown in Figure 2.4. NREL used a weighted average cost of capital of 5.3%, just below the lowest figure shown in Lazard’s sensitivity analysis. Lazard used a weighted average cost of capital of about 9.6% just above the highest figure in the sensitivity analysis.³⁴ Because of the very low cost of capital, the more capital-intensive central resources, particularly coal and nuclear, appear less costly compared to the alternatives. Wind is about \$80 less costly per MWh at the lower cost of capital, but \$127 less costly at the higher cost of capital. Adjusting the amount of capital (and other costs, particularly fuel in the case of gas) and the cost of capital, would reconcile the differences.

The conclusions remain the same, whether or not we adjust the cost of capital, so I prefer to imply input the Lazard costs into the NREL model for purpose of ensuring apple-to-apples comparisons. At current costs, the main renewables, efficiency (added from the earlier analysis), average onshore wind (tier 4) and utility PV are the least costly resources today, but very closely competitive with gas. Aging reactors (added from the earlier analysis) are more costly, as are new reactors. The abatement of carbon emissions makes the fossil fuels much more costly, particularly coal. New nuclear is more costly than the other resources, and gas with carbon capture. At current costs, hydro is more attractive as carbon reduction option than any of the central station low carbon resources.

The advantage of the alternatives improves dramatically when we turn to the mid (2030) and long term (2040), see Figure 2.6. I use these distinctions to reflect the basic economic definitions: in the short term all assets (capital investments) are fixed, long term all assets (capital investments) are variable. Ten years (2030) is a good break point for the short term, since the aging reactors for which subsidies are being sought should all be retired by then. Twenty years (2040) may be a little short for some assets in the electricity system, but most existing generation online today will be replaced in that time frame. There is, of course, a continuous process of investment in these long-lived resources as they expire, which means decisions have to be made about which assets to choose in the near-term.

FIGURE 2.6: RESOURCE COSTS IN THE MID AND LONG TERM



Source: NREL (National Renewable Energy Laboratory). 2018. 2018 Annual Technology Baseline. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/analysis/data_tech_baseline.html. Lazard's Levelized Cost of Energy Analysis, Version 12.0, p.2. November 2018, except CCGasw/CCS, which adds the cost of CCS from Lazard 2014 (Version 8.0) analysis to the 2018 cost of Combined Cycle Gas and efficiency from Lazard 2015 (Version 9.0). NREL/Lazard estimates are based on Lazard costs as inputs to the NREL model.

Figure 2.6 shows that the advantage of the alternatives increases dramatically as we move forward in time. The reason is that the strong technological trends of the decades since the UN

convention on climate change was signed are expected to continue. The core resources of the 21st century system become less costly and cost competitive alternatives expand (community PV, hydro, more wind resource), even against unabated fossil fuels. If the cost of capital is higher than used by NREL, the advantage will be greater and more of the alternative resource options will be competitive. It is clearly possible to argue that the alternative will yield a lower cost electricity system, whether or not decarbonization is a compelling policy target. If decarbonization is a policy concern and low emissions are required. The alternatives are preferable by a wide margin.

NEW YORK'S SUBSIDY FOR AGING NUCLEAR REACTORS³⁵

Not surprisingly, the effort of nuclear advocates to secure subsidies for existing reactors involves a two-pronged attack based on the euphemizing of the subsidies they are demanding and the dysphemization of the ability of the alternatives to meet the need for electricity in a low carbon future. I will note a number of ways the advocates of central station power use these two devices to advance their cause, but here I raise a fundamental complaint about the labelling of the program.

Euphemy: When is a ZEC (Zero Emission Credit) not a ZEC?

I analyze the New York subsidy program for aging reactors in detail and also refer to Illinois. I believe that New York and other states have mislabeled this type of program a Zero Emission Credit (or ZEC) program.

This label is purposefully misleading and should not be used. The subsidy program for aging reactors does not deserve the ZEC label. The program is an explicit subsidy for specific reactors, some of which are and would be profitable without a subsidy. In some cases, the subsidy is likely to be too little to meet the revenue goal of the utility. In other cases, it is too much. But, in all cases it is unnecessary and a huge burden on ratepayers.

The opponents of the Aging Nuclear Reactors Subsidy Program (AGREE/NIRS) of the nuclear subsidy offered in New York point out that, as calculated by the PSC staff, it is over three times as large as the subsidy for renewables.³⁶ I show that a realistic assessment of the mid-term impact is likely to put the subsidy at five times as large as that offered for alternatives.

The stakes are huge and the use of these financial resources need to be properly characterized.

- First, there is no such thing as a zero emissions resource; all have a carbon footprint, if only in their deployment phase. We are analyzing the level of net carbon emissions.
- Second, nuclear power, even from aging reactors, is not zero emission. In fact, the alternative approaches to meeting the need for electricity have lower emissions.
- Third, the name suggests that any zero-emission source should be eligible for the credit. That is not the case for the Aging Nuclear Reactor Subsidy Program; it is available only for nuclear power. In contrast, non-hydro renewables must

compete with all other resources to be included in the portfolio of low carbon assets.

- Fourth, in New York and elsewhere subsidies for the alternatives are explicitly labeled either renewables or clean; so, failing to label the nuclear subsidy explicitly is misleading and deceptive.
- Fifth, in New York and elsewhere, the nuclear subsidies are part of a broader effort to rely on clean power, but the alternatives are much cleaner (emit less carbon and other pollutant) than nuclear power from aging reactors. Nuclear power is not a clean resource by any stretch of the imagination.

The Green New Deal avoids this euphemism. Its primary resolution in Section 1 is “to achieve net-zero greenhouse gas emissions through a fair and just transition for all communities and workers.” Nuclear power is certainly not a zero emissions resources and using the word “net” implies a comparison to other resources. Nuclear power is not “net zero” compared to other, low carbon resources like efficiency, wind, and solar.

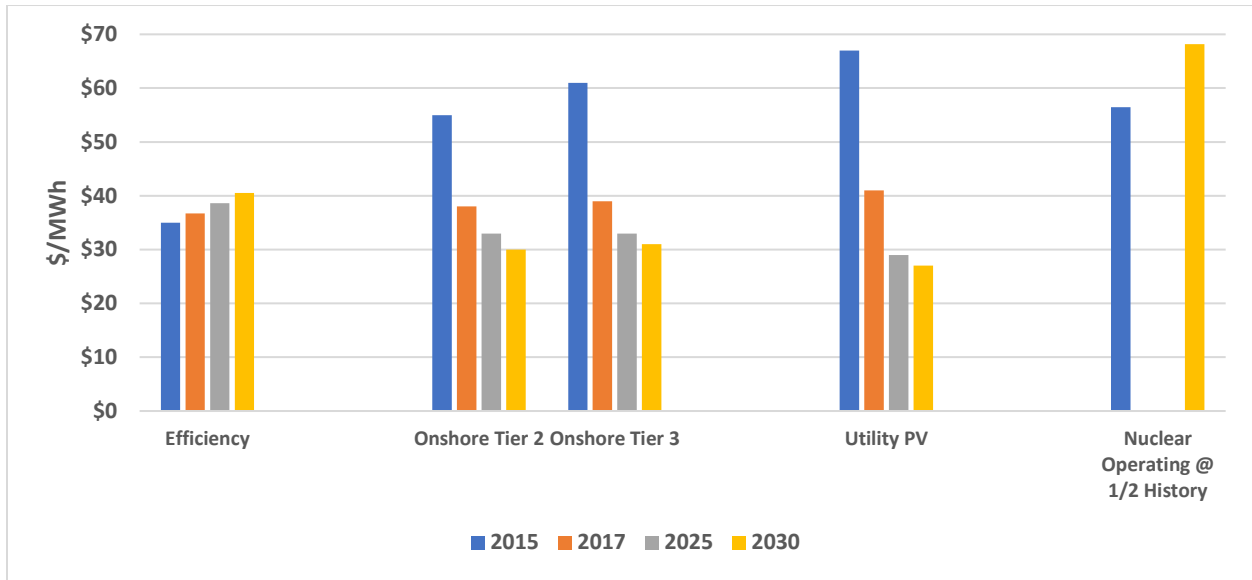
Moreover, looking down the list of specific measures identified to achieve the goals of the Green New Deal in Section 2, nuclear power is disqualified on several other grounds. It is a major polluter, consumer of water and creator of hazardous waste. It undermines the ability to expand renewable resources, including efficiency and integrated demand management. Because aging reactors must be replaced and new reactors are much more costly than the alternatives, nuclear power shrinks economic opportunities and does nothing to transition communities and workers to a stable 21st century electricity sector.

Current and Future Costs

The opponents of the Aging Nuclear Reactors Subsidy Program argue that the staff of the New York State Department of Public Service (DPS) Commission got the cost of resources wrong. They point to Lazard, a source I have used for a decade as superior or short-term forecasts, and the National Renewable Energy Laboratory (NREL) for longer term forecasts. The opponents are correct. Here I focus on NREL and the mid to long term (10 to 30 years), which is the relevant time framed for policy making. NREL does both backward looking and forward-looking analysis, NREL also estimates the levelized cost of energy including all costs and excluding subsidies, as shown in Figure 2.7.

For the purposes of comparison, I have chosen wind tiers as identified by AGREE/NIRS. I have also chosen a solar case in the NREL data that matches the Lazard (Northeast) cost case – i.e. the mid-level forecast for Kansas City. NREL’s estimates for the near term are consistent with those of Lazard. The graph shows mid-term costs of these resources compared to aging reactors. I have included the cost of efficiency and aging reactors (from the AGREE/NIRS comments) in the mid-term projections, since this gives all of the key low carbon options together. I assume that the cost of operating aging reactors continues to increase but at half the rate of recent years.

FIGURE 2.7: NREL MID -TERM LEVELIZED COST



Source: NREL, ATB database, 2018

Aging reactors start the period of the Aging Nuclear Reactor Subsidy Program with substantially higher costs than the alternatives and they become much less economic as their cost rise and the cost of the alternatives declines. As shown in Table 2.1, the cost advantage enjoyed by the three main near-term resources – efficiency, wind and utility PV are substantial, and growing, which NREL attributes to powerful market forces, “The relatively similar prices of wind and PV today means they are also increasingly competing with each other for market share. This dynamic of the relative competitiveness of wind and PV is likely to play a larger role as the costs of these technologies continue to evolve.”³⁷

TABLE 2.1: ALTERNATIVE COST ADVANTAGE (\$/MWH) COMPARED TO NUCLEAR

	2017	2030
Efficiency	\$20	\$27
Wind	\$18	\$38
Utility PV	\$15	\$41

Source: Figure 2.7

3. MARKET DISTORTION AND CROWDING OUT ALTERNATIVES³⁸

DISTORTING WHOLESALE MARKETS

Efforts to defend short term subsidies for aging reactors are based on a fundamental dysphemization of the market and its clearing price/process in deregulated states. The wholesale market does what markets are expected to do, find the lowest possible price to clear the market. Central station facility owners claim, without any evidence that this price fails to put a proper value on key attributes of energy resources – attributes that their facilities happen to possess. Evidence of a market failure – i.e. disruption of supply – is lacking.

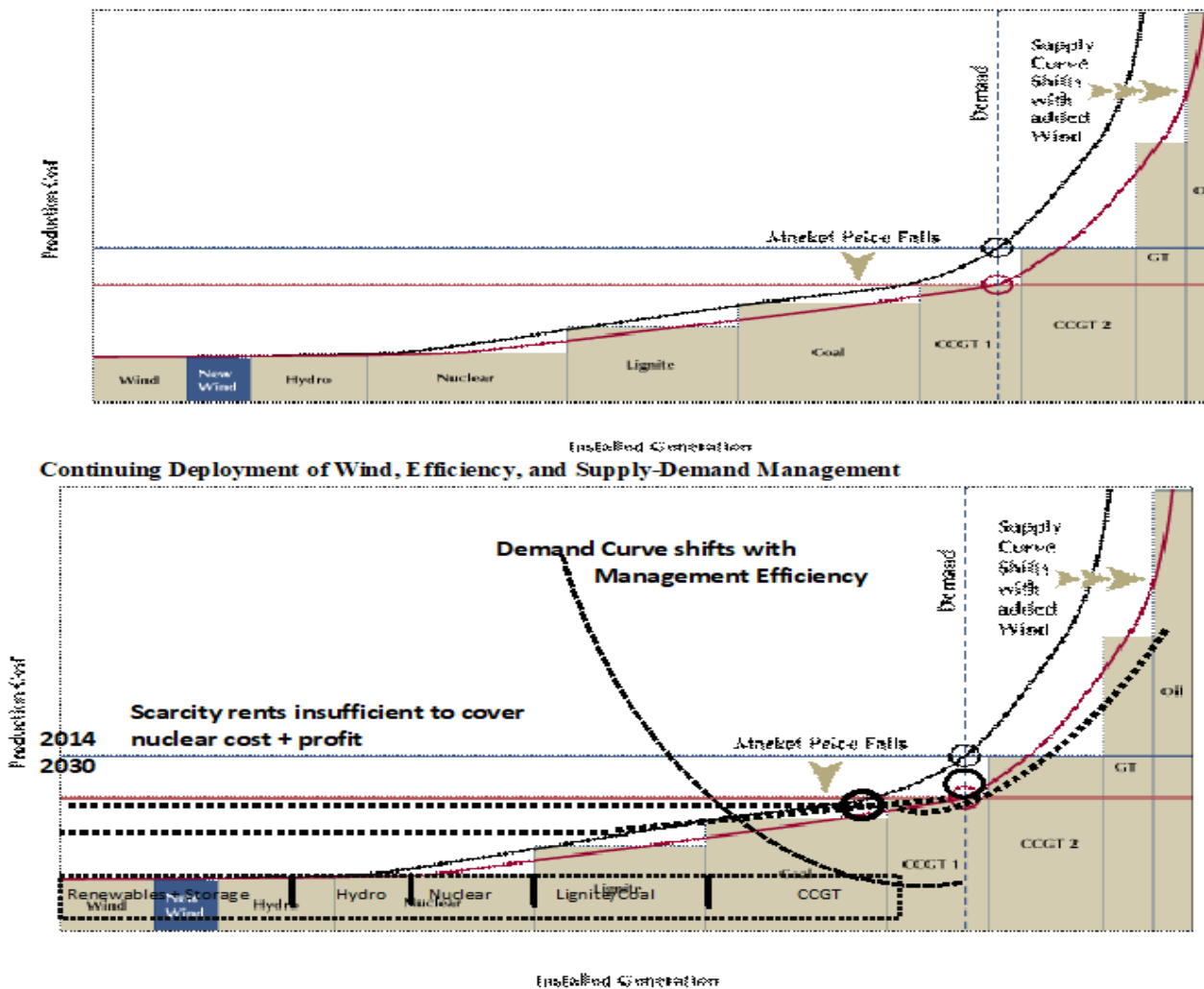
The one example that is frequently cited is not a situation of deficit but one of surplus. There are moments when supply is so plentiful that it is necessary to curtail some output or pay people not to produce to keep the system in balance. Those very rare instances would be reduced, if not eliminated if a fully integrated system were deployed. The behavior of the contemporary system based on central station generation has its “odd” moment and characteristics too. Above all, the system deploys resources that are rarely used (peakers), only at moment when the price escalates dramatically because there is a shortage of available supplies (peak load hockey stick prices). This evidence is dismissed as part of the system, which the grid operators labor to reduce and control. All systems have moments of stress and the existence of one does not provide evidence of market failure or mean that one system is better than the other.

In this Section I argue that the manner in which the Aging Nuclear Reactors Subsidy Program shrinks the market available to non-hydro renewables and keeps aging reactors online, creates a serious distortion in the short term. By doing so it creates the conditions for another crisis in the future, since nuclear advocates will, once again, argue that the system is not ready to give up nuclear power because of the “underdevelopment” of renewables and demand another round of subsidies.³⁹ This is linked directly to the broader pattern of crowding out that we observe in the electricity sector. Reliance on central station facilities crowds out alternatives in the long run, which is also the short run effect of the subsidy program. I describe the short-term problem aging reactors face in terms of a graph used by the industry to argue for subsidies (the upper graph the Figure 3.1. The operating costs are quite high, and total costs are higher still—well above recent market clearing prices.

The flashpoint of the conflict over the transformation of the electricity sector is captured in the lower graph, which is taken from an analysis focused on Illinois. It centers on the market clearing price of electricity in those areas where markets (as opposed to regulators) set that price. The downward pressure on the market clearing price, initially driven by gas, but increasingly driven by renewables that are cost competitive with gas, means not only that aging reactors cannot cover their costs, but are not likely to in the future. Operating costs alone are almost twice the current market clearing price of electricity and things are likely to get worse over time. Reduced demand growth reflecting efficiency and management substantially increase those pressures.

Of equal, if not greater importance is the fact that the cost of keeping aging reactors online is above the full levelized cost of the alternatives and the economic superiority of these alternatives is likely to grow as their costs decline and the cost of aging reactors grows.

FIGURE 3.1: MERIT ORDER EFFECT OF ADDING NEW WIND CAPACITY ON PEAK PRICES
Current Wholesale Market



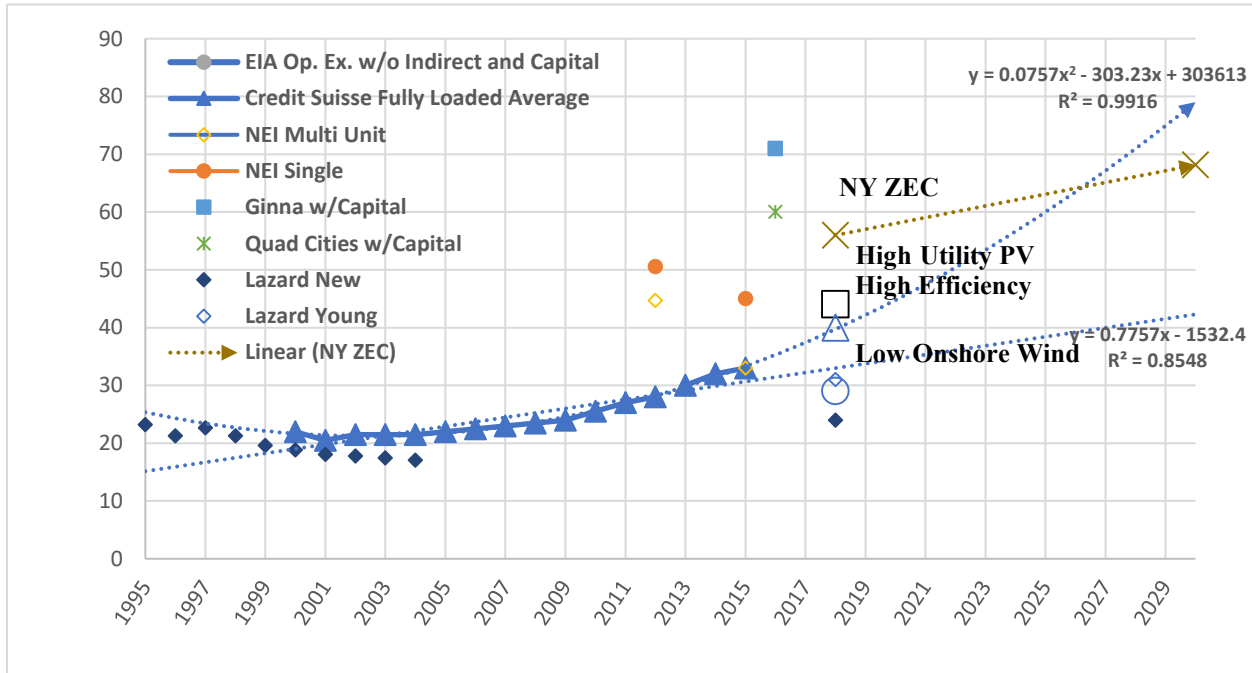
Source: Source: Doug Vine and Timothy Juliant, 2014, *Climate Solutions: The Role of Nuclear Power*, Center for Climate and Energy Solutions, April, p. 6, with author’s additions. Appendix A, short term for price pressures.

Figure 3.2 shows my recent estimates of the cost of keeping aging reactors online compared to some other recent estimates and the full cost of efficiency, wind and solar. Projecting the trend out a decade would put the cost of high-quality wind and utility PV well below \$40/MWh

STATE MARKETS

Utilities in New York,⁴⁰ Illinois,⁴¹ Ohio,⁴² Pennsylvania,⁴³ and New Jersey⁴⁴ asked for above-market prices for numerous reactors. These reactors have lost hundreds of millions of dollars over the last couple of years. The utilities claim that the low price of gas is the cause of the problem, but the situation is more complex than that. As suggested by Figure 3.3 based on Illinois analysis, the real-world underpinnings of these market forces are multiple and complex.

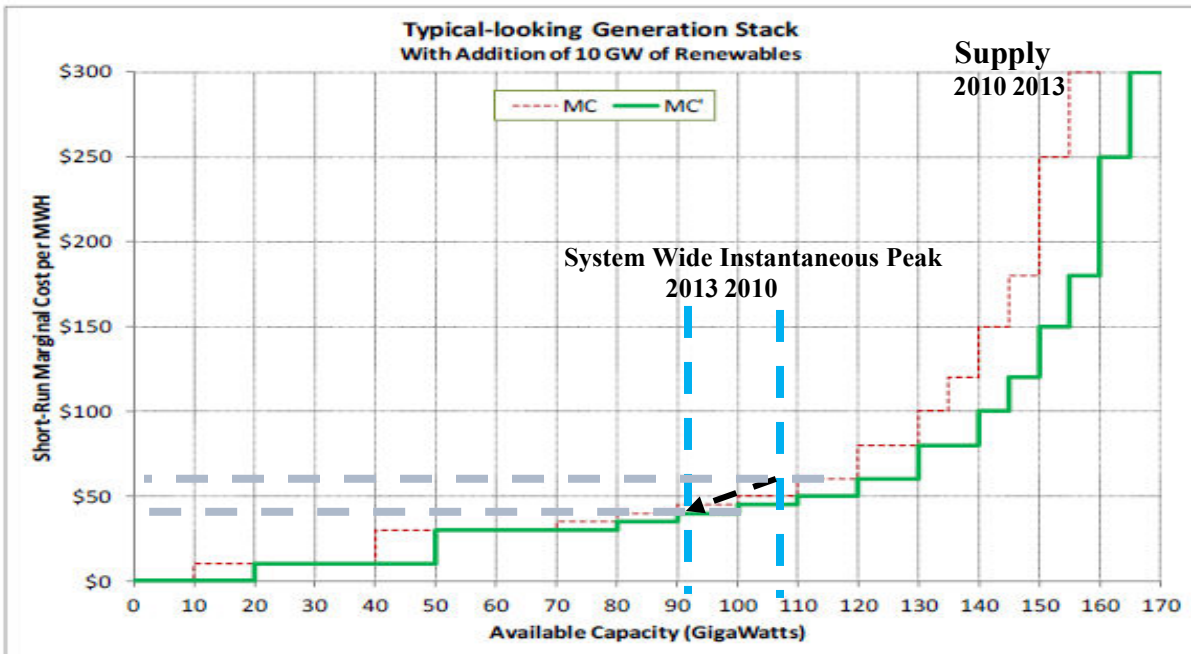
FIGURE 3.2: OPERATING AND TOTAL COST OF AGING REACTORS COMPARED TO WIND & UTILITY PV: NEW YORK



Sources: see Appendix B, short-term.

FIGURE 3.3: THE ECONOMIC COST AND UNECONOMIC CONSEQUENCES OF BAILING OUT AGING NUCLEAR REACTORS: ILLINOIS

Impact of Merit Order and Declining Demand Based on MISO Changes



Source: Appendix A, Illinois for sources

- First, the rising cost of operating reactors accounts for about a third of the problem;
- Second, the addition of wind, which backs inefficient gas out of the market clearing price, contributes to the shift; and

Third, demand has declined due to increased efficiency. The price of gas matters as well, but less than the other three factors. Two-thirds of the revenue shortfall experienced by aging reactors is caused by the rising cost of keeping nuclear reactors online, the superior economics of renewables, and the attractiveness of efficiency. The historical contribution of these three factors varies from state-to-state based on the characteristics of the specific reactors, the development of renewables, and the shift in demand. However, in the transition to a low carbon sector, the latter two forces will inevitably come to dominate.

This analysis of the contemporary market clearing challenges for nuclear power provides the context for analyzing the impact of the Aging Nuclear Reactors Subsidy Program (see Figure 3.4). AGREE/NIRS have noted that the treatment of hydro distorts the perception of the market for low carbon resources.

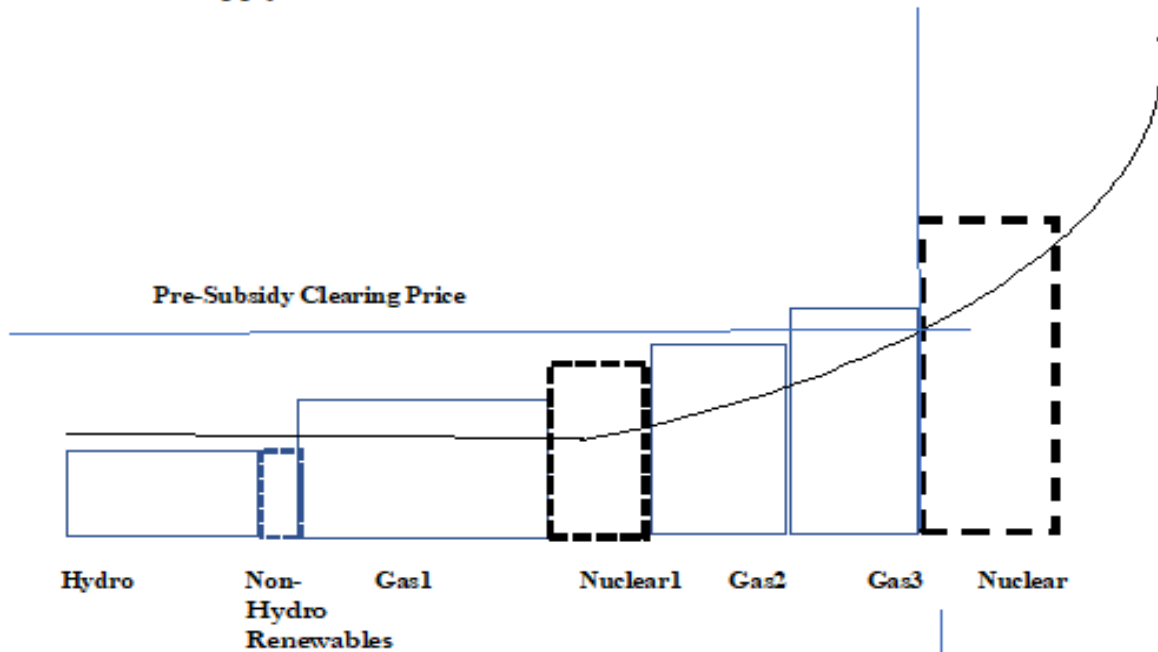
[A] large portion of in-state generation credited to meeting the renewable goal in the Clean Energy Standard is comprised of large hydro facilities-built decades ago.... By those standards, the Clean Energy Standard represents a 35% increase in renewable energy by 2030 from that initial base of hydro. This represents a less aggressive deployment of renewable energy than some other states have adopted. This has the effect of further backloading renewable energy development by making it appear the state has progressed further than it has... It is anticipated that emissions reductions at the later stages of meeting an 80% by 2050 goal will be more difficult than progress at earlier stages, so it would be better to frontload as much easily achievable renewable energy and efficiency as possible.⁴⁵

After counting for hydro, the need for low carbon resources to meet the short-term goal is just under 40GWh.⁴⁶ The aging reactors that are the beneficiary of the Aging reactor subsidy and removed from competition provide over half the nuclear power in the state, at 27 GWh.⁴⁷ Thus, the nuclear carve out equals almost four-fifths of the expected increase in renewables. As shown in Figure 4.4, this severely restricted market will strangle the ability of non-hydro renewables to expand and is likely to drive the market clearing price down, as resource 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,⁴⁸ avoiding another “crisis” at the termination of the current subsidy, a “crisis” that the industry will inevitably invoke to demand another round of subsidies.

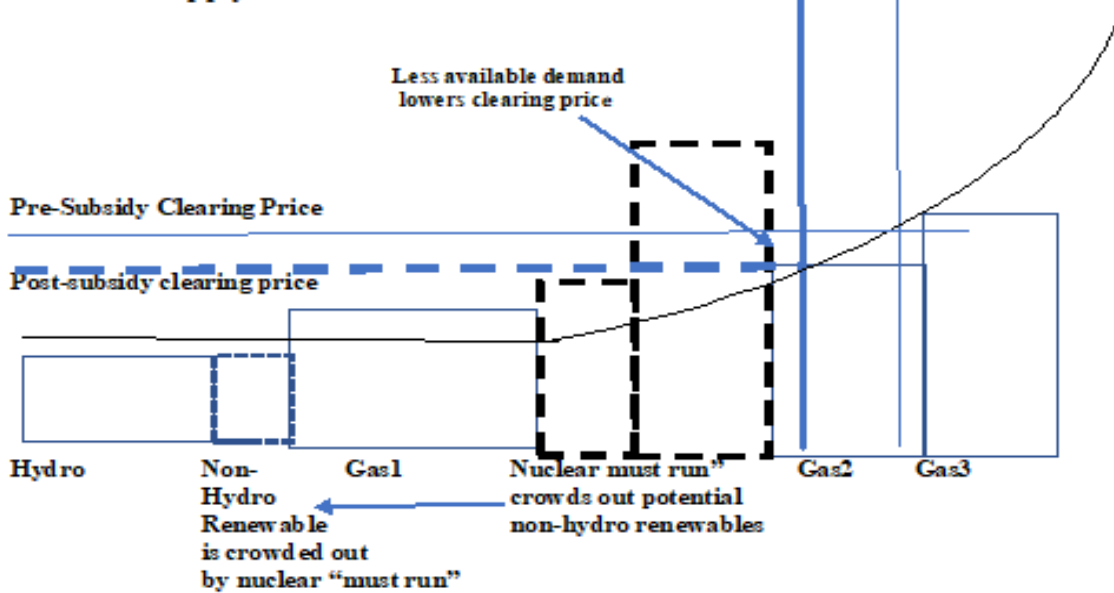
New York State policy seeks to achieve a clean, low carbon electricity sector driven primarily by the market, recognizing that specific standards and subsidies will be necessary to jump start the transition. The Aging Nuclear Reactors Subsidy Program frustrates, slows and perhaps undermines this objective.⁴⁹

FIGURE 3.4: MARKET DISTORTION CAUSED BY THE AGING NUCLEAR REACTOR SUBSIDY, CROWDING OUT NON-HYDRO-RENEWABLES: NEW YORK

Pre-ZEC Supply and Demand



Post-ZEC Supply and demand



Sources: Appendix B, short-term

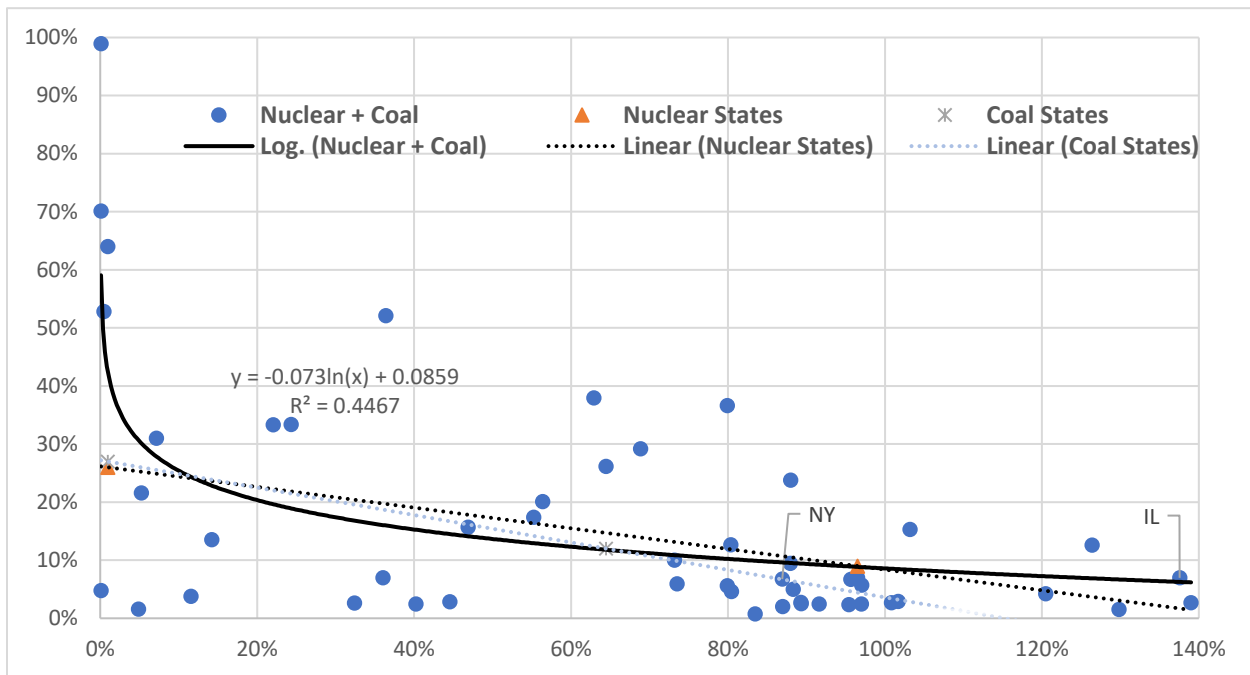
LONG-TERM CROWDING OUT

As shown in Figure 3.5, central station generation has a tendency to crowd out alternatives. The smaller the share of central station facilities, the larger the share of renewables.

One can look at this graph and say, it is just arithmetic. When a state has so much nuclear, there is no need for renewables, but that is the point in two respects.

- First, the math is created by policy choices and those policy choices have consequences. Resources are denied to alternatives. For nuclear facilities in particular, especially during the construction phase, utility management resources are devoured by nuclear reactors.
- Second, since it is a policy choice, it can be reversed and the share of renewables expanded.

FIGURE 3.5: CENTRAL STATION GENERATION CROWDS OUT ALTERNATIVES: LONG-TERM



Source: Appendix B, long-term.

The graph tells a very clear story. Where reliance on central station facilities is high, non-hydro renewables have a low share. The logarithmic regression explains 44% of the variance in renewable penetration. Each of the central station resources has about the same independent impact and they are uncorrelated, so the combined effect is pronounced. To grasp the impact, we show lines that capture the difference between low central station (less than 10% nuclear or less than 10% coal) and renewables. The 23 low nuclear states have 26% nonhydro renewables in the generation for 2017. The high nuclear states have 9%. The 8 low coal states have a nonhydro renewable share of 27%, compared to 12% for the high coal states.

One can also see why New York and Illinois have become focal points of the subsidy debates. The states are very large with very high reliance on central station facilities. They are well above average on nuclear at or above average on coal. They are considerably below average on non-hydro renewables. As discussed below, they are mediocre, at best, on efficiency.

4. ENVIRONMENTAL AND EMPLOYMENT IMPACTS

ALTERNATIVES ARE MUCH MORE ENVIRONMENT-FRIENDLY THAN CENTRAL STATION AND NUCLEAR POWER⁵⁰

Nuclear power is neither clean, nor the lowest cost source of carbon emissions available. From an environmental point of view, new nuclear reactors take so long to build that a substantial part of their low carbon claim is dissipated. While aging reactors emit less carbon than coal or gas, they emit more carbon than the alternatives – efficiency, wind and solar (not to mention existing hydro renewables). With respect to non-carbon pollution, the alternatives impose much less harm and pose much less of a threat than nuclear power.

Carbon Footprint

As shown in Table 4.1, while it is certainly true that aging reactors have fewer greenhouse gas emissions than coal or gas, it is just as clear that they have higher levels of emissions than the alternatives. Thus, if decisions are made on “marginal values,” aging reactors would be chosen after the alternatives.

TABLE 4.1: LIFECYCLE CARBON EMISSIONS OF LOW CARBON SOURCES WITH LOST OPPORTUNITY OF NUCLEAR DELAY (Grams of CO₂/ kwh)

	LIFE CYCLE			COST OF CONSTRUCTION DELAY	
	LOW	AVG.	HIGH	LOW	HIGH
EFFICIENCY		1			
WIND	4	10	7		
CSP	9		11		
SOLAR	19	32	59		
GEOTHERMAL	15		55	1	6
HYDRO	17	25	22	31	49
NUCLEAR: OLD		40	58		
NEW	9	40	70	59	106
NEW GAS W/CCS		45			
NEW COAL W/CCS		90			

Source: Jacobson, Mark Z., “Review of solutions to global warming, air pollution, and energy security,” *Energy and Environmental Science*, 2009, Table 3; Benjamin K. Sovacool and Michael Dworkin, *Global Energy Justice*, Cambridge University Press, 2014 (Non-GHG, p. 149; GHG, p. 108); Benjamin K. Sovacool, “Exposing the Paradoxes of Climate Change Governance,” *International Studies Review*, 16 (2), 2014; Benjamin K. Sovacool, “Valuing the greenhouse gas emissions from nuclear power: A critical survey,” *Energy Policy*, 36(8) August 2008.

Carbon capture is the least effective of the low carbon options. Aging reactors are on a par with gas with carbon capture. The lengthy construction period significantly reduces the effectiveness of nuclear power as a decarbonization option. Long construction periods for fossil fuel carbon capture assets would reduce their attractiveness as well.

In short, aging reactors are the least attractive among the currently available resources with respect to carbon reduction and replacing them with new reactors is less attractive. Because the long-term future does not include nuclear, it is counterproductive to extend its life in the present, even if such a policy just delays the inevitable. Where it makes the transition more difficult, it is particularly important to avoid the mistake of subsidizing resources that play no role in the long-term.

Non-carbon footprint

Although carbon emissions are the central concern in Aging Nuclear Reactors Subsidy Program proceedings, no discussion of subsidies for aging reactors established under a Clear Energy Mandate is complete without examining other environmental impacts. Table 4.2 compares the three primary non-hydro renewables (efficiency, wind and solar) to the two primary low carbon central station resources (nuclear and gas with carbon capture). It presents evidence on the traditional non-carbon environmental concerns, pollutants, land and water use, and accidents.

Central station resources are a much greater concern. Nuclear is not clean by any stretch of the imagination. This ranking was in evidence in the literature on resources long before climate change and carbon emissions were the focal point of concern.⁵¹ Table 4.2 also includes two other factors that enter into the contemporary debate – water and land use. Here there is a mixed message. Central station facilities have much higher water use, but lower land use.

TABLE 4.2: NON-CARBON ENVIRONMENTAL IMPACTS

Resource	Pollutants Cents/MWh	Water (m3/MJ)	Land (m2/GWh)	Accidents Fatalities
Efficiency	~0	0	0	~0
Wind	0.29	0.01	2404	1
PV	0.69	0.042	1232	4
Hydro	3.84	22	1803	12
Geothermal	.66	.005	202	2
Gas w/CCS	5.02	0.1	623	10
Coal w/CCs	14.87	0.31	325	20
Nuclear	8.63	0.59	78	7

Source: Mark Cooper, *The Political Economy of Electricity*, Table 5.8 and 5.9 and accompanying text. ⁵²

Central station generation, particularly nuclear, is a voracious user of water resources. While central station advocates frequently dysphemize renewables by claiming the land use question “disqualifies” non-hydro renewables, that argument is a distraction at best. The potential for rural utility PV is one possible response to the land use issue. It is also important to recognize that renewable resources use land in different areas in different ways and some applications (commercial, residential and even utility scale PV) represent a secondary use of land that is already occupied. The challenge of locating the core facilities of the 21st century electricity system appears to be much smaller than the challenge of permanently locating the huge quantities of radioactive waste created by the operation of nuclear reactors.

The accident category deserves a comment. The reality is that nuclear reactors suffer a series of smaller incidents that raise safety concerns and also put pressure on the system. Since the electricity system must be designed to withstand an outage of its largest generators, the presence of nuclear reactors tends to drive up reserve margins. Because they are so large, those margins will have to be met with natural gas. Consequently, both the carbon and non-carbon impacts of nuclear power can be larger than the simple arithmetic of generation units.⁵³

SUBSIDIZING AGING REACTORS IS A VERY POOR APPROACH TO CREATION OF JOBS AND ECONOMIC DEVELOPMENT PROGRAMS⁵⁴

Nuclear advocates have generally lost the debate on subsidies based on cost and environmental impacts, so they turn to the claim that operating nuclear reactors is crucial to sustaining the local economies in which they are located. Viewed in long term perspective, this claim does not stand scrutiny. There is no net job loss in the short term from shuttering nuclear reactors and alternatives employ much more labor in the long term. Unless one believes that the nuclear reactors can and will operate beyond their scheduled retirement, subsidizing their operation only delays the inevitable shift to alternatives, while imposing excess costs and delaying the transformation.

Above I showed that if policy makers conclude that subsidies are necessary to accelerate and ensure the transition to a low carbon sector, they should target those subsidies at the alternatives. I reach the same conclusion with respect to employment and macroeconomic impacts. If policy makers conclude that the transformation of the electricity sector requires support for local labor and the local economy, they should focus on moving toward the alternative electricity system, not move toward a dead end by extending the life of existing reactors.

As alternatives replace nuclear and back out transitory gas, there is a macroeconomic impact. Construction for the alternatives is much more labor intensive than operating nuclear reactors. Because the cost of the alternatives is lower, they have a larger long-term impact on indirect economic activity because they leave more money in the consumer's pocketbook to buy other things. The literature overwhelmingly supports the proposition that the economy is better off relying on the alternatives.

The macroeconomic impact of energy policy has taken on great significance in the current round of decision making. Every policy is evaluated for its ability to stimulate growth and create jobs. Assessing the macroeconomic impact of policy choice generally relies on complex models of the economy. Cost savings on energy and economically beneficial energy efficiency investments yield net savings; the reduction in energy costs exceeds the increase in technology costs. Such investments have two effects from the point of view of the economy. The increase in economic activity resulting from spending on new technology and the increase in consumer disposable income flows through the economy, raising the income of the producers of the additional products that are purchased and increasing employment.

Expenditures are shifted from purchasing energy to purchasing technology, which has a larger multiplier. The decrease in energy expenditures is substantially larger than the increase in

technology costs, resulting in an increase in the disposable income of individuals to spend on other things.

- The inclusion of energy supply and efficient technologies in energy using durables increases the output of the firms that produce the technology.
- To the extent that the energy using products are consumer durables, they increase the disposable income that households have to do other things, such as buy other goods and services.
- To the extent that the energy using products are utilized as inputs in the production of other goods and service, like trucks used to deliver packages or vegetables, they lower the cost of those goods and services. In competitive markets, those costs are passed on to the consumer in the form of lower prices. This also increases the disposable income of the household to buy other goods and services.

The increase in economic activity resulting from spending on new technology and the increase in consumer disposable income flows through the economy, raising the income of the producers of the additional products that are purchased and increasing employment.⁵⁵ These large increases in economic activity lead to increases in employment. The effect is magnified by the fact that the non-energy sectors of the economy are substantially more labor intensive than energy production. The energy sector is less than half as labor intensive as the rest of the economy, so the ratio of job creation for efficiency, compared to other production option in electricity is also two to one. As consumers substitute away from energy, the goods and services they purchase stimulate economic and, disproportionately large, job growth.

Econometric models that use general flows of resources between economic activities have been used to assess these economic impacts. In a sense, the coefficients in the macro models are representations of the relationships in the economy through which the micro level effects flow. No matter the level or approach, the evidence strongly supports the conclusion that there is a positive impact from both the demand and the supply points of view.⁵⁶

The EPA reviewed the literature on the macroeconomic impact of reduced energy consumption.⁵⁷ These impacts, as discussed in EPA analysis are an indirect effect of the rule, a genuine externality. This approach has become quite common with detailed analyses of energy efficiency across a range of activities (autos, appliances, buildings, industries), sectors (e.g. energy, manufacturing, service, particularly as it impacts use of labor) and with a variety of analytic approaches (qualitative, econometric).⁵⁸ These efforts to model the economic impact of have proliferated with different models being applied to different geographic units, including states and nations.

The results differ across studies because the models are different, the impact varies according to the size of the geographic unit studied and because the assumptions about the level and cost of energy savings differ. These differences are not an indication that the approach is wrong. On the contrary, all the analyses conclude that there will be increases in economic activity and employment. Given that there are different regions and different policies being evaluated, we should expect different results.

The rule of thumb – an approximate doubling of the economic impact – that emerges in the literature reflects the observation on jobs.⁵⁹ Similarly, in a study of 52 examples of increases in industrial productivity, where benefit was monetized, the productivity savings were 1.25 times as large as the energy savings.⁶⁰ Macroeconomic models measuring the outcome in change in GDP yield a “responding” effect that clusters around 90%.

Table 4.3 shows examples of the multiplier, with the GDP impact expressed as a multiplier of the value of net pocketbook savings. That is, we subtract costs from the estimated value of energy savings. This ensures we do not double count benefits.

TABLE 4.3: ESTIMATES OF MACROECONOMIC MULTIPLIERS AS A MULTIPLE OF NET POCKETBOOK SAVINGS

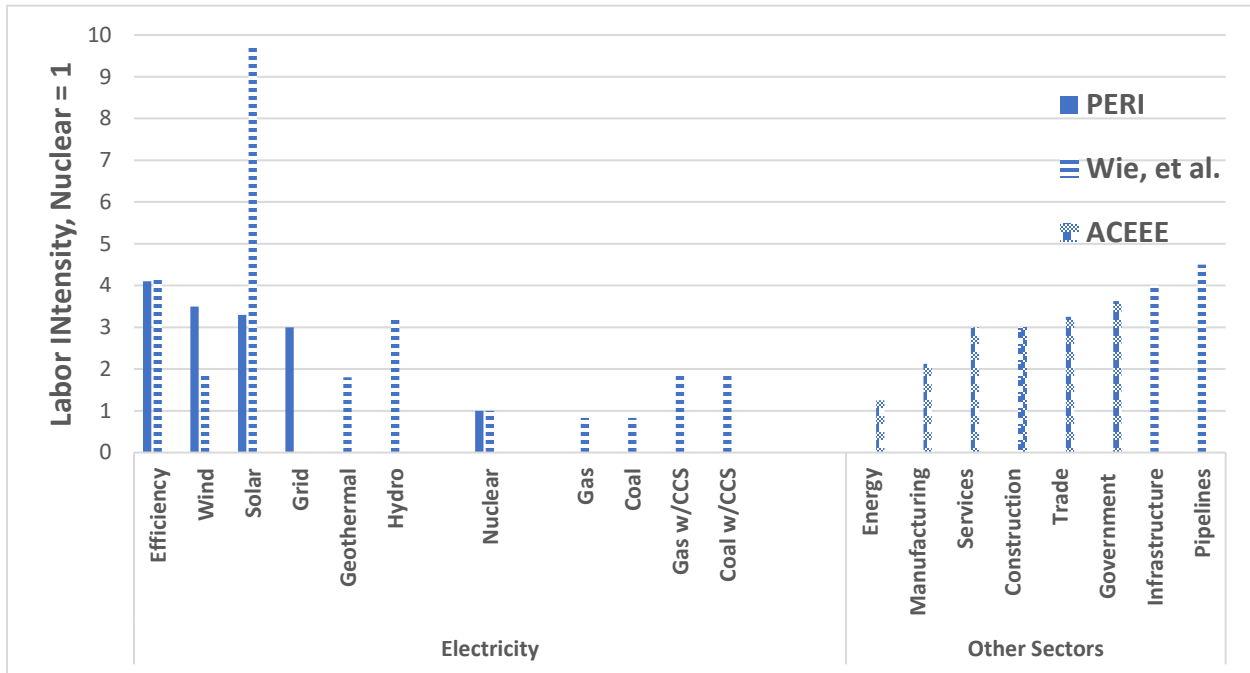
Modeler	Model Date	Policy Assessed	Region	GDP/\$ of Net Savings	
				Base Case	Rebound Adjustment
Roland-Holst	DEAR	Computer Standard	California	1.8	2.0
ENE	REMI	Utility Efficiency	Northeast	2.2	2.4
Cadmus	REMI	Utility Efficiency	Wisconsin	2.5	2.8
Arcadia	REMI	Utility Efficiency	Canada	2.7	3.0

Sources: See Appendix C, note 15.

For the purposes of this analysis, I assume that the approach that relies on alternatives has a multiplier that is twice that of nuclear. Figure 4.1 summarizes the basis for this assumption. It combines the results of three studies that apply a very common approach. Using macroeconomic models, the study estimates the direct and indirect effect of investing in a technology to produce or conserve energy. One such model was used in the effort to defend the continued operation of aging reactors. Some activities have larger multipliers because the results (savings or spending) circulated faster through the economy. This is true both across sectors, as shown in the right-side graph of Figure 4.1 and within the electricity sector, as shown in the left side graph of the Figure.

I have rendered the results of these studies comparable by indexing energy across studies and expressing the outcome as a ratio. The Political Economy Research Institute (PERI) study gives estimates for the impact of investment in nuclear and oil and gas. I equate the energy category from American Council for an Energy Efficient Economy (ACEEE) to the oil and gas category from PERI. Setting nuclear equal to one as the base, I can then calculate the relative job intensive of broad economic sectors (to the right) and electricity resources (to the left). Wei et al., calculated the number of jobs for each of the resources directly. While the correlation is not perfect, it is substantial and the directionality is clear. The nuclear multiplier is the smallest of all sources of electricity and economics sectors. In light of this data, my assumption that the alternatives would have a multiplier twice the size of nuclear is extremely cautious.

FIGURE 4.1: MACROECONOMIC MULTIPLIERS FOR ALTERNATIVE ELECTRICITY RESOURCES AND ECONOMIC SECTORS



Sources: Wie, Max Shana Patadia and Daniel Kammen, 2010, “Putting Renewables and Energy Efficiency to work: How Many Jobs Can the Clean energy Industry Generate in the US?”, *Energy Policy*, 38. Rachel Gold, et al., *Appliance and Equipment Efficiency Standards: A Money Maker and Job Creator*, American Council for an Energy Efficient Economy, January 2011, p. 9, based on the IMPLAN Model, 2009., *How Infrastructure Investments Support the U.S. Economy: Employment, Productivity and Growth*, James Heintz, Robert Pollin, Heidi Garrett-Peltier, Political Economy Research Institute, January 2009.

STATE LEVEL ANALYSIS OF EMPLOYMENT AND THE LOCAL ECONOMY⁶¹

- The 2015 Brattle Group Report, entitled “New York ‘s Upstate Nuclear Power Plants’ Contribution to the State Economy Brattle Group” (“Brattle Report”)⁶² assumes that
- every kilowatt hour of electricity produced by a retired reactor is replaced with a kilowatt hour generated by natural gas,
- there will be no increase in production by wind, solar or efficiency, at the end of the subsidy period,
- the elasticity of price with respect to supply implicit in the analysis is just under one, while the elasticity of demand with respect to price is zero,
- the macroeconomic multiplier on the use of natural gas to generate electricity is assumed to be equal to that of nuclear, so the reduction of direct and indirect jobs and economic activity resulting from the price increase is a total loss.

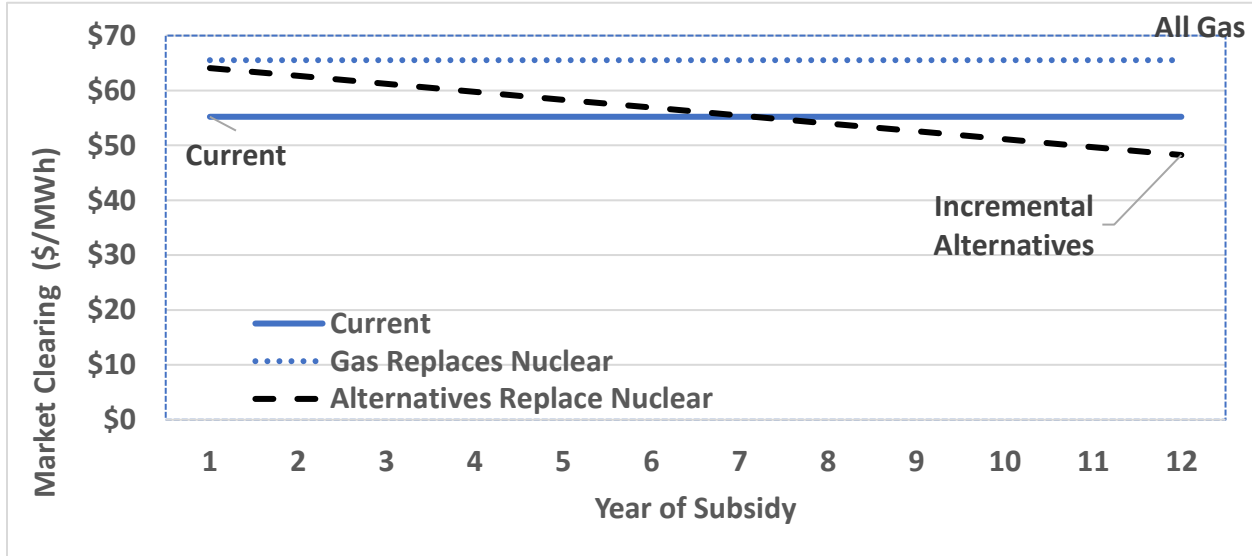
All of these assumptions are incorrect, which means the self-serving analysis should not be taken seriously. Above all, the “dash to gas” is not an unavoidable or inevitable outcome. If

the PSC does not put its thumb on the scale of competition, but allows all low carbon resources to compete to meet increasing levels of carbon reduction set by mandates on utilities, the lower cost alternatives would expand rapidly.

Based on the Brattle Report’s assumption at the end of the period of aging reactor subsidies, New York will find itself in exactly the same position it is in today, having less electricity produced from new renewable technologies and more electricity still being produced by aged, 60+ year, outdated nuclear reactor technology. Therefore, in this analysis I assume that the alternatives expand incrementally to replace nuclear (i.e. it fills 1/12 of the retiring capacity per year). Initially there is reliance on gas, but that is eliminated over time.

Figure 4.2 shows the impact of the alternative scenarios. The upper graph shows the projected market clearing price. The impact study prepared to defend keeping the reactors online assume complete replacement with gas, which drives up the market clearing price by almost 16%. In the alternative scenario, efficiency and non-hydro renewables replace the retired reactors incrementally at a steady pace (1/12 per year). I bring these increments in at a cost of \$45/MWh, consistent with the earlier analysis. Since this is almost 20% below the market clearing price, it incrementally lowers the market clearing prices. The market clearing price increases initially but by year six, it is below the base case. The cost in the early years is offset by savings in the later years, so that consumers break even shortly after the reactors are fully retired.

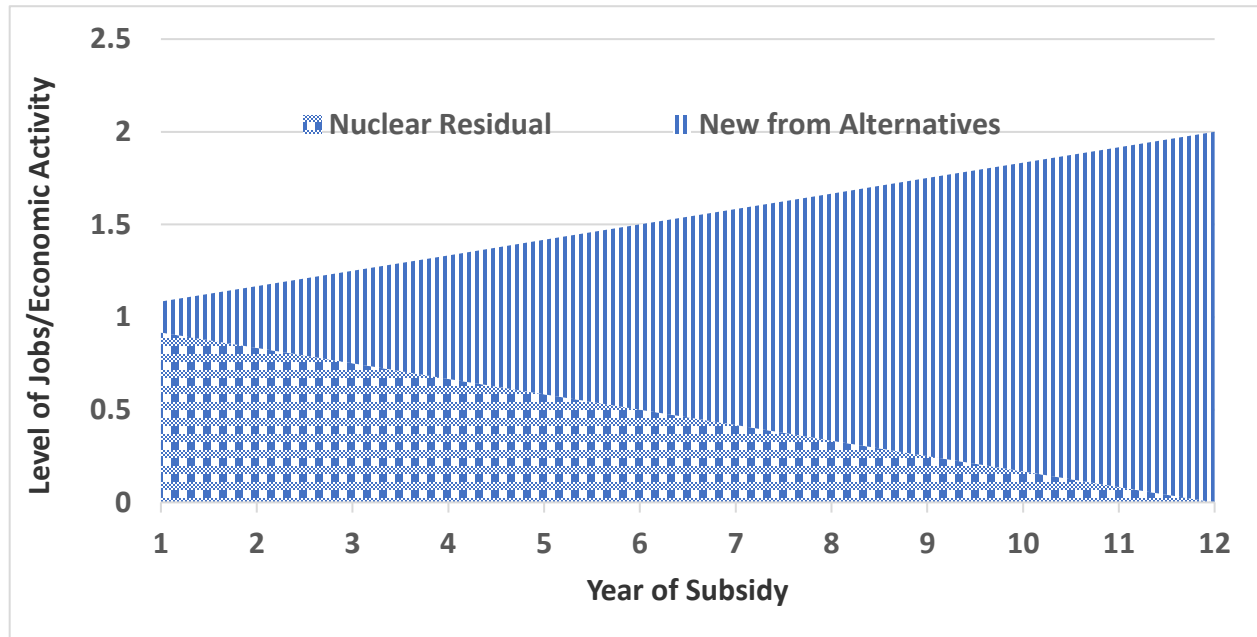
FIGURE 4.2: IMPACT OF RETIRING UPSTATE REACTORS: ALTERNATIVE SCENARIOS FOR THE MARKET CLEARING PRICE WITH RETIREMENT: NEW YORK



Source: Calculated by author as described in text.

In Figure 4.3, I plot the macroeconomic impacts of this alternative scenario. Since “indirect” jobs represent over 90% of total jobs, the multiplier is far and away the most important factor. In this analysis I do not include decommissioning jobs, since those will be captured whenever the reactors close.⁶³ In this orderly transition, there is no net loss of jobs even from the beginning.

FIGURE 4.3: IMPACT OF RETIRING UPSTATE REACTORS: JOBS/MACROECONOMIC IMPACT ASSUMING MULTIPLIER FOR ALTERNATIVES/GAS IS TWICE NUCLEAR: NEW YORK

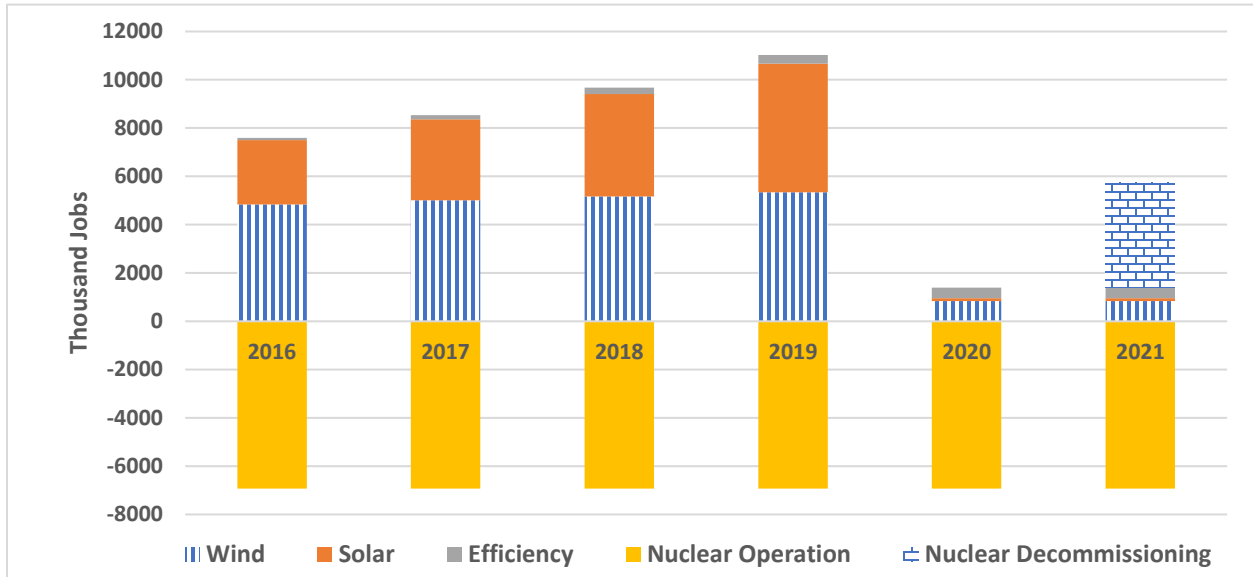


Mark Berkman and Dean Murphy, *New York's Upstate Nuclear Power Plants' Contribution to the State Economy prepared for New York State IBEW Utility Labor Council, Rochester Building and Construction Trades Council, Central and Northern New York Building and Construction Trades Council, Brattle Group, December 2015*

The calculations offered by the Illinois Department of Commerce show that operation of nuclear reactors is almost twice as labor intensive as the operation of the replacement resources of efficiency, wind, and solar. This assumption is at odds with other evidence in the electricity sector, which shows that nuclear creates many fewer jobs than efficiency and solar and about the same number of jobs as wind, as shown in Figure 4.4.⁶⁴ One explanation may be that the challenge of keeping aging reactors online, which has so dramatically increased their operating cost, might also increase the amount of labor needed. In other words, this leads to a perverse economic principle: the more inefficient the resource, the more it should be valued as a jobs project.

However, ultimately the Illinois Department of Commerce analysis presents a more balanced view and raises the question of the impact on the local and state economy. The loss of nuclear reactor-related jobs (direct and indirect) is offset in the early years by construction of alternatives. When the construction jobs expire, the loss of nuclear jobs exceeds the ongoing number of jobs added by the “operation” of replacement resources. However, this calculation does not include decommissioning activities at the reactors. Ironically, while the Department of Commerce does not include decommissioning jobs, it then criticizes the Nuclear Energy Institute analysis that failed to do so.⁶⁵ The oversight is substantial. In the long term, the lower cost of the alternatives and high multipliers far outweigh the small difference in direct jobs, yielding much higher levels of employment and economic activity. There is no reason to delay capturing these benefits, or put them at risk by extending the life of reactors.⁶⁶

FIGURE 4.4: JOBS IMPACT OF EARLY RETIREMENT AND REPLACEMENT, INCLUDING DECOMMISSIONING: ILLINOIS



Sources: Illinois Commerce Commission, Illinois Power Agency, Illinois Environmental Protection Agency, Illinois Department of Commerce and Economic Opportunity, *Potential Nuclear Power Plant Closings in Illinois: Impacts and Market-Based Solutions, Response to The Illinois General Assembly Concerning House Resolution 1146*, January 5, 2015, p. 139. Decommissioning is discussed on p. 134.

PART II: BUILDING A 21ST CENTURY ELECTRICITY SYSTEM

5. THE AVAILABILITY OF RESOURCES FOR DECARBONIZATION OF THE ELECTRICITY SECTOR⁶⁷

To assess the opportunity to meet the need for low carbon alternatives with renewables, we begin with the present and work to the future. There is an ongoing debate about whether renewables can reach 100% of projected load, but that ignores the immediate question of how to get to the future. Resources have to be added in the present to replace aging facilities and retire polluting sources. I have argued that the key principle for making decision under this type of uncertainty is to move in the right direction. I will return to that framework after I review the empirical evidence on the availability of resources.

MEETING SHORT- AND LONG-TERM NEEDS

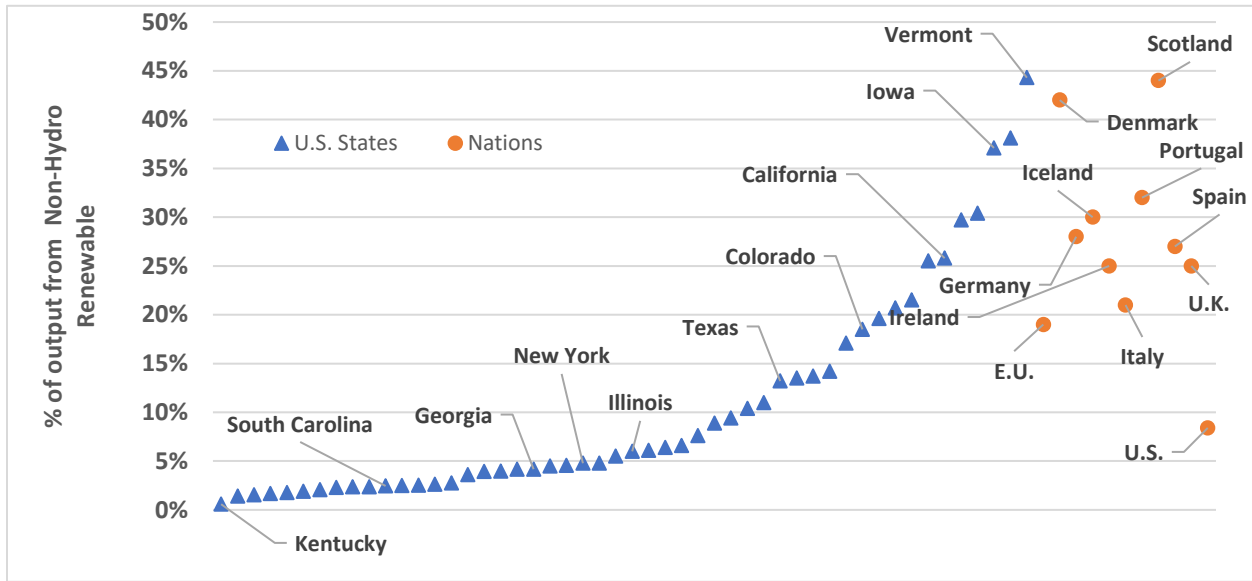
The analysis generally proceeds at two levels. First, as shown in Figure 5.1, we see comparisons of how other states and nations are doing in the effort to deploy clean, low carbon alternatives. The upper graph highlights the fact that New York and Illinois, the two states that have offered nuclear bailouts, have had a mediocre performance, at best. At least two large states with large industrial economies have achieved much higher levels of contribution from efficiency and non-hydro renewables. Other advanced industrial nations have achieved even higher levels of contribution from renewables. States and nations have achieved eight times the contribution of non-hydro renewables to their generation needs as New York and Illinois. In New York, combining this level of non-hydro renewables with its large base of hydro would bring the state to its 2030 goal. Relying on the market in the near term should be preferred because it allows for a smoother transition, in addition to reinforcing the overall market framework.

Perspective on the national potential can be gained by examining EPA's Clean Power Plan. It embodied moderate targets laid out by the EPA. While the reduction of carbon emissions that results from the combination of the base case trends and the policy case in the EPA analysis is impressive, it is well below what the literature deems economic and achievable for efficiency and renewables. According to the CITI projection of base case growth, which includes only existing state RPS programs, at least 60 percent more could be achieved with renewables⁶⁸. Two-fifths of the states have yet to adopt RPS programs, so it is reasonable to assume that a policy case in which the remaining states sought to increase renewable energy to roughly the same level as the RPS states would nearly double renewables.

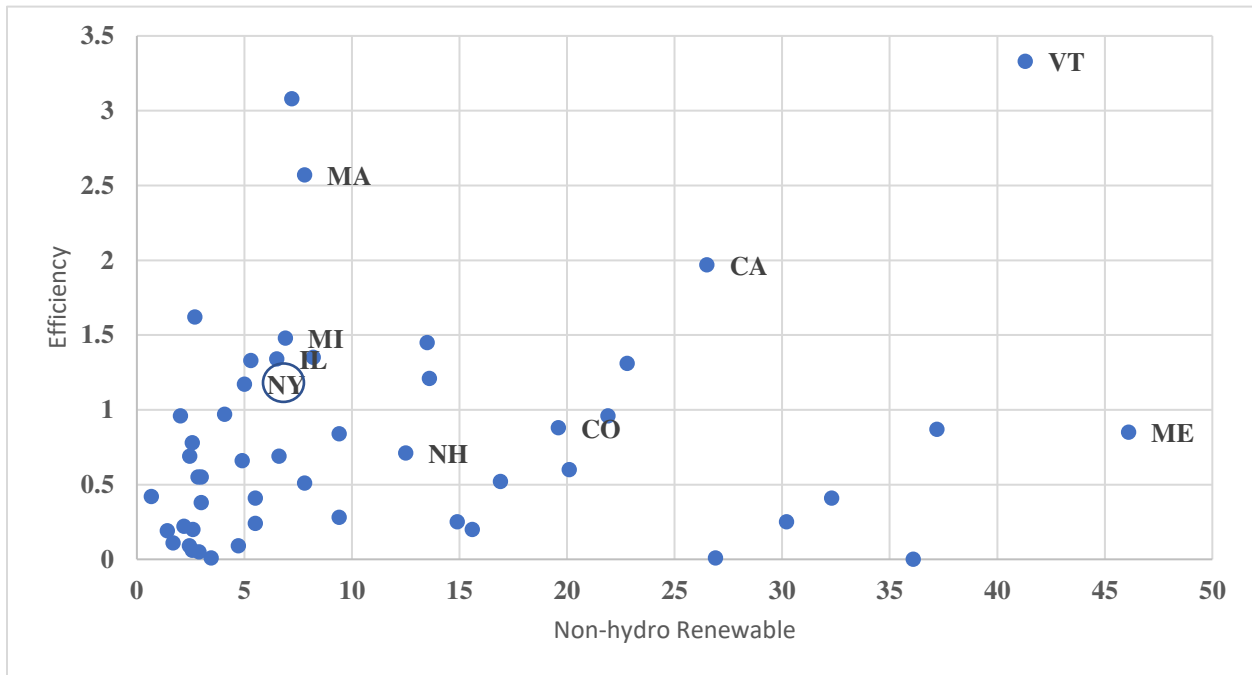
As shown in Figure 5.2 the contribution of efficiency could also be double the EPA assumption, based on the estimates of the national experts. For both renewables and efficiency, the projected costs are competitive with the current cost of natural gas, so these carbon reductions impose very little increase in the cost of electricity. The large potential for additional carbon emissions reductions from low-cost efficiency and renewables has a major implication for the EPA analysis, as shown in Figure 5.5. The aging reactors can be readily offset by the other low-carbon sources.

FIGURE 5.1: AVAILABILITY OF ALTERNATIVE RESOURCES

Penetration of non-hydro Renewables

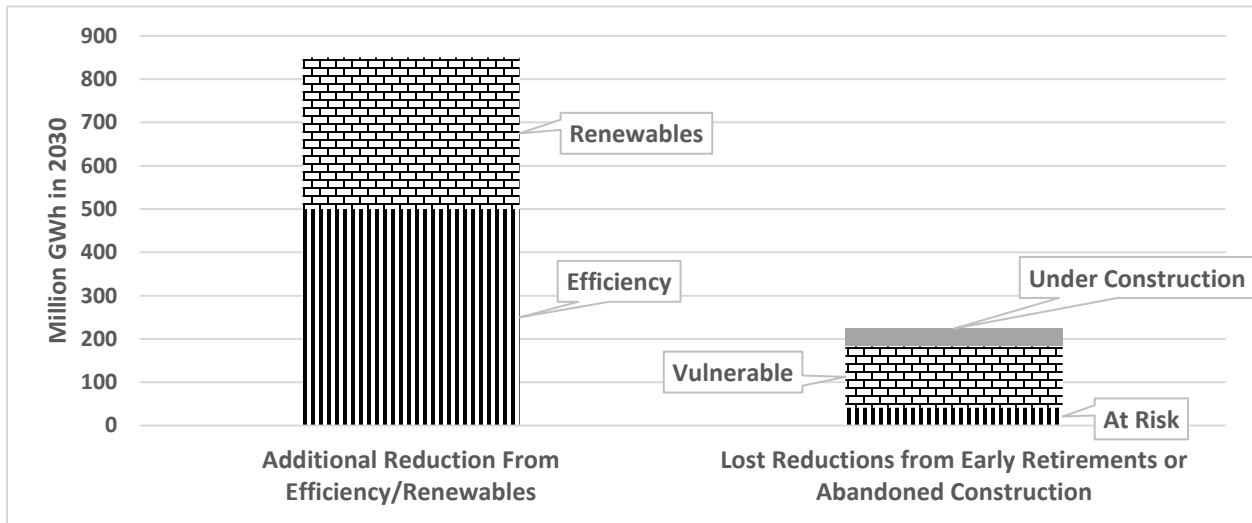


Contribution of Efficiency and Non-Hydro Renewables to Meeting 2017 Need (% of Total)



Source: ACEEE, *The 2018 State Energy Efficiency Scorecard*, 2018, p. 28; Energy Information Administration, *Electric Supply Monthly*, generation and non-hydro renewables.

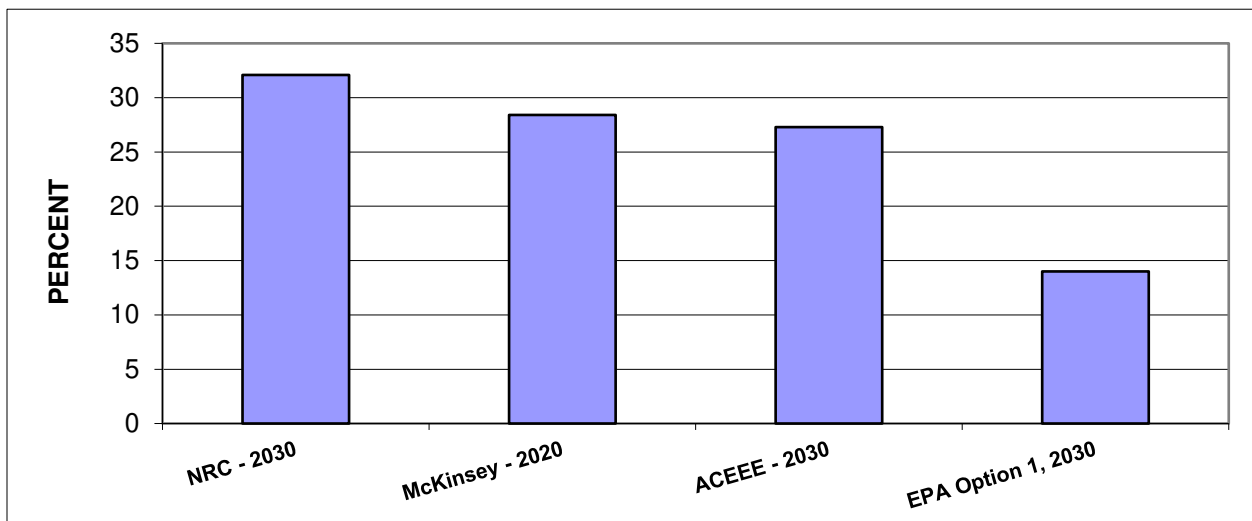
FIGURE 5.2: UNTAPPED CARBON REDUCTION POTENTIAL OF EFFICIENCY & RENEWABLES COMPARED TO “AT-RISK” NUCLEAR REACTORS



Sources and Notes: Figure VIII-3, and EPA, *Regulatory Impact Analysis*, 2004, Table 3-11. At risk reactors and vulnerable reactors are identified in Mark Cooper, *Renaissance in Reverse*, 2013. Quantities are taken from EIA, *Annual Energy Outlook: 2014*, Nuclear Alternative Cases, with 4.7 GW at risk, one-half of the accelerated retirements between 2020 and 2040 assumed by 2030 (19 GW) and 4.5 GW of current construction. An 85% load factor is assumed, since old and new plants tend to have below average load factors.

In this analysis I use a cost for efficiency of \$0.035/KWh, escalating to \$0.04/KWh, which is very cautious.⁶⁹ My finding that the contribution of efficiency to the mid-term goal of decarbonization could be twice what the staff has assumed is consistent with my findings at the national level. As shown in Figure 5.3, the contribution of efficiency could also be double what the EPA assumed in its Clean Power plan, based on the estimates of the national experts.

FIGURE 5.3: EFFICIENCY POTENTIAL FROM MAJOR NATIONAL STUDIES COMPARED TO EPA OPTION 1

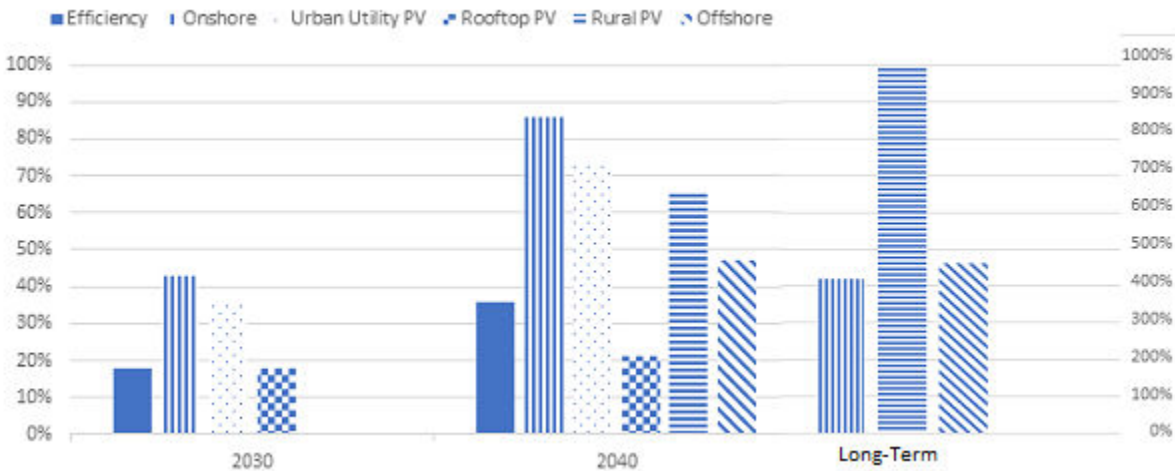


Sources and Notes: See EPA, *Regulatory Impact Analysis*, 2004, Table 3-11.

NEW YORK

Given the mediocre performance of New York on efficiency and renewables and the potential for these resources to play a much larger role at the national level we should not be surprised to find that these resources can more than meet the need in New York without aging reactors. Figure 5.3 and Table 5.1 show that the main renewable resources provide more than adequate resource to meet load and the decarbonization goal.

FIGURE 5.3: POTENTIAL CONTRIBUTION OF ECONOMICALLY VIABLE ALTERNATIVE RESOURCES AS A % OF 2016 LOAD: NEW YORK

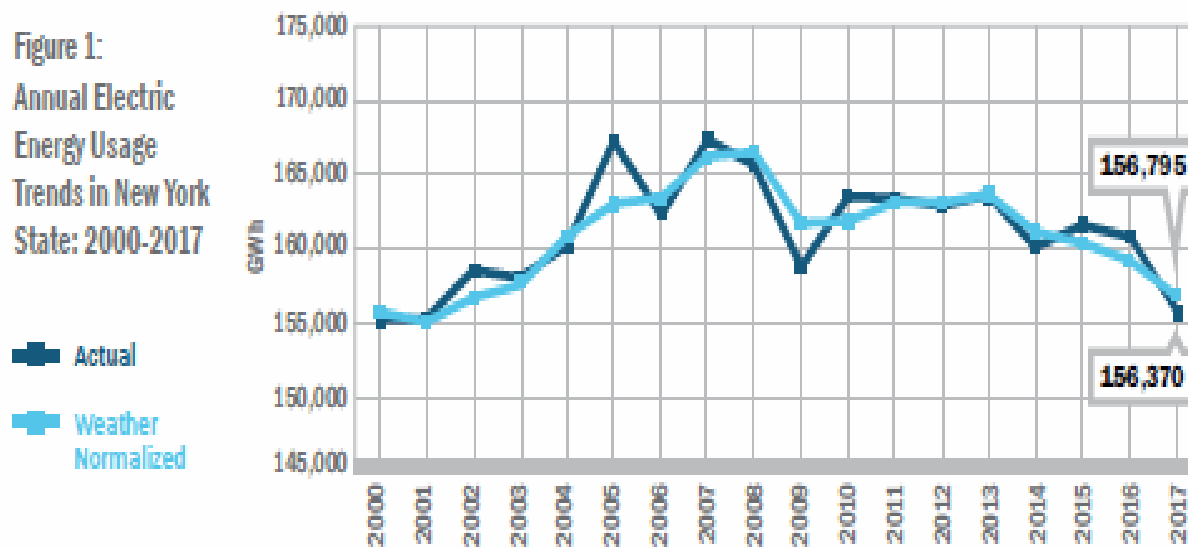


Source: Calculated by author as described in text. Potentials are from Anthony Lopez, et al., *U.S. Renewable Energy Technical Potentials: A GIS-Based Analysis*, NREL, July 2012.

One of the primary points of contention in the current debate is how much load can be served by efficiency,⁷⁰ which is a very low carbon, low pollution resource. Above we saw that Massachusetts and California have much high levels of efficiency. Figure 5.4 shows that demand in New York in 2017 was well-below the level the staff had projected using a fixed quantity of reduction due to efficiency that equals about 1.37 percent of 2017 load. On a weather adjusted basis, the trend was not reversed in 2018. The actual reduction between 2015 and 2017 is closer to 2%, the level achieved by California and well below Massachusetts. Thus, the suggestion that a higher level of annual efficiency gain is achievable seems plausible.

Including efficiency, onshore wind, urban utility PV, and rooftop PV, yields well-over twice as much low carbon resources as would be needed to achieve the 2030 goal, even if existing hydro is not counted. Adding in hydro would push the total to 3.5 times the amount needed, even if no nuclear is counted. In the long term, massive renewable resources become economically viable as technology advances for offshore wind and the grid reorganizes for rural utility PV. The constraint on proceeding without the Aging Nuclear Reactors Subsidy Program is not a lack of potential capacity; but a lack of will by the PSC to move quickly in that direction.

FIGURE 5.4: NYISO ENERGY USAGE TREND SUPPORTS AGREE/NIRS ON DEMAND



Source: NYISO Power Trends New York’s Evolving Electric Grid 2018, p. 12.

Using a slightly higher level of achieved efficiency (2% instead of 1.37%), enables the state to easily achieve its goals without subsidizing nuclear. The reduction in system size made possible by reduced and managed demand and integration of supply and demand, which I call a “transformation dividend” is substantial. The combination of efficiency and the transformation dividend accounts for one-sixth of the total low carbon resources in 2030 and over one-quarter in 2040. Efficiency provides the margin that ensures the renewables will meet the need

While comparisons between states and nations in non-hydro performance is suggestive, the ultimate question involves the resource base in the state. Is it adequate? Table 5.1 addresses this issue. It is based on an NREL analysis of the potential for all supply-side renewable resources in the long term. The NREL estimate of potential contribution as a percentage of 2016 demand taken from an EIA estimate, which ensures uniformity in the comparison between New York and Illinois. Using a slightly different load as the basis would not make much of difference because the potential resources are so much larger than the need, particularly for the 2030 target.

In this analysis I use a cost for efficiency of \$0.035/KWh, escalating to \$0.04/KWh, which is very cautious. My finding that the contribution of efficiency to the mid-term goal of decarbonization could be twice what the staff has assumed is consistent with my findings at the national level. As shown in Figure 5.6, the contribution of efficiency could also be double what the EPA assumed in its Clean Power plan, based on the estimates of the national experts.

Using a slightly higher level of achieved efficiency (2% instead of 1.37%), enables the state to easily achieve its goals without subsidizing nuclear. The reduction in system size made possible by reduced and managed demand and integration of supply and demand, which I call a “transformation dividend” is substantial. The combination of efficiency and the transformation dividend accounts for one-sixth of the total low carbon resources in 2030 and over one-quarter in 2040. Efficiency provides the margin that ensures the renewables will meet the need.

Moreover, there are two important potential resources that the above analysis does not take into account. Offshore wind represents a potential that is four times the 2030 target and rural utility PV represents another 10 times the target. The potential for rural utility scale PV is most interesting since the counties where the subsidized aging reactors are located are quite rural, with population densities just over one third as high as the rest of the state.

TABLE 5.1: MEETING NEW YORK GOALS WITHOUT SUBSIDIZING NUCLEAR

	2030	2040
Efficiency		
Base case = 1.4%/year	35	51
Accelerated = 2%/year	51	78
Load @ Accelerated	135	124
Transformation Dividend = 17%	10	10
Reduction in Coincident Peak (34%) > Reduction in load (17%)		
Effective New Load	125	114
Resources		
Achievable 2030, Economic 2040		
New Non-Hydro	26	88
Unsubsidized Nuclear	17	11
Existing Hydro	36	36
% Low Carbon		
w/o Transformation Dividend	62%	128%
with Transformation Dividend	66%	137%

Sources: Staff White Paper, NYSERDA Energy Efficiency and Renewable Energy Potential Study of New York State, Synapse

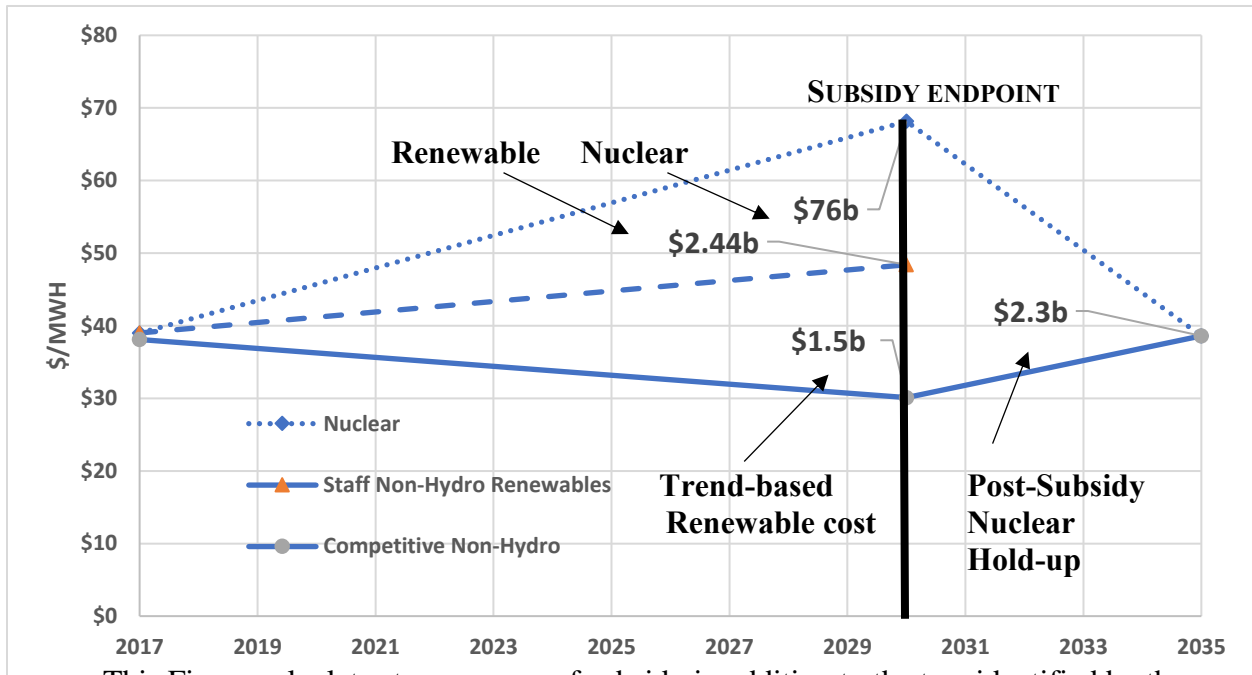
CONCLUSION: THE ULTIMATE COST OF SUBSIDIES FOR AGING REACTOR

The opponents of the Aging Nuclear Reactors Subsidy Program have pointed out that it spends much more subsidy money on old reactors than on new renewables. AGREE/NIRS shows that alternatives are four times more effective at reducing carbon emissions per dollar of subsidy than gaining nuclear reactors.

For example, a policy to replace closing nuclear reactors with energy efficiency or increased renewable energy was not considered, yet analysis by the Department of Public Service indicates such alternatives would be cost effective and viable. The direct costs of the nuclear subsidies (\$7.6 billion through March 31, 2029) are estimated to be more than triple the total direct costs of new renewables supported through the Clean Energy Standard (\$2.44 billion through 2030), though the total annual generation to be provided by new renewables in 2030 (~34 TWh per year) is more than 25% greater than the amount of nuclear to be subsidized through March 2029 (~27 TWh per year). This suggests that incentives spent on new renewable generation sources would be nearly four times more effective in providing zero-carbon generation than subsidies to nuclear generation.⁷¹

I believe that this underestimates the bias in the program when the reality of its impact on renewables is considered. Examining cost trends out to 2040 puts this problem in context, as shown in Figure 5.5

FIGURE 5.5: LOW CARBON SUBSIDIES TIED TO OPERATING COSTS UNDER THE AGING NUCLEAR REACTORS SUBSIDY PROGRAM AND AFTER: NEW YORK



This Figure calculates two sources of subsidy in addition to the two identified by the staff. The hypothesis here is that if non-hydro renewables were allowed to expand on a level competitive playing field for all low carbon power, their lower costs would not only eliminate the \$2.44 billion of assumed subsidies, but lower the cost by another \$1.5 billion. I also assume that it will take half a decade for the non-hydro renewables to overcome the advantage conferred on aging reactors. This could add an additional \$2.3 billion to the total subsidy. In other words, there may be as much as \$14 billion at stake, of which about \$10 billion is locked into the proposal with the Aging Nuclear Reactors Subsidy Program.⁷²

6. SHIFTING SUPPORT TO RENEWABLES ACCELERATES THE TRANSITION⁷³

This section examines three, closely related and fundamentally incorrect and misleading claims that are made to support subsidies, which reflect a blend of euphemism of the subsidies and dysphemism of the alternatives. The main conclusion was clearly stated by the local groups that opposed the subsidies for aging nuclear reactors, "progress in both carbon emissions reduction and in adoption of renewables appears to be inversely related to the strength of continuing nuclear commitments."⁷⁴

(1) The past contribution of nuclear to decarbonizations means they must play a role in the future,

(3) Subsidies for renewables are “unfair” to nuclear,

(3) In contrast to renewables, nuclear power is not subsidized at present.

THE MISLEADING DECARBONIZATION CLAIMS OF AGING REACTORS.

With nuclear power among the least attractive low carbon resources from every point of view, there is no compelling reason to subsidize the continuing operation of aging reactors. Nuclear advocates resort to claims that nuclear is indispensable to the effort to reduce carbon emissions. Backward-looking analysis makes the obvious point that nuclear power has made up a large part of current and total low-carbon generation. However, forward-looking analysis shows that it is not needed to meet the goals of carbon reduction.

Pointing out that 60% of our current low carbon generation comes from nuclear as a basis for suggesting that nuclear must play a central role in the future decarbonization of the electricity sector is simply wrong as a matter of fundamental economics and totally irrelevant to policy making. The existence of nuclear power is a very old sunk cost and its deployment had nothing to do with decarbonization.

In fact, in the past twenty years, 95% of the low carbon resources deployed have been non-hydro renewables. The recent past is much more likely to be relevant to the future.

- Backward looking analysis can only inform forward looking analysis if it has relevance to the future. Sunk costs should not be considered unless they actually influence important future variables or prices, which the existing nuclear reactors do not (except perhaps in the fact that their operating costs are rising dramatically as they age).
- The existing nuclear reactors cannot grow their contribution to decarbonization (except at a huge cost of minor uprating). In the mid-term, the share of the existing reactors to the goal of decarbonization is closer to 10 percent and their share will decline. It is the future that matters.
- In the mid- to long-term, none of the existing nuclear reactors will make any contribution to decarbonization. They will all have to be replaced and their future costs, compared to the available alternatives, are all that matters.

- When a least cost approach is taken to meeting the need for electricity in a low-carbon environment, existing nuclear could easily be replaced by other low-carbon resources at little or no cost increase. The projected wholesale cost increases resulting from early retirement of the reactors are less than or equal to the subsidies being sought by the utilities to keep the reactors online.
- The relevant question is, are there enough low-carbon resources available to replace the aging reactors? As the earlier analysis of resource availability showed, the answer is yes.

RAPIDLY PHASING OUT NUCLEAR ENERGY STIMULATES INVESTMENT IN RENEWABLE TECHNOLOGIES THAT ARE MORE LIKELY TO PAYOFF

The baseload-dominated electricity system of the 20th century was created by policy support and subsidies for physical and institutional infrastructure that favored a specific type of technology.⁷⁵ The dominant incumbents will seek to slow or stop the spread of alternatives to defend these trillion-dollar investments sunk into central station facilities.⁷⁶ Recent climate-change analysis highlights how the inertia of a century of domination by central-station, focused institutions have created a unique challenge.

Because the potential external costs are so large and the need to overcome inertia is so great, climate change puts a spotlight on technological innovation. Targeted approaches that speed and smooth the transition to low carbon resources can have many benefits.⁷⁷ The growing concern over adjustment leads to concern over an “innovation gap.”⁷⁸ Beyond inertia, many of the benefits of alternative generation technology resources or the processes by which their costs would be reduced – e.g., learning by doing, network effects – are externalities themselves, which means the private sector will underinvest in them.⁷⁹ Returns to R&D can be high.⁸⁰ Accelerating innovation and adoption can speed the transition, saving a decade or two⁸¹ while reducing economic disruption.⁸²

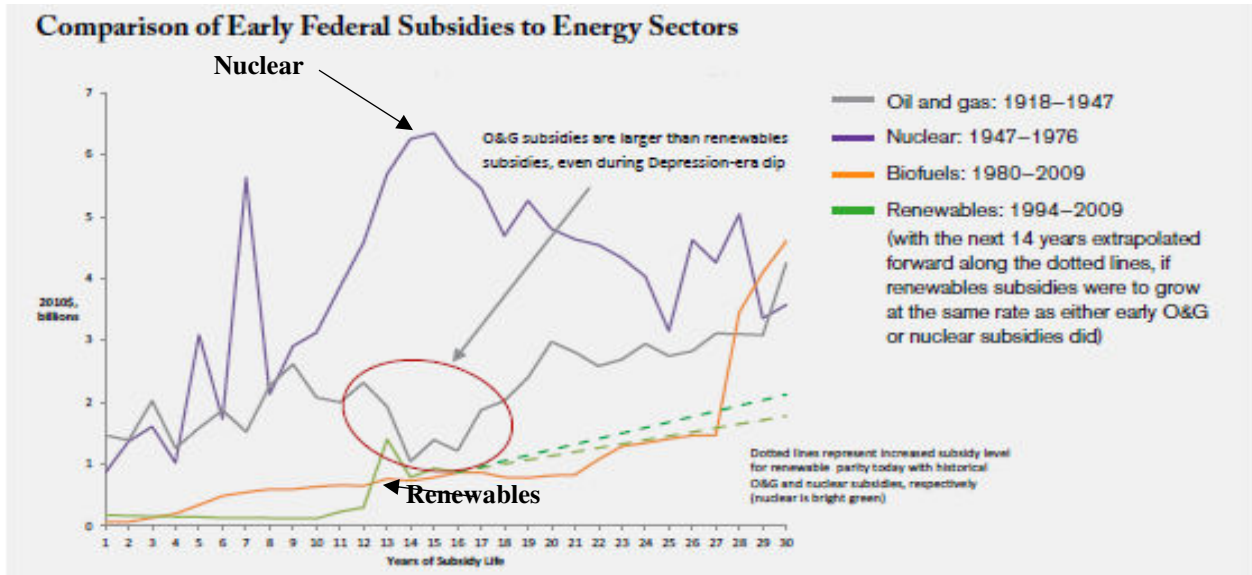
One of the obvious ways to overcome inertia, fill the “innovation gap,” and speed the transition is to shift subsidies away from incumbents to the renewable alternatives.⁸³ In fact, some have argued that the benefits of stimulating innovation are so large that they can offset the apparent “cost” of phasing out nuclear power altogether.⁸⁴ Our results show that phasing out nuclear power would stimulate investment in R&D and deployment of infant technologies with large learning potentials. This could bring about economic benefits, given the under provision of innovation due to market failures related to both intertemporal and international externalities.⁸⁵

The evolution of the renewable costs in the coming years will not be independent of the future of nuclear power and central station generation, as well as of energy and climate policies. In this context of uncertainty, policymakers need to understand the economic consequences of scenarios when accounting for its interplay with innovation and cost reduction in renewables.⁸⁶ Analyzing past subsidies strongly supports the proposition that shifting subsidies to alternative resources will lower the cost and accelerate the speed of transition.⁸⁷ It strongly rejects the notion that new subsidies should be showered on mature old technologies like aging reactors.

While the nuclear industry complains about the subsidies that are bringing renewables into the market today and resists programs to promote energy efficiency, analysis of the

historical pattern demonstrates that the cumulative value of federal subsidies for nuclear power dwarfs the value of subsidies for renewables and efficiency.⁸⁸ Renewables are in the early stage of development, as shown in Figure 6.2. Nuclear received much larger subsidies in its developmental stage and enjoyed truly massive subsidies since its inception, compared to other resources as it grew. Fossil fuels enjoyed more support a well.

FIGURE 6.2: FEDERAL SUBSIDIES FOR INFANT ENERGY INDUSTRIES AND BEYOND



Source: Nancy Pfund and Ben Healey, *What Would Jefferson Do? The Historical Role of Federal Subsidies in Shaping America's Energy Future*, Double Bottom Line Investors, September 2011, pp. 29–30.

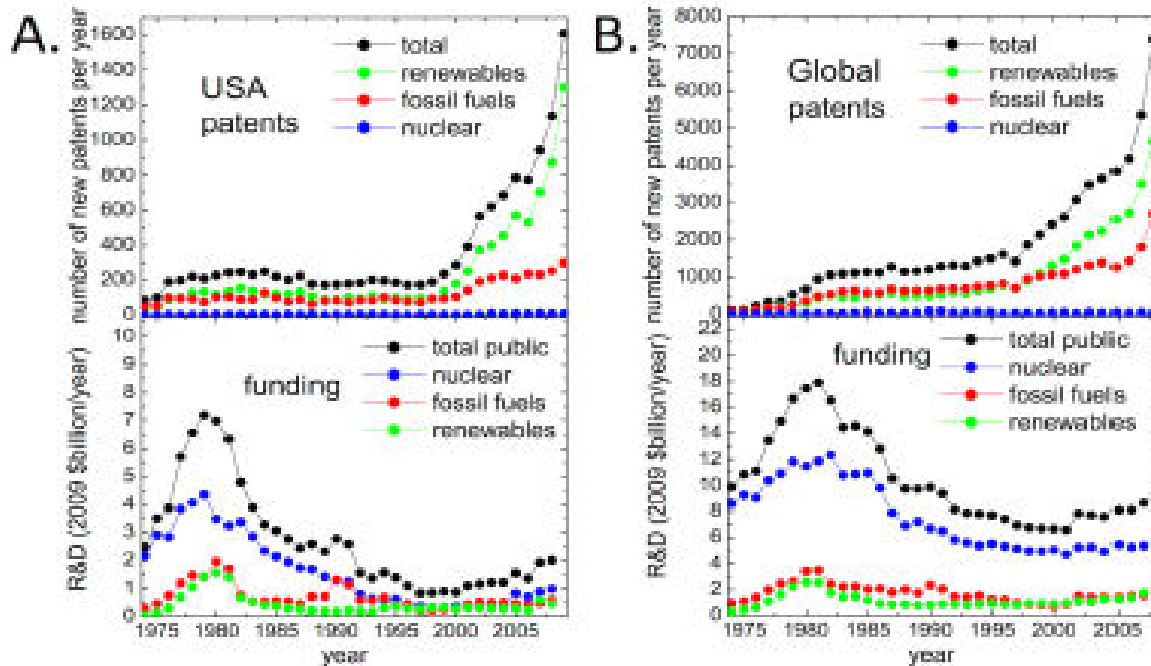
The graph calculates the rate of growth in subsidies that would be necessary to bring renewables into parity with the early rate of growth in subsidies enjoyed by central station resources. Renewables are more than a dozen years behind the central station resources, but given the importance of inertia, parity may not be enough to overcome the advantages of incumbency. There can be debate about the current level of subsidies, particularly given the difficulty of valuing the nuclear insurance and waste subsidies which are existential rather than material (i.e., without the socialization of liability and waste disposal the industry would not exist). However, there is no doubt that the long-term subsidization of nuclear power vastly exceeds the subsidization of renewables and efficiency by an order of magnitude of 10 to 1.⁸⁹

A decision to shift subsidies to the alternatives should have nothing to do with fairness, however, it should be based on the likely payoff of the investment. Analyses of past subsidies globally and in the United States make it clear that renewables are a much better bet⁹⁰ even though the estimates do not include the very large implicit subsidies nuclear enjoys from the socialization of the cost of risk and waste management.⁹¹

It is clear that with a much smaller level of subsidy to drive innovation and economies of scale, the renewables have achieved dramatically declining costs in a little over a decade, which is exactly the economic process that has eluded the nuclear industry for half a century. Figure 6.3 captures the essence of the subsidy issue by juxtaposing the magnitude and timing of subsidies and the extent of innovation, as measured by patents issued. The ultimate irony is that

despite much smaller subsidies to drive innovation and economies of scale, renewables have achieved dramatically declining costs in just over half a decade.

FIGURE 6.3: INNOVATION AND PUBLIC SUPPORT FOR R&D



Source: Bettencourt, Louis M.A., Jessika E. Trancik, and Jasleen Kaur, 2013, “Determinants of the pace of global innovation in energy technologies,” *PLoS ONE*, October 8, p. 10.

The dramatic increase in innovative activity despite relatively low levels of R&D subsidy and much lower cumulative subsidization if alternatives reflects the decentralized nature of innovation in the renewable space. It leads to the dramatic payoff in terms of declining price. As we have seen, wind had the earlier success and solar is now catching up.⁹² Nuclear power has failed to show these results because it lacks the necessary characteristics.

The nature of the renewable technologies involved affords the opportunity for a great deal of real-world development and demonstration work before it is deployed on a wide scale. This is the antithesis of past nuclear development. The alternatives are moving rapidly along their learning curves, which can be explained by the fact that these technologies actually possess the characteristics that stimulate innovation and allow for the capture of economies of mass production. They involve the production of large numbers of units under conditions of competition. Nuclear power, involves an extremely small number of units from a very small number of firms, with the monopoly model offered as the best approach. The monopoly in New York State can be seen in the fact that a single corporation owns all the upstate nuclear reactors and is the sole beneficiary of the Aging Nuclear Reactors Subsidy program.

CURRENT SUBSIDIES AND EFFORTS TO MISALLOCATE COSTS

Ongoing Subsidies

The above discussion of subsidies focuses on long-term patterns of subsidies and underscores the point that much more was invested in nuclear and fossil fuels. This should not be taken to mean that there are no current subsidies enjoyed by nuclear power. In fact, while advocates for nuclear power point to specific subsidies for renewables – production tax credits – there are at least half a dozen policies embedded in current practices that nuclear enjoys.

Current subsidies include the socialization of risk and waste management costs, now under court order to be paid by the Department of Energy to nuclear reactor owners for the failure to provide nuclear waste disposal because no such safe waste repository exists or may ever exist. Tax treatment of capital expenditures is important for the capital-intensive central station resources. They are favored by the tax code treatment of capital, which is a very large cost.⁹³ Capacity payments from RTOs/ISO also subsidize central station facilities. High system burdens due to the risk of large outages and the inflexibility.

Nuclear and other centralized resources also get a pass in the treatment of system costs. They have their system costs “socialized” and recovered from ratepayers, while system costs are imposed directly on developers of alternative resources. Lovins describe this bias in detail.

Specifically, variable renewables’ grid balancing costs are generally borne by their developers or owners, and are usually <\$5/MWh, nearly always <\$10. Yet coal and nuclear plants impose analogous costs on the system without being charged for them, at least outside ERCOT. Instead, the grid balancing costs of managing the intermittence (forced outages) of central thermal plants—reserve margin, spinning reserve, cycling costs, part-load penalties—are traditionally socialized, treated as “inevitable system costs,” and hardly ever analyzed.

This asymmetry appears to favor fossil-fueled and nuclear plants, because their balancing costs, emerging evidence suggests, may be severalfold greater than those of a well-designed and –run portfolio of PV and wind resources.

Conversely, variable renewables may need less backup (or storage) than utilities have already bought to manage the intermittence of their big thermal plants. (For example: utilities have found that high wind fractions can be firmed by fueled generators $\leq 5\%$ of wind capacity—severalfold below classical $\sim 15\text{--}20\%$ reserve margins for thermal-dominated systems. Unbundled ERCOT ancillary services market price data confirm that wind’s reserve costs per MWh are about half those of thermal generation. NREL’s models confirm for the western U.S. that central thermal plants cost more to integrate than variable renewables.⁹⁴

Imposed costs

When utilities deploy assets, they receive a rate of return that is far above the risk-free level. All of the aging reactors were deployed during the period of monopoly supply. The risks for which they are handsomely compensated include the possibility that the asset will not remain viable for its entire economic life, due to failure, breakage or replacement. The effort to claim compensation of the costs imposed on existing facilities by their displacement with new

technology seeks a “double return” on the investment – once during the years when they were earning a risk adjusted rate of return and a second time when they seek to be compensated for output lost to superior alternatives. This double dip is particularly egregious in the case of aging reactors that were fully depreciated.

Lovins aptly summarized this “novel” theory

This novel theory would have had Netflix compensate cable-TV providers and Henry Ford compensate horse stable owners. Such a proposed barrier to competition and innovation confuses economics (sunk costs) with accountancy (unamortized assets). Under the rubric of “utilization effect,” it was soundly rejected by two EU workshops advised by the theory’s originator. Those workshops found that society bears transformation costs and needn’t ascribe them to particular technologies, new or old, nor to particular parts of the power system.⁸⁵ Of course, renewables with virtually zero dispatch cost do push higher-opex thermal plants up the load-duration curve so they run less. Customers then benefit from lower market-clearing prices. Owners suffer from correspondingly lower revenues for which they would love to be made whole. But they were already compensated for all the risks of their investments, including competition and innovation, and should not be paid twice. (28)

CONCLUSION

It is important to keep in mind that the question of subsidies for uneconomic, aging reactors is a very recent challenge for policymakers. After bailing out nuclear power with massive subsidies and special treatment at least three times, they are being asked to do so, at least, a fourth time.⁹⁵ The first support came in the form of massive R&D support. The second subsidy came as bailout a massive rate increases to cover the construction cost overruns that drove the cost of power to two or three times the original estimates. The third special treatment came when nuclear power was granted “must run” status in the transition to wholesale markets. For a decade or so, middle aged reactor earned handsome profits as wholesale markets were designed and implemented. I say, “at least,” because there are numerous other contemporary subsidies that nuclear enjoys, which have failed to make aging reactors economically viable. These include half a dozen subsidies identified above.

Ultimately, competition in markets and economic facts of life overtook the aging reactors. A series of technological revolutions brought about by government policies and vigorous capitalist innovation and investment drove down the cost of cleaner, lower carbon alternatives to the dominant electricity source fuel, coal – a classic and very clear example of progressive capitalism at work. Aging reactors became highly unprofitable, but as in the past, their owners have sought to use their political power to seek special treatment to reverse the verdict of the market. The Aging Nuclear Reactors Subsidy Program in New York is the most blatant example of nuclear socialism at its worst. In this program, the government picks an aging, expiring technology and grants it massive subsidies to extend its life with no guarantees it will ever cease to be a burden or consideration of how badly it will slow or distort the transition to a truly superior, market-tested alternative.

7. INTEGRATION TOOLS AND SYSTEM COSTS

With low costs and high potential for non-hydro renewables, the fear of inadequate resources is misplaced. The barrier is not technological or economic, but policy and effort (or will), primarily institutional and, to a lesser extent, physical. To accomplish the goal, policy must overcome three sources of resistance.

- First, the central station paradigm must be uprooted. It cannot even be part of the solution due to its fundamental conflict with the institutional framework needed by renewable/distributed/demand-based alternatives.
- Second, this institutional and physical infrastructure will have to be built in any event as the demand ramps up to support the electrification of transportation and industry. The primary challenge is now to build the physical and institutional infrastructure that will support a greatly expanded electricity sector that uses only renewable and distributed resources.
- Third, delaying or slowing the process serves no purpose, yet that is precisely what subsidizing aging reactors does.

As shown in Figure 7.1, the emerging 21st century system is so totally different from the 20th century system. that the new system not only supplants the old approach, but the old approach gets in the way because central station generation resources are incapable of engaging in the behaviors, above all, responsive flexibility, that are central to the operation of the new system. Nuclear power is the worst offender from the antiquated, central station approach. ⁹⁶

Second, because the electricity systems require the continuous management of resources, resource acquisition in the near-term is necessary. The compatibility/conflict between the economics of near-term and long-term resource acquisition is an important consideration. If there is a conflict, choosing resources becomes more difficult. In this instance, that is not the case. Three important resources—efficiency, wind, and utility-scale solar—are cost competitive now with the dominant central-station fossil fuels. These three resources account for over 60 percent of the need in the Jacobson et al. analysis. Under an assumption of more aggressive utilization of efficiency (that our review supports later in this analysis), these three resources reach almost three-quarters of the total need. They are also less than half the cost of new nuclear reactors or fossil fuels with carbon capture, and are widely available. Thus, based on current costs, the renewable resources that are the cornerstone of the 100 percent renewable scenarios should be the resources chosen today. There is no conflict between the assets that are preferable in the short-term and the long-term.”⁹⁷

Having concluded that the alternatives are a much better investment in terms of cost and environmental impact, as well as from the macroeconomic and subsidy points of view, this section examines the final hurdle that the 21st century system must negotiate, the integration of the diverse parts of the system and its total cost.

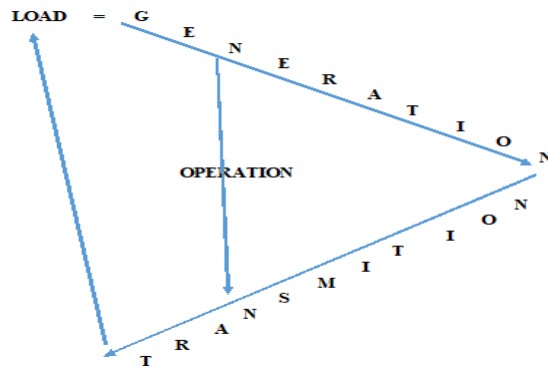
INTEGRATION

The need to overcome inertia should not be underestimated. The transformation of the electricity sector to a dynamic flexible system that integrates diverse resources on the supply and

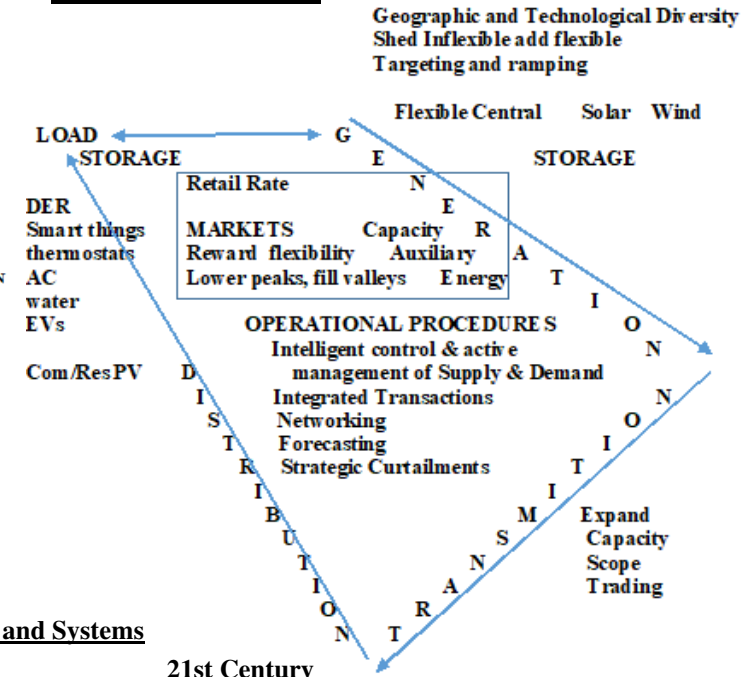
demand sides of the market is a formidable challenge. While the challenge is great, the tools are in hand and the cost is not very large – i.e. it is much smaller than the large advantage that the alternatives have in resources choosing the alternatives, not to mention the environmental benefits. Almost three dozen tools have been identified, as summarized in Table 7.1.

FIGURE 7.1: THE NEW, MORE EFFICIENT 21ST CENTURY ELECTRICITY SYSTEMS

20th Century System



21st Century system



Fundamental Differences between Centuries and Systems

Characteristic	<u>20th Century</u>	<u>21st Century</u>
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

Source: See Appendix D.

7.1 TOOLS FOR INTEGRATING SUPPLY AND DEMAND IN A DYNAMIC FLEXIBLE SECTOR

<u>Outcomes</u>	<u>Citations</u>
1 Penetration: States	1, 2, 23, 47, 51, 52
2 Nations	1, 32, 36, 53, 54, 55, 56, 57, 58, 59, 60, 66, 154
3 Cost: General Components	1, 5, 9, 10, 16, 18, 29, 36, 46, 47, 63, 69, 71, 75, 76, 77, 98, 116, 130, 137, 147, 150, 183, 184, 246
4 System cost/value	5, 75, 155, 184, 216, 217, 243, 244, 260
5 Challenges: With solutions	5, 8, 9, 10, 12, 93, 94, 215, 232
6 Pure negatives	83, 87, 95, 96, 214, 230
7 Generation (100% Scenarios)	143, 182, 257, 258, 259, 261
8 Geographic diversity	5, 7, 8, 12, 36, 151, 152, 153, 237
9 Technological diversity	7, 8, 10, 15, 36, 38, 44, 102, 151, 237, 240, 246, 247, 269, 278
10 Peak targeted solar	7, 155, 156, 246, 247
11 Quick start/rapid ramp	1, 7, 10, 23, 151, 246
12 Shed inflexible baseload	7, 27, 151, 230, 232, 247
13 Shift to flexible	5, 7, 160, 161, 162, 163, 164, 165, 166, 167, 232
14 Flexible central	1, 2, 26, 60, 84, 85, 96, 183
15 Firm renewables (new baseload)	1, 2, 10, 19, 22, 24, 26, 88, 236, 245, 276
16 Value ancillary services;	1, 2, 5, 8, 12, 48, 52, 59, 60, 138, 139, 140, 182, 183, 185
17 Avoid lumpy investment	7, 155
18 Load	1, 3, 26, 70, 105, 106, 107, 108, 109, 110, 111, 112, 113, 224, 262,
19 Supply-side	7, 169,
20 Target peaks	7, 27, 151, 240
21 Use more in slack, less in scarcity	1, 7, 105, 160
22 Demand-side	7, 12, 13, 27, 36, 38, 85, 172, 173, 174, 175, 176, 177, 178, 179, 261, 262, 263, 264
23 Aggressive demand response	7, 27, 105, 151, 175, 177, 178, 179, 181, 269, 270, 280
24 Smart controllers manage AC, water heating, etc.	7, 8, 27, 186, 187, 265
25 Transmission	1, 2, 3, 5, 7, 22, 24, 25, 26, 28, 31, 34, 40, 41, 57, 65, 67, 68, 103, 126, 127, 128, 129, 181, 183, 185, 188, 189, 190, 191, 192
26 Expand balance areas	5, 7, 27, 151, 160, 181
27 Storage	1, 5, 7, 8, 12, 19, 20, 21, 22, 23, 41, 43, 49, 100, 101, 102, 151, 157, 185, 194, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 230, 268, 274
28 Dispatchable, traditional	1, 36, 111, 183, 232
29 Distributed (virtual powerplant)	1, 2, 11, 13, 27, 36, 39, 45, 56, 115, 116, 117, 118, 119, 194, 233, 254
30 Electric vehicles	1, 11, 13, 35, 104, 113, 114, 233, 266, 272, 273, 276, 277, 279
31 Operational Procedures	1, 7, 12, 25, 26, 136, 212, 213, 231, 250, 252
32 Flexibility/integration	1, 5, 8, 9, 10, 13, 17, 18, 24, 26, 30, 31, 32, 34, 36, 72, 73, 78, 82, 97, 99, 127, 147, 173, 171, 180, 183, 185, 194, 230, 231, 245, 253
33 Integrated Transactions	8, 9, 18, 241, 242
34 Strategic Curtailment	1, 8, 23, 61, 120, 121, 122, 123, 124, 125, 248, 249
35 Improve forecasting	1, 7, 12, 36, 37, 53, 142, 143, 144, 145, 151, 215, 216, 217, 218, 219
36 Market Design	1, 2, 8, 12, 13, 18, 23, 26, 32, 33, 40, 41, 56, 57, 58, 59, 60, 62, 94, 146, 147, 148, 181, 183, 184, 248, 250, 252
37 Positive and Negative prices	1, 5, 8, 10, 17, 57, 148, 175, 181, 235, 238, 253
38 Target fixed cost recovery;	9, 14, 181, 183, 184
39 TOU (cut peaks, fill valleys)	7, 8, 9, 27, 64, 105, 106, 107, 108, 109, 110, 111, 112, 93, 193, 220, 221, 222, 223, 234, 235, 239
40 Smart Grid	1, 3, 7, 8, 11, 12, 22, 42, 79, 80, 81, 82, 119, 131, 132, 133, 134, 135, 169, 224, 225, 226, 227, 228, 229, 263
41 CHP	2, 26, 50, 54, 89, 90

Source: See Appendix D.

The DOE Wind *Vision* analysis argues that “wind generation variability has a minimal and manageable impact on grid reliability and related costs.”⁹⁸ 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 been found effective in the past: “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.”⁹⁹ These highlight the impact and necessity of changes to the grid, and the prospect of achieving reliability that equals or exceeds current levels with the alternative approach is increasingly seen as quite good.

NREL identifies eleven integration strategies.¹⁰⁰ Lovins identifies nine measures.¹⁰¹ The Regulatory Assistance Project (RAP) identifies ten policies that can be implemented in a dynamic electricity system that actively manages supply and demand. Together, almost two dozen policies (see Table 7.1) can lower the peak by 30 percent and dramatically increase the system-wide load factor.¹⁰² In fact, the RAP counts “retire inflexible generating plants with high off-peak must run requirements” as a benefit to developing the integrated system of supply and demand management.

The potential transformation of the electricity system involves the movement of resources that were marginal (at best) into leading roles. The same is true of demand response, storage, and intelligent integration. They move from bit players to important supporting actors. Their impact and importance come not only from a much larger role, but also from providing much more important functions. This analysis shows that the trade and academic literature, as well as real-world experience, indicate that following a path toward a 21st-century electricity system poses minimal challenges and costs of integrating renewable resources on grid reliability up to a 30–40 percent penetration. The literature has also identified the specific actions that can carry the system to much higher penetration of renewables without reducing reliability or raising costs significantly. Combining the threads of this analysis, the measures that allow the system to operate at high penetration with the implementation of aggressive efficiency measures meets 80 percent of business-as-usual or base case demand. Adding in a transformation dividend of reduced and managed demand would put the total above 90 percent.

Demand management and storage are two of the key elements in the active 21st-century electricity system, which can be viewed as building virtual power plants. Here, it suffices to say that reducing the need for generation through intelligent management is estimated to be in the range of 10–20 percent of aggregate demand, and a higher percentage of peak demand. This should be considered a transformational dividend—an expansion of output relative to demand that occurs as an external benefit or network effect that is larger than the sum of the individual elements added to the system. This should be added to the downward pressure on peak and average prices, which are an economic dividend that would be reinforced by a successful transformation of the system. Thus, virtual power plants can have a substantial impact and value. The intense interest in – and debate over these two key elements of the emerging system highlight two critical characteristics of the current development of technology.

- First, because it is important, it is attracting an immense amount of resources and entrepreneurial activity.

- Second, as a result, an extremely rich technology palate of options is being created from which all the key stakeholders in the electricity space (consumers, utilities, grid operators, and policy makers) can choose.

Demand response and storage have been around for decades, growing out of a need to manage peaks that became more intense as air conditioning spread. However, their 20th-century manifestation was small, slow, inconsistent, uncertain, and an afterthought. Their contemporary manifestation is quite different and widely recognized as one of the key building blocks of the 21st-century electricity model. It embodies the essential active feature of the system, relying on information about the state of the network delivered on a real time basis to technologies that can instantaneously control and match load with resources. As demand management and storage are built into the heart of the electricity system, they provide a range of functions (i.e., have a number of sources of value that are recognized in the trade and academic literatures).

While much of the analysis focuses on the private costs and benefits, some have argued that there are public benefits that need to be considered. These benefits include reduction in production, investment and outage costs, and improved reliability. The analysis conducted by the Brattle group for a Texas distribution utility found that the system-wide benefits constituted a significant part of the total benefit (30–40 percent)—enough to tip the scale in favor of much larger investment than would be driven by private incentives alone.

The evidence from detailed engineering studies, as well as the real-world experience of advanced industrial nations, continues to mount and is now overwhelming. Penetration of wind and solar to levels far beyond what is projected (in base case U.S. Energy Information Administration [EIA] analysis of the United States, or in EPA’s Clean Power Plan to reduce carbon emissions from the electricity sector or in the New York PSC analysis) can be achieved without compromising system reliability at all. The more flexible the system is made with geographic diversity, low-cost storage, demand shaping, technological diversity, short interval scheduling, and “quick start” generation, the higher are the levels that can be achieved.

EXAMPLES OF EVOLVING APPROACHES

California attracts a great deal of attention because it is a large U.S. electricity market (the sixth largest economy in the world) with a strong commitment to shifting to renewables. California is also of interest because it experienced the largest early retirement of nuclear reactors in almost two decades. In fact, it is the largest early retirement of nuclear reactors in U.S. history. The fact that it was handled with relative ease is a good indication that early retirements are manageable.

Taken together, these scenarios indicate that relatively high penetrations of total VG [variable generation] can be achieved using combinations of wind and solar technologies while maintaining or even enhancing the value of the wind/solar generation compared with the value of using single wind and solar technologies in isolation.¹⁰³

In the LBNL analysis, a “relatively high level” is a mix of wind and PV to 30–45 percent, with wind generally making a contribution that is two or three times as large as solar,¹⁰⁴ and

central station solar with six hours of battery storage potentially adding an additional 20 percent. These levels are achieved within the constraints of maintaining the reliable operation of the system at base case levels. This conclusion is based only on an evaluation of the economic value, measured as “avoiding the capital investment cost and variable fuel and O&M costs for other (fossil-fuel-based) power plants in the power system.”¹⁰⁵ The baseline total cost for the fossil fuel plant is \$70/MWh, which is close to the “unabated” natural gas cost. This puts renewables at almost two-thirds of total generation at a value equal to the flat fossil baseline, without reducing the value of the other renewables.

The LBNL analysis shows that the technical and economic processes by which policies work to mitigate the impact of variability are straight forward. The LBNL analysis does “not consider many other costs and impacts that may be important, including environmental impacts, transmission and distribution costs or benefits, effects related to the “lumpiness” and irreversibility of investment decisions, and uncertainty in future fuel and investment capital costs.”¹⁰⁶ As discussed above, the consideration of “lumpiness, irreversibility, and uncertainty” strongly favor investment in efficiency and renewables. Increases in transmission costs, which might cut against renewables, are small and offset by potential distribution cost savings. As discussed below, the empirical evidence indicates that the costs of integration are not very large.¹⁰⁷

Although the utilities in California put together an analysis that takes a very different approach than the LBNL analysis and seems much more ominous, close examination shows that when the utility analysis introduces mitigation measures, it reaches a similar end point. The utility study identifies four “least regrets opportunities,” and a number of opportunities for “research and development for technologies to address over-generation.”¹⁰⁸ 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. This is consistent with general finding of a transformation benefit.

The conclusion that high levels of penetration of renewables can be achieved without undermining reliability is supported in the literature. Other studies of California reach the same conclusions, while simultaneously analyzing other U.S. areas. Numerous studies of other states support the basic findings of these California studies, including very diverse areas like Texas, Mid-America, and the Mid-Atlantic. Studies of other nations, particularly in Europe, come to the same conclusions.

SYSTEM COST

Integration Cost

If policies to manage the integration of renewable resources are implemented, The literature puts the cost of integration well below \$10 per MWh.¹⁰⁹ Recalling the cost advantage that renewables enjoy today, and the even larger cost advantage that they are expected to enjoy in the mid-term, this makes the 21st-century electricity system based on alternatives the least-cost approach in a low-carbon environment by a wide margin.

Another particularly interesting case of a continental ecosystem is Australia. The analysis of the potential for renewables in Australia produces similar results as the United States.¹¹⁰ It puts the technical potential of wind at 30 times 2011 consumption, and solar at 200–350 times 2001 consumption.¹¹¹ The estimated cost of integration is similar to the United States and European estimates—in the range of \$5 to \$10/MWh, including transmission costs.¹¹² The conclusion is also strongly evident in looking at the least-cost penetration of renewables and their cost impact. High levels (~75 percent) yield lower cost, lower-risk, low-carbon portfolios. As the study of the potential for renewable resource in Australia concluded:

In 2030, the lowest expected cost generation portfolio includes 60% renewable energy. Increasing the renewable proportion to 75% slightly increased expected cost (by \$0.2/MWh), but significantly decreased the standard deviation of cost (representing the cost risk). Increasing the renewable proportion from the present 15% to 75% by 2030 is found to decrease expected wholesale electricity costs by \$17/MWh.... This modelling suggests that policy mechanisms to promote an increase in renewable generation towards a level of 75% by 2030 would minimize costs to consumers, and mitigate the risk of extreme electricity prices due to uncertain gas and carbon prices.¹¹³

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, and is reflected in the DOE *Wind Vision*. The DOE analysis provides a simple explanation. 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.”¹¹⁴ 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.¹¹⁵ 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.

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 “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.”¹¹⁶ 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*.¹¹⁷

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 ¹¹⁸

I call difference between LCOE and LACE “inflexibility waste” to capture the key concept.¹¹⁹ 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 alternative, analysts at two national laboratories (LBNL and Argonne), suggested an alternative approach that rested on system costs. The 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.¹²⁰

This approach was also advocated by a major research institution in Germany evaluating the aggressive transition to renewables being pursued in that nation. ¹²¹

Figure 7.2 uses Lazard unsubsidized LCOE from Section 2. I also show 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.

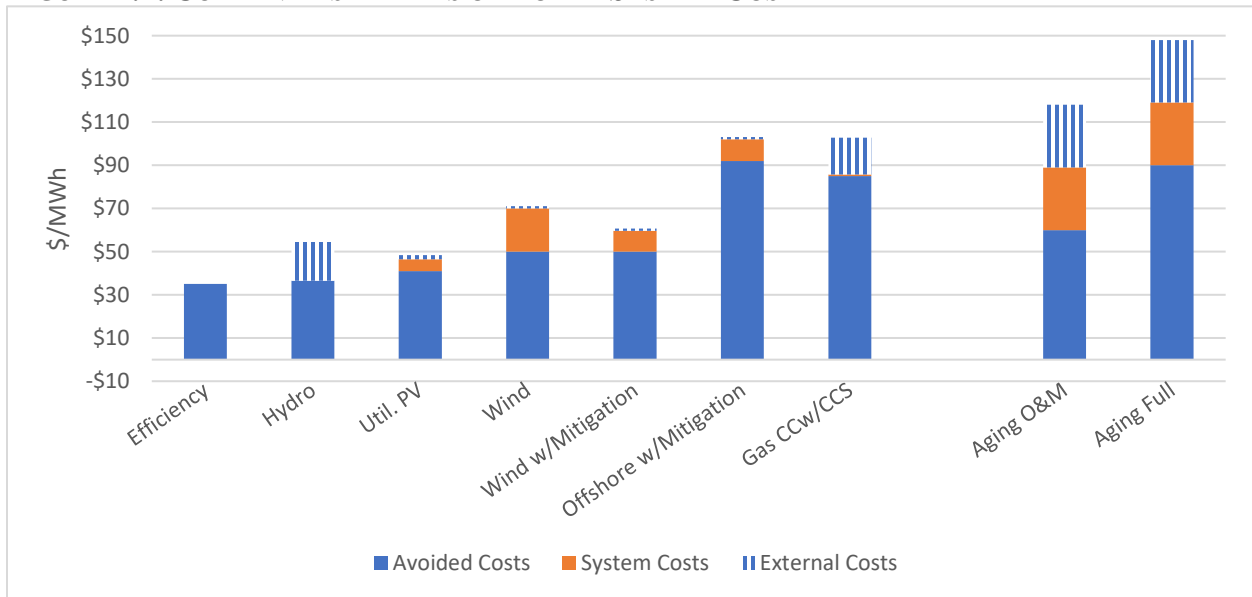
To make a fair comparison between low carbon resources, I use the cost of natural gas combined cycle plants with 90% carbon capture. I have not included the cost of coal with 90% carbon capture because it is so far off the charts (50% higher than natural gas on LCOE) that it is not a contender and would 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 high than aging reactors because of the long construction period and intensive carbon emissions of construction. The LCOE costs are adjusted for EIA’s estimate of system value

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. ¹²² Given all of the positive attributes of efficiency discussed above, this approach is likely to underestimate its benefit in terms of system costs. For political decision-making, the comparison of total system costs in different scenarios can be a more appropriate tool. Unfortunately, various methodological challenges persist, most importantly how to define system boundaries and how to consider externalities. Yet establishing a relevant and transparent analysis is much easier, as is the discussion of key sensitivities and implications. In the following, we describe an approach for comparing scenarios with high and low shares of renewables....

Each of these scenarios must be equal from a technical point of view. That is to say, the same level of security of supply (i.e. loss of load expectation) must be achieved and all

components should be reasonably adapted to the respective mix of renewable energies. Based on an initial definition of costs, which may or may not include the costs of externalities, the total costs for power generation are calculated for each scenario. This must include costs for power generation by renewable and non-renewable technologies as well as all costs for grids and for the balancing of supply and demand

FIGURE 7.2: 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. Wisser, 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.

The compelling conclusion of this analysis is quite clear, the renewables are preferable by far and all of the underlying trends reinforce these conclusions.¹²³ 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.¹²⁴

PART III.
THE PROGRESSIVE CAPITALISM SOLUTION
TO THE DILEMMA OF DEVELOPMENT WITH DECARBONATION

8. PROGRESSIVE POLITICAL ECONOMY AND THE GREEN NEW DEAL

POLITICAL ECONOMY

Local opposition to the Aging Reactor Subsidy Program in New York (AGREE/NIRS) used the term “progressive” once in their comments to describe the rate structure they propose, which tries to ensure that electricity is affordable to low income households.¹²⁵ That is a very traditional and legitimate use of the term. But my framework for an evaluation of the Aging Nuclear Reactors Subsidy Program from the point of view of “progressive capitalism” uses the term in a much broader sense. In fact, this approach to progressive capitalism is also quite traditional, measured by its use starting almost 150 years ago to describe a major era of American economic policy. The broad approach to political economy is older still, stretching back almost 300 years to the very origins of economic analysis in the capitalist era.

I use the term “political economy” in three ways.

First, **Political economy is a scientific discipline** with deep roots in social analysis.

Until recent times the common name for the study of the economic process. The term has connotations of the interrelationship between the practical aspects of political action and the pure theory of economics. It is sometimes argued that classical political economy was concerned more with this aspect of the economy and that modern economists have tended to be more restricted in the range of their studies.¹²⁶

Second, flowing from this connotation of the term, **political economy is also a pragmatic approach to action.** There is no separation between analytical and political practice. Thus, Thomas Piketty urges social scientists to engage in the “old-fashioned” practice of political economy, which argues is set apart from the other social sciences “by its political, normative and pragmatic purpose. . . . The question it asks is: What public policies and institutions bring us closer to the ideal society?”¹²⁷ We hope that our analysis is “objective” in the sense that it correctly depicts reality, but there is no escaping the fact that subjectivity is inherent in all thought, nor should there be any effort made to hide the fact that we seek to influence the structure and function of the political economy through analysis and action.

Third, a **political economy is a constellation of political and economic institutions** forming a coherent system that produces the material conditions in which people live. I prefer “political economy” to “mode of production” (Marx) or “mode of subsistence” (Smith) because it reminds us there are two spheres of paramount importance the -- political and economic. A functioning and compatible polity and economy are necessary to create a successful system. The term “political economy” also reminds us that the political is not only of equal importance, but in some senses is more important.

WHY THE GREEN NEW DEAL IS A GENUINE “NEW DEAL”

The Green New Deal proudly adopts the label of a “New Deal,” a label it richly deserves for a number of reasons. First, I argue that technological revolutions in renewables on the supply-side and grid management to integrate supply and demand have undercut the economics of central station power generation that dominated the 20th century electricity system.¹²⁸ Even without the increasingly urgent concern about fossil fuel emissions and pollution, the alternative 21st century system based on distributed resources should be preferred on economic grounds.¹²⁹ Adding in concerns about climate change and pollution gives the alternatives a huge advantage in terms of the total cost of electricity.

Second, I argue that a very good case can be made that the development of renewables and the shift to progressive policies are examples of a repeated pattern in capitalist industrial revolutions. In this context, I argue that the Paris Agreement implementing the UN Framework Convention on Climate Change (UNFCCC) should be seen as exactly the right response.¹³⁰ There is a strong similarity between the Green New Deal and the Paris Agreement.

In this context, the paper addresses a number of issues that have been raised about the Green New Deal. First, it shows that pursuing a green strategy makes perfect economic sense. These resources are and are likely to remain the least cost approach, not only because they address externalities (i.e. climate change and pollution), but also because they address other market failures and imperfections. They cost less and make the economy work better. This was true of important parts of the New Deal.

Second, the deployment of these resources generates more jobs than the central station alternatives, nuclear in particular. Increasing employment was a major goal and accomplishment of the New Deal and is a goal of the Green New Deal.

Third, the ability of the alternatives to deliver least cost, clean electricity, while creating more employment in the long-term requires deployment of significant new physical and institutional infrastructure. A new electricity system has to be built. Again, this was one of the major challenges confronted by the New Deal in several infrastructural industries. It is an important challenge for green resources and extending the life of aging reactors makes the challenge more difficult.

Fourth, identifying the specific resources that should be deployed in the long term provides key guidance for the resources that should be subsidized in the near- and mid-terms to ensure the long-term success of the new electricity system. The 20th century electricity system was created with large explicit subsidies to central station resources, nuclear in particular. Therefore, it should not be surprising that building the 21st century system will need subsidies. The question is, which resources should be subsidized and what tool are best suited for the task. Well-targeted incentives for alternatives will have a much higher payoff than nuclear ever did. Because the alternatives are lower in cost and can much more easily be driven by market forces, the necessary subsidies are likely to be smaller.

Finally, the analysis shows that the least cost solution involves utilities because of the more intensive need for management and the lower cost of utility scale renewables. The low

cost for renewables has been achieved through the partnership of government policy and market activity.¹³¹ This, too, parallels the New Deal, which preserved the role of utilities in infrastructure industries, but subjected them to much more vigorous public interest oversight. The goal of affordable, universal services, while relying on a regulated private sector to the greatest extent possible and consumer-owned utilities where necessary, typified the New Deal in utility infrastructure (e.g. power and communications). Progressive capitalism was the core of the New Deal, as it can be for the Green New Deal.

THE GREEN NEW DEAL AND THE PARIS AGREEMENT AS PROGRESSIVE CAPITALISM

The approach I have outline here is consistent with key parts of the Green New Deal. It can help to overcome the obstacles to the transformation of the electricity sector and carry it far into the future based on the sound economic principles of progressive capitalism. Table 2.1 identifies the key characteristics of the Green New Deal and the Paris Agreement.

The resolution introducing the Green New Deal is a broad programmatic statement that identifies principles to be applied in its implementation. The analogy to the Paris Agreement may or may not enhance the ability to implement the Green New Deal, but it is quite strong. The first set of characteristics involves goal and values. This is consistent with the view of economic analysis that emphasizes its original framing as not merely the study of the economy, but also the commitment to active policy to create the economy that was the goal of policy and political action.

The goals and values part of the program is an expression of choice and will. As a political goal, it is “non-negotiable” a statement about the economy that we want. While it may be non-negotiable, it can be the subject of evaluation and assessment, from three perspectives.

Are the goals achievable?

Can the instruments chosen to achieve those goals do the job?

How high the costs?

In this paper I have shown that the goals are not only achievable, but they are essential to a sustainable future. The broad outline of the instruments chosen is “correct” from an economic point of view – well-grounded in the principles of progressive capitalism that have been successful throughout the period of the industrial revolution. The costs will certain not be too high in fact, the 21st century electricity system to which the Green New Deal and the Paris Agreement aspire will be lower in cost than trying to impose the 20th century, central station approach on the 21st century economy.

Of course, the New Deal went farther in many ways, as some advocate for the Green New Deal. This analysis shows that those broader aspirations are consistent with the underlying economics in two respects.

TABLE 8.1: THE POLITICAL ECONOMY OF A PROGRESSIVE, CAPITALIST RESPONSE TO CLIMATE CHANGE: THE PARIS AGREEMENT AND THE GREEN NEW DEAL

Goals and Values

Decarbonization and development need vigorous policies to achieve the goals of access to, and local control of, electricity for developing nations and sustainable development (1)

Democratic Governance (2)

- The subsidiarity principle looking to local and state governments and corporations for support and implementation
- Involvement of civil society
- Progressive and inclusive goals to involve and meet the needs of diverse communities underrepresented in the centralized system
 - Differential contributions from Parties to reflect capabilities
 - Transfer of resources from developed to developing nations.

Economics

The goals are achievable (3)

A critical role for analysis of options in which least-cost measures should take precedence (4) and recognize that mitigation costs are smaller than adaptation costs (5)

Multiple approaches including markets and public private partnerships, flexible, overlapping policies are needed that recognize

- localism (6) and
- complexity (7)

The general finding that the social return from R&D is twice as large as the private return appears to hold in the energy technology space (8)

Early action lowers the transitional and total economic cost of decarbonization dramatically (9)

Estimates of the speed of innovation suggest a delay of 1–2 decades, if targeted policies to accelerate the diffusion of innovation are not adopted. (10)

Early, swift action requires targeted and induced technological change (11)

Institutional capacity is crucial to effective, least-cost implementation, (12)

Technology transfer and learning play a vital role in meeting the challenge in a cost-effective manner, (13)

Targeted financial incentives deliver three times as much monetary support for low-carbon alternatives, (14)

Macroeconomic impacts of decarbonization are crucial with clear evidence that a smoother, swifter transition yields macroeconomic savings of at least 50 percent. (15)

Sources: See Appendix C.

First, the Green New Deal, aspires to go faster in the transition than current plans target. The data clearly indicates that it can economically do so. At some point the acceleration could impose higher cost, but the goals chosen are in line with the development of the sector. How much more could and should be done is an open question, but the paper shows a significant acceleration toward 2030 is possible.

Second, there are much broader social goals to which the Green New Deal aspires that are separate from the question of transforming the electricity sector. However, although the transformation of the electricity sector is consistent with the direction of the broad social change desired.

Climate change is a problem of a global common pool resource and there is no overarching authority to “order” individual nations to reduce their emissions.¹³² The solution had to be a collaborative effort of the “commoners,” the individual nations that inhabit the commons “because it recognizes the fundamental challenge of climate change as a dilemma that must balance development and decarbonization. It also recognizes the reality of the global structure of political authority in which policy must be implemented by states.”¹³³

Because the Green New Deal is a national policy it has the opportunity to exercise greater authority in selecting policies. However, the Green New Deal is cognizant of American federalism, which delegates authority to subnational units. It also recognizes the need for civic engagement to achieve the overall goal. In this way, it is the antithesis of the Trump administration’s approach which seeks to use federal subsidies and favors to expand reliance on central station generation and fossil fuels.

The Green New Deal adopts the decarbonization goal to be achieved with other considerations in mind including:

- Decarbonization and development
- Progressive and inclusive goals to involve and meet the needs of diverse communities underrepresented in the centralized system
- The subsidiarity principle looking to local and state governments and corporations for support and implementation
- Involvement of civil society

The evaluation/assessment challenge is in the economic section, to evaluate whether and how the goals are achievable. In that section of the table I offer a baker’s dozen observations/conclusions from the climate change literature that strongly support the conclusion that the goals are achievable and a progressive capitalist path is the best route to a least-cost, low-carbon outcome. We can see this in the extremely active role of state policy in guiding the sector in the right direction.

Table 8.2 puts the specific outline of the Green New Deal approach in the broader context of progressive policies.

The first column uses one of the leading texts in the field of Industrial Organization to identify the broad features of a progressive economy. The authors argue that the preference for markets reflects what people want from markets, which is economic progress defined as efficiency, innovation, investment to seize opportunities made possible by science, progressive distribution of those opportunities, and equitable distribution of the resulting benefits. Markets are the tool for achieving these outcomes and competition is the key to driving markets toward them. Competition and markets are never perfect, so the authors provide measures for workable competition and acknowledge that policy may be necessary to correct markets that fail to deliver on their promise. They also argue that competitive markets are associated with (virtually a necessary condition for) democracy.

The second column identifies progressive tax policy as a more concrete example. Tax policy is particularly important because it is one of the primary policy instruments in the progressive toolkit. Regulatory rate setting and incentive structures are akin to taxation in the sense that they provide incentives for specific actions, beyond the basic questions of efficiency and equity. These principles are embodied in Stiglitz's critique of simple-minded "soak the rich" taxes, which underscores the broad scope of progressive principles. "A well-designed tax system can do more than just raise money—it can be used to improve economic efficiency and reduce inequality."¹³⁴

As shown in Table 2.2, Stiglitz argues that tax policy can be used to accomplish a number of goals beyond reducing inequality and raising revenue, including improving efficiency by reducing monopoly rents, discouraging harmful behaviors/encouraging beneficial behaviors, and stimulating investment and job creation. Efficiency is improved when taxes reduce monopoly profits and rents, provide incentives to invest and create jobs, and generally fall heavier on "bad" things than "good." Equity is served with progressive taxes, closing loopholes, and creation of jobs.¹³⁵ Price, like taxation, should be a refined, not a blunt instrument.

Taken together, these proposals would make real inroads into reducing inequality, returning us to an economy more like that of the post-war years. Those were the years when America was becoming the middle-class society it had long professed to be, with decades of rapid growth and widely shared prosperity, when those at the bottom saw their incomes grow faster than those at the top. They are also the years that Thomas Piketty views as an anomaly in the history of capitalism. But getting back to that time doesn't require eliminating capitalism; it requires eliminating the market distortions of the ersatz capitalism practiced in this country today. This is less about economics than it is about politics. We don't have to choose between capitalism and fairness. We must choose both.¹³⁶

TABLE 8.2: PRINCIPLES FOR PROGRESSIVE CAPITALISM

INDUSTRIAL ORGANIZATION (1)	PROGRESSIVE TAXATION (2)	ENVIRONMENTAL POLICY (3)	COMMAND-BUT-NOT-CONTROL REGULATION (4)
Performance desired from markets, Workable Competition	Why and what to tax	Recognize complex uncertainty	Competition & Progressive policy go hand-in-hand
Progressive = Contribute to long run growth of income per capita	Stimulate investment, Raise money for social purposes		Long-term, gradual and persistent targets
Exploiting science and technology to increase output	Tax worse, not better activities	Subsidize R&D	Technology Neutral: Externalities: capture positive/reduce negative
Provide consumers with superior products, Encourage rational choice	Tax things that do not disappear when taxed	Tax bads, be impartial	Responsive to consumer needs; Demand-side ensures choice
Guide markets to equilibrium	Stimulate job creation	Promote coordination	Long-term, gradual and persistent targets
Facilitate stable full employment	Stimulate job creation		
Promote equity in the distribution of income	Improve income distribution		Redistribution: Differential marginal utility of income & wealth
No excess profits, Prices should be just sufficient to reward efficiency, Independent action of firms	Reduce monopoly profits	Control rent seeking	Pro-competitive: Eliminates XS profits, Deconcentrate supply
Achieve reasonable price stability, Not intensify cyclical instability		Be stable and risk aware	
Efficient = Increase efficiency	Improve efficiency	Engage in market creation	Supply-side controls cost
Not wasteful, Largest # of suppliers consistent with Minimum Efficient Scale; inefficient should not be shielded permanently	Close loopholes	Externalize non-marginal effects	Product Neutral: Neutrality prevents bypass; avoid incumbent bias and mis-targeting of subsidies, Cost-Casuation
No artificial barriers to mobility & entry or unfair, exclusionary, predatory or coercive tactics			Responsive to producer needs: Avoid XS profits & Diseconomies of scale
Responsive to demand in variety, durability, safety, reliability/ Success accrues to sellers who best serve consumers, Promotion should be informative/not misleading or excessive		Recognize unwillingness to pay	Responsive to consumer and producer needs: Consumer choice is preserved
Address market imperfections = For a variety of reasons, markets may fail yielding performance that falls below norms considered acceptable		Address imperfections of price, principle agent problems,	Address multiple market imperfections, Behavioral & Institutional
Social values	Raise money for social purposes	Promote quality administration of rules	Socially responsible rates, Greater value/subsidy for low income, or high cost
Promote Democracy			Democratic equality, Shared and Individual responsibility

- (1) Scherer, Frederic M., and David Ross. *Industrial Market Structure and Economic Performance* (3rd ed.). Boston, MA: Houghton Mifflin, 1990.
- (2) Stiglitz, Joseph E. “Phony Capitalism.” *Harper’s Magazine*, September 2014;
- (3) Hepburn, Cameron, “Environmental Policy, Government and the Market,” *Oxford Review of Economic Policy* 26 (2010), pp. 117-136.
- (4) Cooper, Mark, *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a sustainable Power Sector*, (Praeger, 2017), pp. 173-175, 223-225; Mark Cooper, “Energy Justice in Theory and Practice: Building a Pragmatic Progressive Road Map,” in This, Van de Graaf, et al. (Eds), *The Palgrave Handbook of the International Political Economy of energy* (Palgrave/MacMillan, 2016), pp. 703-707, 713-716).

The third column provides progressive views on policy to address climate change. This is, of course, directly relevant to the Aging Nuclear Reactors Subsidy Program. I will elaborate on this at the end of this section, where I present a discussion of why price should not be among the first policies adopted

The Hepburn article parallels the arguments made in this paper. Hepburn starts from the premise that values are the starting point for policy analysis, “Approaches to environmental protection, like other policy areas, reflect the prevailing value judgements about the role and size of the state.”¹³⁷ He rejects the market as the solution and the narrow,¹³⁸ “night watchman” role for the state, citing the continuing and expanding role of the state: “government involvement in the economy has climbed to record highs in recent years, with the state playing a more comprehensive role in providing social security, education, physical and mental health, and in other resource-allocation decisions.”¹³⁹ He observes the ebb and flow of policy in the reaction to the slowdown of the late maturity phase of the second industrial revolution¹⁴⁰ and the important role of the financial meltdown in shaking the faith in the efficient market hypothesis.¹⁴¹ He ties these historical developments to the more progressive approach to climate policy.

The crisis has also created doubts about market-based approaches to environmental problems. At the international level, climate-change policy appears to be moving from being predominantly market-based... to a mixed system which includes a role for national planning, a focus on ‘nationally appropriate mitigation actions’ for developing countries, and the actions in the Copenhagen Accord.¹⁴²

He identifies a series of important market failures that must be addressed, including public goods (such as the military), infrastructure, information, coordination, principle agent (rent seeking), and perverse incentives supported by inaccurate and inappropriate accounting.

Table.8.3 identifies five dozen market imperfections that have been supported by empirical evidence in the efficiency and climate change literature. Policy is necessary to address these, but the state has significant limitations in its ability to do so, particularly in its inability to sustain the “evolutionary dynamic that generates diversity and wealth.”¹⁴³ The solution lies in command but not control, with the state setting the overall objectives and leaving it to the market to deliver.

His solution is essentially what we call pragmatic progressive capitalism.

On the one hand, leaving environmental protection to the free market, relying on notions of corporate social responsibility and altruistic consumer and shareholder preferences, will not deliver optimal results. On the other hand, nationalizing the delivery of environmental protection is likely to fail because nation states rarely have the depth and quality of information required to instruct all the relevant agents to make appropriate decisions. Thus, as for many areas of policy, appropriate models of environmental intervention will lie between these two extremes.¹⁴⁴

TABLE 8.3: RECENT EMPIRICAL EVIDENCE OF MARKET IMPERFECTIONS IN RELEVANT LITERATURE

<u>Schools of Thought/ Imperfection</u>	<u>Efficiency</u>	<u>Climate</u>	<u>Schools of Thought/ Imperfections</u>	<u>Efficiency</u>	<u>Climate</u>
<u>Traditional</u>			<u>Transaction Cost/ Institutional</u>		
Externalities			Search and Information	88, 108	
Public goods & Bads	28, 55, a, b	24,132, 177, 197, ZL	Imperfect information	10, 100, n	19, 62, 90, U
Basic research/Stock of Knowledge	46, 37, N		Availability	10, 185, d	
Network effects	127,,ak	82, 134, I, K	Accuracy		
Learning-by-doing & Using	47, i	134, 105,120, 153 E	Search cost	41, 185, u	
Localization		101, 153, 182, H	Bargaining		
Industry Structure	122, 127, 163, 167		Risk & Uncertainty	32, 33, 165, t	42, 83, 103, 180, 188, R
Imperfect Competition			Liability		
Concentration	16, m		Enforcement		
Barriers to entry			Fuel Price		82, 134.
Scale	39, r	151, G	Sunk costs		83
Cost structure		44, 106, 134, I	Hidden cost	185, ab	106
Switching costs	165, t		High Risk Premia		106, T
Technology	136, w		Incomplete Markets		82, 97, 179
R&D		90, 143, 15, E	<u>Endemic Imperfections</u>		
Investment			Asymmetric Info		
Marketing			Agency	72, 163, 185, c, ad	83, 193, Q
Bundling: Multi-attribute	162, 21, 116, z		Adverse selection	41, e	79, 44, X
Cost-Price			Perverse incentives	167, f	
Limit impact of price	74, 116, ac		Lack of capital		
Sluggish Demand/Fragmented Mkt.		82, 97, 110, W	<u>Political Power & Policy</u>		
Limited payback	74, 165, ae		Monopoly/lack of competition		101, 155, 187, 188, ZB
<u>Behavioral</u>	117,133,144,149,159,173		Incumbent power		182, ZA
Motivation & Values	7, 6, h	39, ZM	Institutional support	167, af	
Non-economic	4,		Inertia	136, ag	83, 1, 69, 106, M, V
Influence & Commitment			Regulation		
Custom	145, 146		Price	41, 88, 121, ah	
Social group & status	6, h	97, ZN	Aggregate, Avg.-cost	95, ai	
Perception	13, al		Allocating fuel price volatility		82, 98, 203, O
Bounded Vision/Attention	1,162, k		Permitting		
Prospect/ Risk Aversion	151,165, l		Lack of commitment	108, aj	83, 110, 156, 181,
Calculation.		77, 78 8, Z			
Bounded rationality	10, 75, d, o				
Limited ability to process info	4, q				
Heuristic decision making					
Discounting difficulty	47,95,96,113,136, v				

Sources: Appendix B, from Mark Cooper, *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a sustainable Power Sector*, (Praeger, 2017), Appendix B. Numbers are sources; letter are specific page citations and quotations.

The fourth column presents a specific set of principles to guide rulemaking that I have developed and applied in the fields of energy and communications. I call it “command-but-not-control” regulation. The primary “practical” recommendations fit each of the major progressive capitalism characteristics. The Green New Deal will inevitably entail regulation of a sector that needs direct oversight in much more than setting goals, the idea is to harness market forces to lower costs to the greatest extent possible. The crucial point here is that while establishing goals is essential, designing institutions and mechanism to facilitate and support the effort to achieve the goals is at least as important.

“command-but-not control” sets a performance standard but affords the manufacturers of energy-using consumer durables freedom and flexibility to meet the standards. They are technology and product neutral, setting moderately aggressive and progressive targets that are responsive to the needs of consumers and producers. They unleash market forces of competition and innovation around the standard, which explains why compliance costs have repeatedly, almost invariably, been well below the estimates made by regulators and far below the bloated cost estimates of industry.¹⁴⁵

It hardly needs repeating that this analysis has shown that New York’s Aging Reactor Subsidy Program fails on every one of these principles of progressive capitalism. It is a complete failure as progressive capitalism and as a response to climate change.

9. CRUCIAL, FIRST STEPS IN THE RIGHT DIRECTION

In this section I identify two major mistakes that must be avoided to navigate around the potholes on the road to an alternative 21st century electricity system – over-reliance on prices and under-estimation of the negative effect of subsidies for central station facilities, particularly aging reactors. I then suggest principles to follow of decision making in the initial phases of the journey to that alternative sector.

WHY PRICE IS (AMONG) THE LAST POLICY TOOLS TO USE, NOT THE FIRST

Placing the decision to decarbonize in a broader historical context provides an important perspective to help appreciate both the challenge and the opportunity. The central station approach has been in place for a long period and has a great deal of inertia on its side. Without policies to break the inertia, change will not come about (or will be slower and more costly).

If the only barrier to an efficient response to the end of the implicit and explicit subsidies for fossil fuels were the internalization of the cost of carbon, policy makers could just impose a substantial tax on carbon and let the marketplace work. Unfortunately, that simple approach would not be as effective as hoped because, as we have seen, the electricity market is plagued by other significant market barriers and imperfections. Many of the market barriers and imperfections identified in the efficiency gap and climate change literatures afflict the transition toward alternatives and are magnified by two centuries of inertia behind central station facilities.¹⁴⁶ The challenge of climate change magnifies the importance of those barriers; it does not eliminate them.

One way to appreciate this institutional problem is to bring the two most important literatures – on efficiency and climate change – to bear on one of the central questions raised about the Green New Deal – putting a price on carbon. The supporters of the Green New Deal take the position against early and excessive reliance on price, which has emerged as dominant in the climate change literature.¹⁴⁷ While free market economists continue to push for an immediate and large price on carbon, the literature and political economy argue against that because of the existence of pervasive market imperfections.

The intense interest in the issues of barriers to change and the limitations on price as a policy tool has broken through to the popular press, as demonstrated by a report by Ryan Avent, the Washington-based economic correspondent for the *Economist*. Reporting on “a great session on climate policy”¹⁴⁸ focused on “the environment and directed technical change.” Avent noted that it suggested

Economics is clearly moving beyond the carbon-tax alone position on climate change, which is a good thing. If the world is to reduce emissions, it needs technologies that are both green and cheap enough to be attractive to economically-stressed countries and people. And a carbon tax alone may not generate the necessary innovation. . . . The carbon externality isn't the only relevant externality in the mix. There is another important dynamic in which technological innovation draws on previous research, and so firms are more likely to continue on established innovation trajectories than to start new ones.”¹⁴⁹

About a year later, David Leonhardt, an economic columnist for the *New York Times*, discussed the practical implications of the growing recognition of the challenge of overcoming inertia and closing the “innovation gap.” He contrasted the two approaches saying, “To describe the two approaches is to underline their political differences. A cap-and-trade program sets out to make the energy we use more expensive. An investment program aims to make alternative energy less expensive.”¹⁵⁰

An exchange in *Energy Economics* provides background, as well as a direct link from the climate change debate to the central issue of the market imperfection/barrier framework through the problem of pricing carbon. It was set up as a debate between William Nordhaus and Jon Weyant, who offered contrasting points of view, with Roger Noll commenting.

Nordhaus’ defense of what he calls the “price fundamentalism” approach to climate change analysis and policymaking concedes a long list of exceptions to “price fundamentalism”—exceptions considered extremely important by a growing number of energy analysts.

Under very limited conditions, setting carbon prices to reflect the damages from carbon emission is also a sufficient condition for the appropriate innovation to be undertaken in market-oriented sectors. This conclusion, which I have labeled “price fundamentalism,” must be qualified if the price is wrong and for those parts of research that are not profit-driven (particularly basic research), and when energy investments have particular burdens such as networking or large scale.

However, Weyant elaborates on—and goes well beyond—the list of qualifications offered by Nordhaus. He sees several additional supply-side problems.

[E]ntry is risky and expensive, market organization is more likely to be oligopolistic than perfectly competitive, and information is strategically held and difficult to obtain... Further complicating matters, existing companies in energy-related industries... can have substantial incentives to delay the introduction of new technologies...

Imperfections in the market for energy-converting and energy-consuming equipment may be impeding the rate of diffusion of new technologies that are already economically competitive and welfare improving. This situation can result for several different types of market failure, including poor or asymmetric information available to purchasers, limits on individual’s ability to make rational decisions because of time or skill constraints, principal-agent incongruities between building owners and building residents, and lack of financing opportunities.¹⁵¹

Roger Noll, moderated the debate Avent commented upon, between free market fundamentalists and policy activists¹⁵² concluded that “with minor amendments, these articles provide the right approach to near-term U.S. climate policy.”¹⁵³ The key amendment recognized that price was not enough.

In the absence of targeted government interventions utilities are unlikely to make socially optimal investments in these technologies simply on the basis of an optimal emissions tax and a general R&D subsidy . . . potential entrants face a problem that, for the foreseeable future, the infrastructure is . . . a complement as well as a substitute. . . . Thus, efficient diffusion of new green technologies requires involving the incumbents.¹⁵⁴

Noll cautions that “the key question is how much delay is the commercialization of new green technologies likely to occur even if Pigovian taxes and subsidies are imposed. The answer to this question remains unclear.” While the available answer is not precise, the evidence suggests that the cost of inertia is quite large, and targeted approaches lower costs and speed the transition,¹⁵⁵ as strongly supported by the literature noted in Table 8.1.

Further, Table 9.1 highlights the empirical findings from the climate change literature that bear on this question and constitute the real-world evidence that has shifted opinions.

TABLE 9.1: EMPIRICAL EVIDENCE ON POLICY DIRECTLY EVALUATING PRICE IN THE CLIMATE CHANGE ANALYSIS

Limitations of Markets

Market failures (incumbency, uncertainty, collective action, principle agent, low WTP)

(16, 34, 37, 38, 73, 98, 115, 123, 130, 137, D)

Market power (123, 137, ZAD)

Non-market Factor (35, 50, ZO, ZP)

Complex causes of adoption (34, 115, 183, ZZ, ZAC)

Institutional capacity is crucial to effective, least-cost implementation (17,50, 105, 106, 119, 120, 161)

Technology transfer and learning play a key role (90, 110, 130, D)

Integration: Challenge and Response (5, 13, 18, 54, 56, 58, 114, 138, 139, 199, 201, ZT, ZU)

Inertia v. Urgency (6, 59, 126, 202, F, ZQ)

Avoid lock in (7, 69, 89, 106, J)

Early action lowers the transitional and total economic (41, 6, 69, 70, 83, 101, 106)

Evidence on Price and Other Policies

The ineffectiveness of price/ Tax as policy

Price Insufficiency (4, 11, 15, 19, 20, 25, 29, 63, 70, 81, 82, 102, 144, 160, 188, 191, 193, A, L, S)

Tax: Difficulty of setting and sustaining “optimal” levels (81, 82, 160, B)

Tradable permits do not increase innovation (22, 147, 191, C)

Effective Policy Responses (ZR, ZS)

Public goods (101, 195, ZC)

Institution Building (90, 94, 110, 195,195, ZN, ZE)

Research and Development (22, 57, 82, 97, 101, 102,103, 106, 130, 141, 148, 188, ZD, ZF)

Capital subsidies Adders, premium prices (25, 160, ZG, ZY)

Obligations/Consenting (101, 102, 106,141, 188, M, (ZH, ZS, ZAA)

Standards (44, 90, 100, 171, 172, ZI, ZX)

Feed in Tariffs (106, 1156, 60, 182, 188, ZJ)

Merit order (27, 67,85, ZK)

Flexible, overlapping policies are needed that recognize complexity (17, 81, 125, 126, 130,

152, 169, 179, E, ZV, ZAF)

Source: Appendix D [updated from Mark Cooper, *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a sustainable Power Sector*, (Praeger, 2017)],

The Table begins with a listing of market imperfections followed by two sets of policy evaluations. Price does not perform as well as other policies that directly address market imperfections. Targeted subsidies performed better than price and standards better still.

Here we should recall that nuclear power is completely cornered by economic analysis. On the one hand, as many have pointed out, a simple tax on carbon does nuclear no good because it helps the other low carbon resources more because they are lower emitters. On the other hand, if economically rational targeting of subsidies is the choice, nuclear loses again because it is a vastly inferior choice for further subsidization.

PRINCIPLES FOR DECISION MAKING TO AVOID THE POTHOLES

An analysis by energy researchers at Imperial College moves the theoretical concerns about market imperfections and the problem of seeing a price on carbon into the center of the ongoing debate.¹⁵⁶ It provides a useful transition to guidelines for decision making.

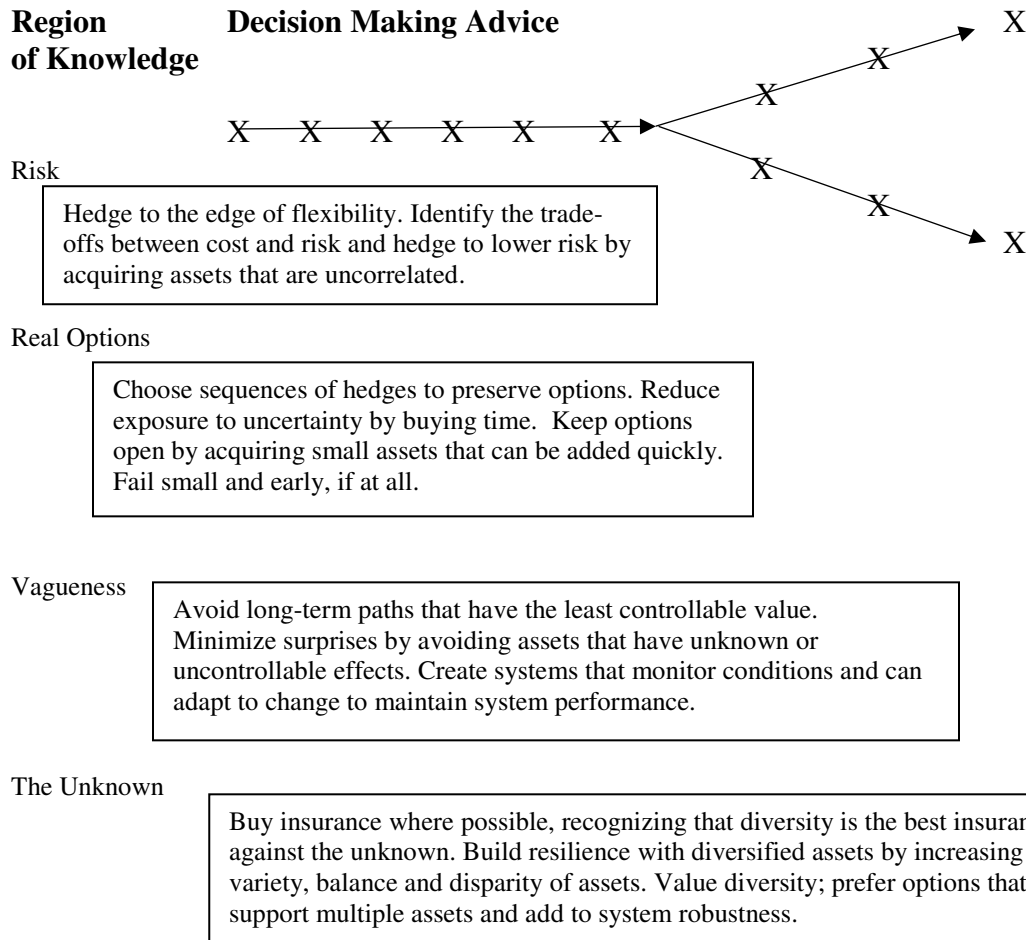
The authors start at the theoretical level by cataloguing the very restrictive assumptions that are necessary to reach the conclusion that imposing a hefty tax on carbon is the efficient, first-best way to internalize the carbon externality—perfect, costless information, rational, maximizing behavior, lack of economic market power, frictionless transactions, no political obstacles.¹⁵⁷ They point out that in the energy space, there is a great deal of evidence that demonstrates the simple theory is confronted with and contradicted by a complex reality.¹⁵⁸ The incumbent market and institutional structure is riddled with important and concrete problems that ensure the market outcome will fall short of the theoretical optimum. Getting the sequence right by adopting policies that lower the cost by addressing market imperfections first is strongly supported by key findings in the literature.

My earlier analysis offered a road map to getting the sequence right. It makes clear that adding the resources that will constitute the 21st century electricity system in the long term as early and as extensively as possible makes perfect sense from a risk/decision making point of view. I have argued that the challenge of the transition requires three key steps

- The central station paradigm must be uprooted. Above all, nuclear power—pushed by a large and powerful constituency—is not the solution. It cannot even be part of the solution due to its fundamental conflict with the institutional framework needed by renewable/distributed/demand-based alternatives.
- Progressive principles applied in the key policies are needed—particularly the development of “command but not control” performance standards that are aggressive, long-term, procompetitive, and technology neutral. These have been successful in the past and are likely to be so in the future because they harness and orient the power of markets.
- A decision-making approach that uses a formal portfolio analysis provides transparency, precision, and legitimacy to resource selection is preferable. It is the “common sense” approach to decision-making in a complex, interconnected, and uncertain environment.

Figure 9.1 summarizes the general principles I derived from the broader analysis of the transition to a low carbon electricity sector. The clear conclusion reached in that analysis is reinforced by this more detailed analysis of subsidies for aging reactors. Nuclear power is never the preferred resource.

FIGURE 9.1: SEQUENCING DECISIONS BASED ON THE MAP OF THE TERRAIN OF KNOWLEDGE



Source: Mark Cooper, *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Sector* (Santa Barbara, Praeger, 2017).

Applying least cost principles, yields the lowest cost, lowest carbon and least polluting portfolio. In the short-term, the main resources of the 100 percent renewable approach are currently less costly and widely available. Therefore, there is no reason to hesitate in pursuing the low-carbon, low-pollution path. Spreading the renewable resource base across geographic regions and resources creates a less variable pattern of generation. Storage capacity enhances the value of all variable resources and reduces the volatility of input prices. Smarter networks increase the ability to balance generation and load. Smart grid development creates export markets for surpluses and more efficient import markets to meet deficits.

In the mid-term, the “economic merit order” follows the “environmental merit order” to a large extent (75–90%), depending on costs used. Since the deviation of the “environmental merit

order” is so small and the economic benefit of pursuing a 100 percent renewable electricity sector is so large, it is not worthwhile to relax the carbon or the other pollutant constraints.

In the long-term, the economic and environmental “merit orders” are almost identical. Because the cost of the low-carbon, low-pollution technologies has plummeted and their cost is expected to continue to decline, the shift away from baseload resources (fossil fuels and nuclear power) to reliance on flexible renewable resources—linked with active management of supply and demand—will lower the cost of electricity.

Subsidizing aging reactors contradicts every recommendation. This resource is inflexible and has difficulty adapting to change. It forecloses options and does nothing to support the development of the overall system. In states where there are multiple reactors, like New York and Illinois, it continues concentrated market while slowing true diversification across technologies and geographic areas, and ownership models.

AVOIDING MISTAKES, THE UCS ANALYSIS

Having evaluated the impact of nuclear power broadly and the specific concerns about a state-based programs as they are being implemented in the real-world, a recent analysis of policies to subsidize aging nuclear reactors by the Union of Concerned Scientists requires mention in this context.¹⁵⁹ The UCS report purports to show the conditions under which policymakers could consider such subsidies. Needless to say, nuclear advocates seized on the report as supporting their efforts to secure subsidies. To the contrary, the UCS analysis does no such thing. Read carefully, the UCS analysis shows that the New York Aging Nuclear Reactor Subsidy Program is a perfect example of what is wrong with subsidies for aging reactors.

The UCS analysis shows that the New York Aging Nuclear Reactors Subsidy Program fails to adopt any of the safeguards that the report insisted were necessary to ensure the program was economically and environmentally acceptable. In fact, local environmental and consumer advocates have demanded exactly these conditions, but the PSC failed to adopt any of the safeguards and the Aging Nuclear Reactors Subsidy Program has landed in the courts. Of equal, or greater, importance the UCS report failed to consider the negative impact such subsidies would have on the transition to a clean, low carbon future based on renewable and distributed generation and intensive management of supply and demand.

While the UCS analysis argues for a national cap or tax on carbon to drive reductions,¹⁶⁰ it also points to regional and state actions to cap or tax carbon as an important first step.¹⁶¹ However, here the important point is that the Aging Nuclear Reactors Subsidy Program does not adopt a broad cap, as envisioned by UCS. Rather than create a broad incentive to use market forces to achieve least cost carbon reduction, the Aging Nuclear Reactors Subsidy Program subsidizes a specific technology that imposes excessive costs on consumers. Local environmental and consumer advocates have also explicitly argued that the social cost of carbon has been misused by the Aging Nuclear Reactors Subsidy Program. They have argued strenuously for the approach UCS prefers, but they have been rebuffed.

A second, critically important economic conditions stipulated by UCS is a careful analysis of the profitability of reactors so that excessive charges are not imposed on the public.

The Aging Nuclear Reactors Subsidy Program does not do so. It is a blanket subsidy for a collection of reactors, some of which are and would be profitable without a subsidy. Failing to take this simple, but critical step, the subsidy envisioned by the Aging Nuclear Reactors Subsidy Program is almost three times as large as the subsidy calculated by UCS.¹⁶² The difference is huge. As calculated by AGREE/NIRSS, on a nationwide basis, the excess cost imposed on consumers would be at least \$20 billion dollars, which would buy a great deal of non-nuclear carbon reduction.¹⁶³ To no avail, local advocates have called on the PSC to conduct exactly the detailed analyses of reactor finances that UCS demands.¹⁶⁴

UCS argues for a carefully targeted, set aside for nuclear power, insulating it from competition from alternative sources, claiming that this will prevent the concentration of the market power and allow the subsidy to be adjusted to market conditions.¹⁶⁵ In fact the Aging Nuclear Reactors Subsidy Program does the opposite, enshrining a single company as a dominant provider of electricity. Moreover, only by assuming cost trends that are contradicted by history and virtually every other analyst (including UCS's own modelling in other contexts), can the PSC make it appear as though the size of the subsidy will decline over time, although it cannot claim that the cost of electricity will not increase on a dollar-for-dollar basis.

The UCS analysis calls on policymakers to “Ensure that qualifying plants maintain strong safety performance,” and expresses a naïve hope that “Economic assistance to at-risk plants would help alleviate financial pressures—and could reduce industry pressure on the NRC to cut corners,” which is contradicted by history and contemporary evidence.¹⁶⁶ It is very hard to see how this concession would lead the industry and the NRC to address the host of concerns UCS expresses about nuclear safety measures (or lack thereof).

UCS calls on policymakers to strengthen renewable energy and efficiency standards,¹⁶⁷ but the nuclear subsidy offered by the Aging Nuclear Reactor Subsidy Program, as calculated by the staff, is over three times as large as the subsidy for renewables, under assumptions that include little increase in energy efficiency in a program that does nothing to incentivize efficiency.

UCS calls on local policymakers to “Develop transition plans for affected workers and communities,”¹⁶⁸ but the New York Aging Nuclear Reactor Subsidy Program is a simple nuclear bailout with no such efforts. Given the lack of a transition plan, it is hard to see how that same concerns, a decade hence, will not be put forward as an excuse to continue operation of nuclear reactors.

The failure of the New York Aging Nuclear Reactors Subsidy Program to adopt any of the policy conditions UCS deemed essential to considering nuclear subsidies points to another weakness of the analysis of equal, if not greater importance. The report fails to consider the long-term impact that subsidizing nuclear power will have. Nuclear power has always and will always crowd out the alternatives. That is the inevitable result of the nature of nuclear power which produces huge quantities of “must run” power.

The ultimate failure of the UCS analysis is to underestimate the conflict between the central station approach and the alternative approach. One of the opponents to the New York subsidy found a broad-based campaign of euphemism and dysphemism, summarized in Table

9.2, conducted by the industry. There is no way to reconcile the characteristics of the electricity system that nuclear power needs with the characteristics of an electricity system based on renewable, distributed generation and flexible supply-demand management needs.

TABLE 9.2: THE NUCLEAR INDUSTRY’S BROAD ATTACK ON RENEWABLES

	Federal States	
Direct (Attack Programs that Support Renewables)		
Renewable Energy Production Credit (1)	X	X
Renewable Energy Portfolio Standard (2)	X	X
Efficiency Portfolio Standard (3)	X	X
Net Metering		X
Taxes and Fees (4)	X	X
Indirect (Implement Programs to Support Nuclear)		
EPA Rule Bias (5)	X	X
Wholesale market manipulation		
Above Market/Guaranteed Rates	X	X
Alter dispatch order to favor base load (6)	X	X
Restrict Demand Response (7)	X	X

Notes:

- 1) General opposition to and specific cutbacks in renewable commitments.
- 2) Includes shifting from “renewable” to “clean” standard.
- 3) General opposition to and specific cutbacks in utility efficiency programs.
- 4) Taxes on renewables, Minimum Offer Price Rules.
- 5) Allowing subsidies and incentives for nuclear. Giving system benefits for reliability, onsite fuel storage.
- 6) Must run rules/Take or pay clauses.
- 7) Opposition to bidding demand

Source: Nuclear Information and Resource Service, Killing the Competition: The Nuclear Industry Agenda to Block Climate Action, Stop Renewable Energy, and Subsidize Old Reactors, September 2014.

By excusing aging reactors from competition, shrinking the market for alternatives, doing little to expand the alternatives and making no plans for the closure of these reactors, the Aging Nuclear Reactor Subsidy Program proposal and the blind spot in the UCS analysis open the door for the argument that, when the subsidy terminates, the arguments made today by the nuclear reactor owners will be repeated. New York would “need” more nuclear power, not because it is a preferable low carbon resource, but because policy had retarded the development of the alternatives.

CONCLUSION

This view of the Green New Deal and the Paris Agreement as responses to climate change frames them as a pattern that has been repeated several times in the quarter millennium of capitalist industrial revolutions. The historical analysis of technological revolutions in the industrial era and the importance of the turn toward progressive policy implemented by an entrepreneurial state at the critical junctures or turning points is well-grounded at the macro-level of analysis. Locating the Green New Deal and the Paris Agreement in the flow of progressive, capitalist technological revolutions reinforces the conclusions in this paper, by showing the applicability of the stages of the historical process, the specific policies that created the revolution in renewables, and the innovation systems that sustain the process, particularly in the ongoing third industrial revolution. These are briefly summarized in Appendix G for the key generation resources (wind and solar) of the alternative, 21st century electricity sector.

A new technology, nurtured by the state with early support and market creation policies, is now moving to dominance and... has produced the tools to sustain development and overcome the problems it has created, but a socio-institutional

paradigm must be created to guide it.¹⁶⁹

However, history teaches that technical and economic progress alone are not enough to ensure the transformation of society. They require the creation of socio-political institutions that support and anchor the new economy. A new “common sense” must be created in which the solutions offered by the new approach seem obvious. The Paris Agreement and the Green New Deal are expressions of that new way of thinking. History also teaches that leading nations that fail to make the transition or turn toward regressive policies instead of a progressive direction can lose their leadership position and fall behind, not to mention plunge the world into war. The outcome at these critical junctures and turning point is uncertain and the stakes are high. The critical initial steps are to avoid the obvious potholes.

In this paper I have shown that the first aspirations of the Green New Deal are consistent with the key principles and practices of the New Deal, like economic development, employment, universal service for utilities, and a cleaner environment achieved by providing guidance and oversight for markets and market behavior. They are also consistent with the economics of the electricity sector at the turning point. A great deal is within the reach of the Green New Deal based on basic economics, markets that are well-regulated with “command-but-not-control” strategies, and well-targeted subsidies. Even if the Green New Deal does only what can be accomplished within these limits of long-run, least cost, cleanest power, it will have accomplished a great deal.

ENDNOTES

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- ¹ Daron Acemoglu and James A. Robinson, *Why Nations Fail: The Origins of Power, Prosperity, and Poverty* (New York: Crown Publishers, 2012);
- ² Pérez, Carlota. *Technology Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*. Northampton, MA: Elgar Publishing, 2002. (Hereafter Perez, *Technology Revolutions*) I call it a a quartererlife crisis,” Mark Cooper, “Why Growing Up is Hard to Do: Institutional Challenges for Internet Governance in the ‘Quarter Life Crisis’ of the Digital Revolution,” *Journal on Telecommunications and High Technology Law* 11 [2013]). See Mark Cooper, The 21st Century Electricity System at a Turning Point (50-Years in 8 Exhibits, with Annotation): How The Paris Agreement and the Green New Deal Map a Route to a Progressive, Capitalist, Low Cost, Low Carbon Sector, prepared for 2nd Annual Conference on Energy Research and Social Science, Arizona State University, May 28-31, 2019. (Hereafter Cooper, *Turning Point*). Mark Cooper, The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Sector (Santa Barbara, Praeger, 2017). Hereafter Cooper, *The Political Economy of Electricity*, Chapter 4 provides a full discussion.
- ³ Pérez, *Technology Revolutions* I call it a a quartererlife crisis,” Mark Cooper, “Why Growing Up is Hard to Do: Institutional Challenges for Internet Governance in the ‘Quarter Life Crisis’ of the Digital Revolution,” *Journal on Telecommunications and High Technology Law* 11 [2013]).
- ⁴ Cooper, *The Political Economy of Electricity*: Chapter 8.
- ⁵ Of course, a second path of resistance, lead by coal, is to deny the need to decarbonize the sector. but that generally has much less traction, except in the Trump Administration.
- ⁶ Mark Cooper, *Renaissance in Reverse*, 2013; Mark Cooper, “Nuclear Aging: Not so gracefully,” *Bulletin of the Atomic Scientists*, 69, 2013; and Cooper, The Political Economy of Electricity, Chapter 8.
- ⁷ The immediate headlines scream with controversy from expected directions. The usual suspects oppose it without analysis, see for example: Merrill Matthew, “Is the Green New Deal even feasible?,” *Institute for Policy Innovation*, February 9, 2019; David Olive, “Green New Deal movement is a counter-reaction to decades of middle-class decline,” *Wall Street Journal*, Feb. 15, 2019; John Barrasso (R-WY, U.S. Senate), *Green New Deal is a Raw Deal*, February 7, 2019; Nick Loris, Heritage.org, *Heritage Expert: The Green New Deal is a Raw Deal for the American People*, February 7, 2019; The most blatantly half-baked (perhaps one should say half-assed) analysis comes from the American Action Forum, which, in typical fashion calculates costs, but not benefits and vastly overstates costs, assuming that the marketplace will not work, even though most programs (except for the nuclear bailout) provide market incentives for least cost approaches. Douglas Holtz-Eakin, “An Initial Analysis of the Green New Deal,” *Daily Dish*, February 25, 2019). For the electricity sector analysis it ignores the much lower cost of efficiency and renewables and the fact that investment in the grid is constant, so the issue is not whether to spend the money, but how. I have criticized this approach to cost benefit analysis in, Mark Cooper, *Pocketbook Savings, Macroeconomic Growth and other Public Benefits of Energy Efficiency appliance Standards: Benefit-Cost Analysis of Four Decades of Rules Shows they have Delivered Trillions of Dollars of Economic Value to Consumer and the Nation* (Consumer Federation of America, July 2017, and *Trump’s \$2 Trillion Mistake, The “War on Energy Efficiency: The “command-but-not-control” approach to energy efficiency performance standards for appliance and vehicles corrects market failures and delivers consumer pocketbook savings, macroeconomic and public health benefits* (Consumer Federation of America), December 1, 2017. On the other side, see for example, Liam, Denning, *The Green New Deal is Unrealistic? Get Real*, February 11, 2019; Ken Simmel, *Green New Deal Resolution Pushes Congress to Act on Climate*, February 7, 2019; Ben Geman, “The Green New Deal is Here,” *Axios*, February 7 Sarah Ladislaw, “How to Grow the Green New Deal,” Center for Strategic and International Studies, February 7, 2019; Jacobin Roundup, *A Plan to Save the Planet*, February 13, 2019; John H. Cushman, Jr. “The Green New Deal Lands in Congress,” *inside climate news.org*, February 7, 2019; The link to nuclear power was raised immediately, both by those advocating for it and those opposed, Akeal Lacy, *South Carolina Spent \$9 Billion to Dig a Hole in the Ground and then fill it Back in*, February 6, 2019; Linda Pentz Gunter, “The Green New Deal Goes to Washington: Now the battle is on to keep nuclear power out of it,” *beyondnuclearinternational*; February 8, 2019; Avery Thompson, “the Alexandria Ocasio-Cortez ‘Green New Deal’ Wants to Get Rid of Nuclear Power. That’s a Great Idea. Nuclear power is simply too risky and complicated to supply our country’s energy,” *Popular Mechanics*, February 8, 2019; Gavin Bade, “Nukes can have small role in Green New Deal, backers say” *Utilitydive.com*, February, 8 2019. David Titley, *Liberals who want a Green New Deal must include nuclear power*, February 22, 2019; Dino Grandoni, “The Energy 202: Green New Deal is already sparking debate over nuclear energy,” *Washington Post*, February 11, 2019; Lee Rogers, “A Real “Green New Deal” Would Involve a Mass Expansion

of Nuclear Power,” *Daily Stormer*, February 10, 2019; Michael Shellenberger, “Green New Deal Excludes Nuclear And Would Thus Increase Emissions -- Just Like It Did In Vermont,” *Forbes*, February 7, 2019.

⁸ David Roberts, *Here’s one fight the Green New Deal should Avoid for Now*, January 15, 2019.

⁹ Cooper, *The Political Economy of Electricity*:

¹⁰ The concept of a Green New Deal had international roots in the 2008-2012, period (see https://en.wikipedia.org/wiki/Green_New_Deal), has its origins in the late 2018 period. One of the first pieces that seems to have called for it from the point of view of broad social policy and public opinion polling (Greg Carlock, Emily Mnagan and Sean McElwee, *A Green New Deal: A Progressive Vision for Environmental Sustainability and Economic Stability*, Cata for Progress, September 2018). made only brief mention of the economic basis and feasibility of the greening of the economy.

¹¹ See note 6 above.

¹² See, note 6 above

¹³ Bade, *Nukes can have small role.*”

¹⁴ See, Mark Cooper, “Governing the Global Climate Commons: The Political Economy of State and Local Action, After the U.S. Flip-Flop on the Paris Agreement,” *Energy Policy*, 2018 (hereafter, Cooper, *Governing the Global Climate Commons*); and the earlier, “Renewable and distributed resources in a post-Paris low carbon future. The key role and political economy of sustainable electricity” *Energy Research & Social Science*, 2016.

¹⁵ The term was used explicitly in late 1998, although the ideas underlying the concept were criticized somewhat earlier. Stiglitz used it in his Nobel lecture in 2001. See “Market fundamentalism” at https://en.wikipedia.org/wiki/Market_fundamentalism.

¹⁶ Hammond, Samuel, *The Free-Market Welfare State: Preserving Dynamism in a Volatile World Poverty and Welfare Policy Analyst*, Niskanen Center May 2018; Lindsey, Brink, Steven Teles, Will Wilkinson and Samuel Hammond, *The Center Can Hold: Public Policy for an Age of Extremes*, Niskanen Center, December 2018.

¹⁷ Touchberry Ramsey “Here’s How the Green New Deal Compares to a Proposed Republican Climate Plan,” *Politico*, April 3, 2019.

¹⁸ Ari Natter, “Democratic Green New Deal Defectors chart their Own Climate Path,” Bloomberg, April 2, 2019.

¹⁹ Brad Plumer, “Outcomes Hazy for Countries that Tax Carbon Emissions,” New York Times, April 5, 2019).

²⁰ As discussed in Section 9.

²¹ Mark Cooper, A Clean Slate for Vogtle, Clean Energy for Georgia: The Case for Ending Construction at the Vogtle Nuclear Power Plant and Reorienting Policy to Least-Cost, Clean Alternatives, for the Sierra Club of Georgia, February 2018; The Failure of The Nuclear Gamble In South Carolina: Regulators can Save Consumers Billions by Pulling the Plug on Summer 2 & 3 Already Years behind Schedule and Billions Over Budget Things are Likely to Get Much Worse if the Project Continues, for the Sierra Club of South Carolina, July 2017.

²² I served as an expert on behalf of the local groups opposing the subsidy making each of the arguments contained in this paper before the court (see Affidavit of Mark Cooper on Behalf of Nuclear Information Resource Service, et al., In the Matter of Hudson River Sloop Clearwater, Inc., Goshen Green Farms, LLC, Nuclear Information And Resource Service, Indian Point Safe Energy Coalition, And Promoting Health And Sustainable Energy, Inc., Petitioners-Plaintiffs, For A Judgment Pursuant To Article 78 Of The Cplr Against- New York State Public Service Commission, Along With Kathleen Burgess In Her Official Capacity As Secretary, Audrey Zibelman, In Her Official Capacity As Chair, Patricia L. Acampora, Gregg C. Sayre, And Diane X. Burman, In Their Official Capacities As Commissioners, Respondents-Defendants, And, Constellation Energy Nuclear Group, LLC, With Subsidiaries And Affiliates Exelon Generation Company, Llc, R.E. Ginna Nuclear Power Plant, LLC, Nine Mile Point Nuclear Station, LLC, Nominal Respondents-Defendants, Supreme Court Of The State Of New York County Of Albany, Index No. 07242-16).

²³ It is a consumer rip-off to force New York’s consumers to buy nuclear power at such costly rates when real clean energy options are available for lower cost, and those costs are falling. Given the environmental, health, and public safety threats imposed by nuclear reactors are considered, staff’s “responsive proposal” is even more one-sided. Responsive 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; CASE 15-E-0302: Proceeding on Motion of the Commission to Implement a Large-Scale

Renewable Program and a Clean Energy Standard Petition for Rehearing, August 31, 2016. P. 5 (hereafter Responsive Comments)

²⁴ Cooper, *The Political Economy of Electricity*, p. 1.

²⁵ *Id.*, p.6.

²⁶ *Id.*, p. 6.

²⁷ Cooper, *The Political Economy*, Chapter 3 discusses these revolutions and the technologies of which they are composed. Cooper, *Governing the Global Climate Commons*, discusses the analogy between the core information and communications technologies of the digital revolution and the transformation of the electricity sector, including advanced control technologies

²⁸ Cooper, *The Political Economy*, p. 7.

²⁹ The adjustment is necessary because of differences in the structure of costs between the resources. The low-carbon resources—wind, solar, and nuclear—are capital intensive, with capital costs and fixed O&M costs equal to 85 to 95 percent of total costs. Coal’s capital and O&M costs are about two-thirds of total costs.

³⁰ The recognition of the technological revolution came first in the academic literature, then in the popular press. See, for example, Ryan Avent, “Creating the Clean Economy,” *The Economist*, June 11, 2011; David Leonhardt, “There’s Still Hope for the Planet,” *New York Times*, July 21, 2012. Marshall Goldberg, *Federal Energy Subsidies: Not All Technologies Are Created Equal* (Washington, DC: Renewable Energy Policy Project, 2000); Nancy Pfund and Ben Healey, *What Would Jefferson Do? The Historical Role of Federal Subsidies in Shaping America’s Energy Future* (San Francisco, CA: DBL Investors, 2011); Luis M. A. Bettencourt, Jessika E. Trancik, and Jasleen Kaur, “Determinants of the Pace of Global Innovation in Energy Technologies,” *PLOS ONE* 8 (2013): 10, doi:10.1371/journal.pone.0067894.

³¹ Cooper, *The Political Economy*, p.16.

³² *Id.*, Chapter 2; .“US Real GDP by Year,” *multipl.com*, 2016 <http://www.multipl.com/us-gdp-inflation-adjusted/table>, Department of Commerce

³³ Wesley Cole, et al., *2017 Standard Scenarios Report: A U.S. Electricity Sector Outlook*, NREL/TP-6A20-68548, October 2017, (hereafter NREL, 2017, pp. 18-19.

³⁴ This is calculated based on Lazard’s 60% debt at 8% and 40% equity at 12%.

³⁵ Though New York has been making some progress toward meeting its renewable energy goals, our state has lacked an *enforceable* Renewable Portfolio Standard requiring utilities to meet aggressive mandates for the purchase of renewable energy. Without these mandates, New York has made inconsistent and relatively slow progress in meeting its renewable energy aspirations, especially when compared to states that do have enforceable utility purchasing requirements for renewable energy.(Comment, p. 4)

³⁶ For example, a policy to replace closing nuclear reactors with energy efficiency or increased renewable energy was not considered, yet analysis by the Department of Public Service indicates such alternatives would be cost effective and viable. The direct costs of the nuclear subsidies (\$7.6 billion through March 31, 2029) are estimated to be more than triple the total direct costs of new renewables supported through the Clean Energy Standard (\$2.44 billion through 2030),⁴ though the total annual generation to be provided by new renewables in 2030 (~34 TWh per year) is more than 25% greater than the amount of nuclear to be subsidized through March 2029 (~27 TWh per year).⁵ This suggests that incentives spent on new renewable generation sources would be nearly four times more effective in providing zero-carbon generation than subsidies to nuclear generation. (Rehearing Comment, pp. 5-6)

³⁷ *Id.*, p. 30.

³⁸ AGREE/NIRS, *Responsive Comments*, Under this plan, no other company or resource would be allowed to compete for these subsidies, even if they can offer comparative emissions reductions for lower costs and without the dangers and environmental harm caused by nuclear plants... All of the upstate nuclear reactors become eligible for long-term out-of-market contract through 2029. despite one of the proposed eligibility criteria requiring an assessment of "the costs and benefits of such a subsidy for zero-emissions attributes for the facility in relation to other clean energy alternatives for the benefit of the electric system, its customers and the environment," no such analysis has been produced or even implied to support the staff’s recommendation that certain nuclear facilities receive the 12-year indication of public necessity (Responsive Comment, p. 4). The uncompetitive nature of the nuclear subsidies proposed flies in the face of the rest of the Clean Energy Standard proposal, under which renewable energy providers will have to compete for either power purchase agreements or renewable energy credits (or both). It contradicts the entire framework of the Reforming the Energy Vision, under which utilities are asked to provide competitive opportunities to find the most efficient and affordable ways to avoid large consumer investments in big infrastructure and centralized power plants. And it distorts New

York's long-standing competitive wholesale marketplace at a moment that it is finally bringing down costs for consumers. (Responsive Comments, p. 6). . (Responsive Comments, p. 4).

- ³⁹ In 2017, Amory Lovins (Lovins, *Do coal and nuclear*). challenged the Secretary of Energy, who had launched a report on whether coal and nuclear should be subsidized under the guise of maintaining grid reliability by offering 14 points that argued they should not. I use Lovins' analysis to note the critique at the federal level. Cost and cost trends in Lovins are similar to those used in this paper (p. 24) with aging reactor operating expenses put at \$0.06/kwh and efficiency put somewhat lower than I assume at \$0.02-\$0.03/kwh. In this analysis I use \$0.035/kwh for the present escalating to \$0.04 over a decade.
- ⁴⁰ Malik and Polson, "New York Reactors"; William Opalka, "New York Adopts Clean Energy Standard, Nuclear Subsidy," RTOinsider, August 1, 2016; William Opalka, "CES Under Attack on Multiple Fronts in Rehearing Requests," RTOinside,r,September 5, 2016
- ⁴¹ Illinois Commerce Commission et al., *Response*.
- ⁴² Tom Sanzillo and Cathy Kunkel, *First Energy: A Major Utility Seeks a Subsidized Turnaround*, Institute for Energy Economics and Financial Analysis, October 2014.
- ⁴³ Richard Helman, "Exelon: Need Pa. Action by May to Save TMI," *Crain's*, February 10, 2019.
- ⁴⁴ Tom Johnson, "PSEG: We're Not Bluffing About Shutting Down Nuke Plants," NJSPOTLIGHT, February 15, 2019.
- ⁴⁵ AGREE/NIRS, Responsive Comments, p. 6.
- ⁴⁶ Staff White Paper, NYSERDA, *Energy Efficiency and Renewable Energy Potential Study of New York State, Final Report April 2014*, projects demand at 150GWH (Appendix B, p. 2), which requires 75 GWh to meet the 50% goal. With hydro at 36 GWh (Appendix B, p. 3), the need for low carbon resources is 39GWh.
- ⁴⁷ Id., p. 3, AGREE/NIRS comment, pp. 6, 7, 10.
- ⁴⁸ Lovins, *Do coal and nuclear*, notes the uncompetitive nature of nuclear and coal (p. 23) and lists numerous harmful effects of distorting the market clearing process including, crowding out and reduced entry of alternatives, loss of flexibility, innovation and undermining competition (pp. 24-25), not to mention excess costs (p. 29)
- ⁴⁹ Pursuant to Section 3.7 of the New York State Public Service Commission's Rules of Practice and Procedure, Alliance for Green Energy ("AGREE") and Nuclear Information and Resource Service ("NIRS") petition the Public Service Commission for rehearing of certain parts of the Commission's Order issued on August 1, 2016 in the Clean Energy Standard proceeding (Case 16-E-0302). CASE 15-E-0302, p. 5 progress in both carbon emissions reduction and in adoption of renewables appears to be inversely related to the strength of continuing nuclear commitments." (hereafter Rehearing Comment). The closure of unprofitable nuclear reactors is "a true bridge to the renewable energy economy. Freed from wasting ratepayer money on these old plants, New York's consumers could invest in clean technologies and a grid that supports them. This path would provide more durable and long-term investments in the state's decarbonization efforts. (Comment, p. 5) This suggests that incentives spent on new renewable generation sources would be nearly four times more effective in providing zero-carbon generation than subsidies to nuclear generation. (Rehearing Comment, pp. 6)
- ⁵⁰ AGREE/NIRS 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 (hereafter, AGREE/NIRS, *Comments*), p. 5. Though nuclear energy is often seen as a carbon-free energy source, it remains one of the most dirty (and dangerous) ways to generate electricity. The nuclear fuel cycle is rife with environmental racism against Native American, indigenous, and other environmental justice communities, elevated cancer rates for miners, energy intensive and greenhouse gas emitting processes, radioactive leaks and emissions, thermal pollution of rivers and lakes, intractable and costly nuclear waste issues, and environmental catastrophes.
- ⁵¹ Older Rankings can be found in Wilson B. Goddard, *A Comparative Study of the Total Environmental Costs Associated with Electrical Generation Systems* (G&GE Applied Research, 1997); U.S Congressional Office of Technology Assessment, *Studies of the Environmental Costs of Electricity* (Washington, D.C. September 1994), evaluating Richard Ottinger, et al., Pace University Center for Environmental Legal Studies, *Environmental Costs of Electricity* (New York,: Oceana, 1990), Paul Chernik and Emily Caverhill, "The Valuation of Externalities from Energy Production, Delivery and Use" (Fall 1989); Olave Hohmeyer, *Social Costs of Energy Consumption: External Effects of Electricity Generation in the Federal Republic of Germany* (Berlin: Springer-

Verlag, 1988); Michael Shuman and Ralph Cavanagh, *A Model of Conservation and Electric Power Plan for the Pacific Northwest: Appendix 2: Environmental Costs* (Seattle, WA: Northwest Conservation Act Coalition, November 1982).

- ⁵² Underlying data is from Benjamin K. Sovacool and Michael Dworkin, *Global Energy Justice*, Cambridge University Press, 2014 (Non-GHG, p. 149; GHG, p. 108); Benjamin K. Sovacool, “Exposing the Paradoxes of Climate Change Governance,” *International Studies Review*, 16 (2), 2014; Mark Z. Jacobson, “Review of solutions to global warming, air pollution and energy security,” *Energy Environ. Sci.*, 2, p. 165, 2009; Saeed Hadian and Kaveh Madani, “A system of systems approach to energy sustainability assessment: Are all renewables really green?” *Ecological Indicators* 52, 2015. Sharon J. Klein and Stephanie Whalley, “Comparing the sustainability of U.S. electricity Options through multi-criteria decision analysis,” *Energy Policy*, 79 (2015). BEV=battery electric vehicle; CCS = carbon capture and storage.
- ⁵³ Lovins, *Do coal and nuclear*, pp. 25, 29, notes that the alternatives are cleaner.
- ⁵⁴ The Commission, the Governor, or the NYS Legislature could implement a community and worker protection program to ensure a responsible and effective economic transition for communities and workers impacted by power plant closures. Multiple pieces of New York State energy policy are designed to supplant the state’s current dirty energy resources with new, renewable, and/or distributed resources. The state should recognize this fact and approach it proactively and with a commitment to ensure that workers and communities land on their feet. (Responsive Comments, p. 10)..
- ⁵⁵ See Appendix C, Note 15.
- ⁵⁶ U.S. EPA, Memorandum To: Docket EPA-HQ-OAR-2009-0472, Subject: Economy-Wide Impacts of Greenhouse Gas Tailpipe Standards, March 4, 2010 (hereafter, *Memorandum*).
- ⁵⁷ *Id.*, pp. 3-4. “Lower prices allow for additional purchase of investment goods, which, in turn, lead to a larger capital stock. These price reductions also allow higher levels of government spending while improving U.S. competitiveness thus promoting increased exports relative to the growth driven increase in imports. As a result, GDP is expected to increase because of this rule
- ⁵⁸ See Appendix C, Note 15.
- ⁵⁹ Rachel Gold, et al., *Appliance and Equipment Efficiency Standards: A Money Maker and Job Creator*, American Council for an Energy Efficient Economy, January 2011, “In our experience modeling efficiency investments, we find that re-spending the energy savings typically creates an equivalent number of jobs as implementing the investment.” (p. 2)
- ⁶⁰ Ernst Worrell, John A. Laitner, Michael Ruth, and Hodayah Finman, . “Productivity Benefits of Industrial Energy Efficiency Measures.” *Energy* 28 (2003) identified 70 industrial case studies, with 52 that monetized the benefits., p. 5.
- ⁶¹ The Commission, the Governor, or the NYS Legislature could implement a community and worker protection program to ensure a responsible and effective economic transition for communities and workers impacted by power plant closures. Multiple pieces of New York State energy policy are designed to supplant the state’s current dirty energy resources with new, renewable, and/or distributed resources. The state should recognize this fact and approach it proactively and with a commitment to ensure that workers and communities land on their feet. AGREE/NIRS, Responsive Comments, p. 10
- ⁶² Mark Berkman and Dean Murphy, Brattle Group, *New York’s Upstate Nuclear Power Plants’ Contribution to the State Economy*, prepared for New York State IBEW Utility Labor Council Rochester Building and Construction Trades Council Central and Northern New York Building and Construction, December 2015 (hereafter, Berkman, Upstate Power Plants).
- ⁶³ Lovins, *Do coal and nuclear*, p. 24, notes that decommissioning jobs will be the same whenever the reactors are shut down and do not affect the employment picture in the long-term.
- ⁶⁴ Wei, *Putting Renewables*.
- ⁶⁵ Illinois Commerce Commission, Illinois Power Agency, Illinois Environmental Protection Agency, and Illinois Department of Commerce and Economic Opportunity. *Response To The Illinois General Assembly Concerning House Resolution 1146*. January 5, 2015, p. 150.
- ⁶⁶ Lovins, *Do coal and nuclear*, argues that the jobs claims are little more than climate change blackmail (unsupported by empirical evidence, pp. 23, 28) and that the number decommissioning jobs are unaffected by the timing of plant retirement (p. 24).
- ⁶⁷ Agree/NIRS, The DPS white paper is overly conservative in its projections of renewable generation required to meet the 50% renewable energy goal. This is due principally to significant underestimates in three categories: On-shore Wind ... Off-shore Wind. Residential and Commercial Solar PV... In addition, DPS has greatly underestimated energy efficiency potential, resulting in 2030 electricity load projections that are either too high,

or do not account for achievable levels of electrification in transportation and heating. (Comment, pp. 5-6); no analysis was ever provided to show whether the state can or cannot meet the 2030 goal without some or all of the nuclear reactors that are being proposed for subsidies. This is a key weakness in how the nuclear tier has been approached from the very beginning. (Responsive Comments, p. 6); The nuclear power industry's last hope is to make it seem as though reactors are the only option Upstate jobs, tax revenues, or climate mitigation.... Our analysis below will show that New York has all the tools necessary to increase its energy efficiency and renewable energy targets to accommodate a rapid phase-out of nuclear power while meeting its climate goals. (Comment, p. 5)

- ⁶⁸ Dan Eggers, Kevin Cole, Matthew Davis, *The Transformational Impact of Renewables*, Credit Suisse, December 20, 2013, p. 18., EPA, *Regulatory Impact Analysis*, 2004, Table 3-11, Illinois Commerce Commission, et al., *Potential Nuclear Power Plant Closings In Illinois: Impacts And Market-Based Solutions, Response To The Illinois General Assembly Concerning House Resolution 1146*, January 5, 2015, p. 139.
- ⁶⁹ See Mark Cooper, *Energy Efficiency Performance Standards: Driving Consumer and Energy Savings in California*, California Energy Commission's Energy Academy, February 20, 2014 and the underlying studies including Kenji Takahasi 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).
- ⁷⁰ Berkman and Murphy, *New York's Upstate Nuclear Power Plants*). Synapse submitted a report to the PSC on incorporating an Energy Efficiency Standard (EES) in the CES, in which they modeled a 3% EES, and projected increased load reductions beyond PSC's base case of more than 25TWh/year by 2030 – nearly as much as the subsidized nuclear – at a net cost savings of \$3 billion.
- ⁷¹ AGREE/NIRS, Rehearing Comment, pp. 5-6.
- ⁷² Lovins, *Do coal and nuclear*, argues that alternatives have the ability to meet the need (pp. 22, 26, 27, 29), making extensive reference to the key role of efficiency (p. 24) and notes that extending the life of central station facilities raises the cost of decarbonization (pp. 28-29).
- ⁷³ Under this plan, no other company or resource would be allowed to compete for these subsidies, even if they can offer comparative emissions reductions for lower costs and without the dangers and environmental harm caused by nuclear plants. (Responsive Comment, p. 4). The uncompetitive nature of the nuclear subsidies proposed flies in the face of the rest of the Clean Energy Standard proposal, under which renewable energy providers will have to compete for either power purchase agreements or renewable energy credits (or both). It contradicts the entire framework of the Reforming the Energy Vision, under which utilities are asked to provide competitive opportunities to find the most efficient and affordable ways to avoid large consumer investments in big infrastructure and centralized power plants. And it distorts New York's long-standing competitive wholesale marketplace at a moment that it is finally bringing down costs for consumers. (Responsive Comments, p. 6)
- ⁷⁴ AGREE/NIRS, Rehearing Comments, p. 5.
- ⁷⁵ Gross, Robert, Jonathan Stern, Chris Charles, Jack Nicholls, Chiara Candelise, Phil Heptonstall, and Philip Greenacre. *On Picking Winners: The Need for Targeted Support for Renewable Energy*. London: Imperial College London, 2012, p.18.
- ⁷⁶ Cooper, *Political Economy of Electricity*, Chapter 9; Bianconi, Marcelo, and Joe A. Yoshino. "Risk Factors and Value at Risk in Publicly Traded Companies of the Nonrenewable Energy Sector." *Energy Economics* 45 (2014): 19–32, refer to this as the escalation of commitment. See also Katherine D., Arbuthnott, and Brett Dolter. "Escalation of Commitment to Fossil Fuels." *Ecological Economics* 89 (2013): 7–13; Bloomberg New Energy Finance, *Fossil Fuel Divestment: a \$5 Trillion Challenge*, White Paper, August 2014; Farrar-Rivas, Patricia, and Anders Ferguson. *Emerging Research on Climate Change Risk and Fossil-Fuel Divestment*. Veris, July 2014.
- ⁷⁷ Daron, Acemoglu, Philippe Aghion, Leonardo Bursztyn, and David Hemous. "The Environment and Dedicated Technical Change." *American Economic Review*, 102 (2012), p. 132; Daron, Acemoglu, Akcigit, Ufuk Douglas Hanley, and William Kerr. *Transition to Clean Technology*. Working Paper, Harvard Business School, December 3, 2014.
- ⁷⁸ Gross, et al., *On Picking Winner*.

- ⁷⁹ Gross, et al., *On Picking Winner*, 18; Emanuele, Massetti, and Lea Nicita. *The Optimal Climate Policy Portfolio*. CESifo Working Paper no. 2988, Energy and Climate Economics, 2010, (Hereafter, Massetti and Nicita, *The Optimal Climate Policy Portfolio*). p. 1
- ⁸⁰ Yeuming, Qui and Laura D. Anadon. “The Price of Wind in China During its Expansion: Technology Adoption, Learning-by-Doing, Economies of Scale, and Manufacturing Localization.” *Energy Economics* 34 (2012); Massetti and Nicita, *The Optimal Climate Policy Portfolio*.
- ⁸¹ Antoine Dechezleperre, et al, *Climate Change & Directed Innovation: Evidence from the Auto Industry*. London: London School of Economics and Political Science, 2011.
- ⁸² Michael Grubb, Thierry Chapuis, and Minh Ha Duong. “The Economics of Changing Course: Implications of Adaptability and Inertia for Optimal Climate Policy.” *Energy Policy* 23 (1995): 417–431, p. 428.
- ⁸³ Cooper, *Political Economy of Electricity*, Chapter 9
- ⁸⁴ I., Zelenika-Zovko and J. M. Pearce. “Diverting Indirect Subsidies from the Nuclear Industry to the Photovoltaic Industry: Energy and Financial Returns.” *Energy Policy* 39 (2011): 2626–2632. (Hereafter, Zelemic-Zoyoko and Pearce, *Diverting Indirect Subsidies*)
- ⁸⁵ Enrica De Cian, Samuel Carrara, and Massimo Tavoni. *Innovation Benefits from Nuclear Phase-Out: Can They Compensate the Cost?* Fondazione Eni Enrico Mattei, 2012., p. 14.
- ⁸⁶ Enrica De Cian, Samuel Carrara, and Massimo Tavoni. “Nuclear Expansion or Phase Out? Costs and Opportunities.” *Review of Environment, Energy and Economics*, January 9 2014, p. 1-2.
- ⁸⁷ Cooper, *The Political Economy of Electricity*, pp. 80-85, 220-234, discusses the vastly superior effectiveness of comparatively small subsidies for renewables versus the much larger and less effective subsidies for nuclear.
- ⁸⁸ Marshall, Goldberg, *Federal Energy Subsidies: Not All Technologies Are Created Equal*. Washington, DC: Renewable Energy Policy Project, 2000; Matthew Slavin, “The Federal Energy Subsidy Scorecard: How Renewables Stack Up.” *Renewable Energy World.com*, November 3, 2009.; Kadra, Branker, Michael Pathak, and Joshua M. Pearce. “A Review of Solar Photovoltaic Levelized Cost of Electricity, *Renewable and Sustainable Energy Reviews* 15 (2011) (.” (Branker and Pearce, *Review of Solar*:: 4470–4482; Jeremy, Badcock and Manfred Lenzen. “Subsidies for Electricity-Generating Technologies: A Review.” *Energy Policy* 38 (2010): 5038–5047 (hereafter, (Badcock and Lenzen. *Subsidies for Electricity-Generating Technologies*); Pfund, Nancy, and Ben Healey, 2011, *What Would Jefferson Do? The Historical Role of Federal Subsidies in Shaping America’s Energy Future*. San Francisco, CA: DBL Investors, 2011. (Hereafter, Pfund and Healey, *What Would Jefferson do?*)
- ⁸⁹ BWE, German Wind Energy Association. *The Full Costs of Power Generation: A Comparison of Subsidies and Societal Cost of Renewable and Conventional Energy Sources*. BWE, Berlin, August 2012.; Lucy Kitson, Peter Wooders, and Tom Moerenhout. *Subsidies and External Costs in Electric Power Generation: A Comparative Review of Estimates*. Geneva, Switzerland, 2011; Ann G. Berwick, *Comparing Federal Subsidies for Renewables and Other Sources of Electric Generation*. Massachusetts Department of Public Utilities Massachusetts Solar Summit, June 13, 2012; U.S. GAO. *Federal Electricity Subsidies: Information on Research Funding, Tax Expenditures, and Other Activities That Support Electricity Production*, GAO-08-102. Washington, DC: U.S. Government Printing Office, 2007.; Goldberg, *Federal Energy Subsidies*, Pfund and Healey, *What Would Jefferson do?*.
- ⁹⁰ Badcock, and Lenzen, *Subsidies for Electricity-Generating Technologies*.
- ⁹¹ Zelenika-Zovk and Pearce, *Diverting Indirect Subsidies*, p. 2626,
- ⁹² Badcock and Lenzen, *Subsidies for Electricity-Generating Technologies*, Branker and Pearce, *Review of Solar*.
- ⁹³ Lovins, *Do Coal and Nuclear*, p.25.
- ⁹⁴ *Ibid.*, p. 2.
- ⁹⁵ Various aspects of the history are reviewed in a series of papers including, Mark Cooper, “Nuclear Safety and Affordable Reactors: Can We Have Both?,” *Bulletin of the Atomic Scientists*, 68, 2012 and “Nuclear Safety and Nuclear Economics, Fukushima Reignites the Never-ending Debate: Is Nuclear Power not worth the risk at any price?,” *Symposium on the Future of Nuclear Power*, University of Pittsburgh, March 27-28, 2012, for an analysis of the problems of the first round of nuclear reactor development; *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Power Sector* (Santa Barbara, Praeger, 2017). For a discussion of the development of lower cost alternatives; *The Economics of Nuclear Reactors: Renaissance or Relapse*, Institute for Energy and the Environment, Vermont Law School, June 2009, “Nuclear Aging: Not so gracefully,” *Bulletin of the Atomic Scientists*, 69, 2013; on the pattern of cancellations, abandonments and early retirements, in the 20th century; *Renaissance in Reverse: Competition Pushes Aging U.S. Nuclear Reactors to the Brink of Economic Abandonment*, July 2013; on the pressures placed on aging reactors by recent developments.

- ⁹⁶ Lovins, Amory B., and Rocky Mountain Institute. *Reinventing Fire: Bold Business Solutions for the New Energy Era*. Boulder, CO: Rocky Mountain Institute, 2011, p. 216) had earlier elaborated on the deep-seated sources of conflict between nuclear power and the alternatives, making it clear that a truce that tries to accommodate both sides is neither very likely, nor good policy. “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% less than comparable U.S. systems, despite access to the same modules and other technologies at the same global prices.”
- ⁹⁷ It is important to note here that the Jacobson long term analysis of a 100% renewable sector in New York, excludes nuclear power and increases in hydro.” These assumptions are consistent with the AGREE/NIRS comments and the approach taken by policy in New York, before the imposition of large nuclear subsidies.
- ⁹⁸ U.S. Department of Energy, *Wind Vision*, xxiii.
- ⁹⁹ U.S. Department of Energy, *Wind Vision*, xlii.
- ¹⁰⁰ U.S. Department of Energy, *Wind Vision: A New Era for Wind Power in the United States*, 2015, p. 90, citing M. Milligan et al., *Impact of Electric Industry Structure on High Wind Penetration Potential*, NREL, July 2009, p. 23
- ¹⁰¹ Amory Lovins, An initial critique of Dr. Charles R. Frank, Jr.’s working paper “The Net Benefits of Low and No-Carbon Electricity Technologies,” summarized in *The Economist* as “Free exchange: Sun, Wind and Drain,” Rocky Mountain Institute, August 7, 2014;
- ¹⁰² Jim Lazar, *Teaching the “Duck” to Fly*, Regulatory Assistance Project, January 2014. Needless to say, there are many other general analyses of the possibility and benefits to aggressively integrating renewable supply and demand in the long term. The RAP analysis provides a clear, concrete basis for translating these benefits into cost analysis of presently deployed systems.
- ¹⁰³ 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, (hereafter, Mills and Wiser, *Strategies for Mitigating*), p. 17
- ¹⁰⁴ The LBNL study shows the ratio as high as 3-to-1, and cites (p. 14) a similar study for ERCOT, which put the ratio at 2.33-to-1. Other studies have arrive at ratios that favor solar, when that resource is richer.
- ¹⁰⁵ Mills and Wiser, *Strategies for Mitigating*, 19.
- ¹⁰⁶ *Ibid.*, p. 19.
- ¹⁰⁷ *Ibid.*, p. 2, We conclude that the costs of managing the short-term variability of PV are dramatically reduced by geographic diversity and are not substantially different from the costs for managing the short-term variability of similarly sited wind in this region. Michael Milligan et al., *Wind Power Myths Debunked: Common Questions and Misconceptions*, *IEEE Power & Energy Magazine*, 2009, The incremental balancing costs caused by wind are 10% or less of the wholesale value of the wind power... The experience of countries and regions that already have quite a high wind penetration (from 5% to 20% of gross electric energy demand) has been that there existing reserves are deployed more often after wind power is added to the system, but no additional reserve capacity is required.
- ¹⁰⁸ 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. . . . 5. Promising technologies, storage (Solar thermal with energy storage, Pumped storage, Other forms of energy storage including battery storage, Electric vehicle charging, Thermal energy storage). . . . 6. Flexible loads that can increase energy demand during daylight hours (Advanced demand response and flexible loads). . . . 7. Sub-five minute operations. . . . 8. Size of potential export markets for excess energy from California. . . . 9. Transmission constraints. . . . 10. Changing profile of daily energy demand. . . . 11. Future business model for thermal generation and market design. . . . 12. Optimal thermal generation fleet under high RPS.” (pp. 31–35)
- ¹⁰⁹ 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:

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- 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).
- ¹¹⁰ AEMO, *100 Percent Renewables Study: Modelling Outcomes*, AEMO, July 2013; Elliston, MacGill, and Diesendorf, 2013, “Least Cost 100% Renewable Electricity Scenarios.”
- ¹¹¹ Australian Energy Management Organization, 2012, 14, for 2011 consumption, 18 for technical potential, 22 for projected economic potential.
- ¹¹² *Id.*, p. 34.
- ¹¹³ Peerapat Vithayasrichareon, Jenny Riesz, and Iain F. MacGill, “Using Renewables to Hedge Against Future Electricity Industry Uncertainties—An Australian Case Study,” *Energy Policy* 76 (2015), 43. Lynette Molyneaux et al., *Australian Power: Can Renewable Technologies Change the Dominant Industry View?* Paper presented at the Australian Solar Energy Society Conference, Melbourne, December 2012. **The results indicate that a transition to gas fired generation reduces emissions only marginally and that wholesale prices will be higher than the renewable energy option.**
- ¹¹⁴ U.S. Department of Energy, *Wind Vision*, xv.
- ¹¹⁵ Shrimali, Lynes and, Indvik, “Wind Energy Deployment,” 454, “The complementary characteristic of battery (large energy density for long term storage, but low power density, low charge and discharge efficiency) and super-capacitor (low energy density, but high power density, fast charge and discharge rate) has . . . revealed that, the hybrid of the duo can optimize the battery charge and discharge process, thereby . . . can extend system lifetime by 62% and reduce the cost of energy storage system by 41%. . . . A suitable energy storage device combined with wind turbines, can firm and shape wind power output, transforming the wind generation into a firm and predictable energy source. . . . However, no single storage technology can meet up with all the criteria. Thus hybrid storage technology is being explored as a potential solution.” 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: “A micro grid can be defined as a part of the grid consisting of prime energy movers, power electronics converters, distributed energy storage systems, and local loads. This makes the electrical network more flexible and intelligent. Micro grids and virtual power plants (VPPs) are two low voltage distribution network concepts that can participate in active network management of a smart grid. They are becoming an important concept to integrate distributed generation (DG) and energy storage systems.”
- ¹¹⁶ EIA, 2013, *Assessing the Economic Value of New Utility-Scale Electricity Generation Projects*, Workshop Discussion Paper: LCOE and LACE, July, p. 1.
- ¹¹⁷ EIA, 2017, *Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2017*, p.3 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).⁶ The LACE value may then be compared with the LCOE value for the candidate project to provide an indication of whether or not the project’s value exceeds its cost. If multiple technologies are available to meet load, comparisons of each project’s LACE to its LCOE may be used to determine which project provides the best net economic value. Estimating avoided costs is more complex than estimating levelized costs because it requires information about how the system would have operated without the option under evaluation. In this discussion, the calculation of avoided costs is based on the marginal value of energy and capacity that would result from adding a unit of a given technology to the system as it exists or is projected to exist at a specified future date and represents the potential value available to the project owner from the project’s contribution to satisfying both energy and capacity requirements
- ¹¹⁸ EIA, 2013, *Assessing the Economic Value of New Utility-Scale Electricity Generation Projects*, Workshop Discussion Paper: LCOE and LACE, July, p. 1.
- ¹¹⁹ Johnson, Nils 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*. 64 230 (hereafter, Johnson, et al., A reduced form approach). “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..

- ¹²⁰ 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. If properly defined, the ‘system cost’ of VRE (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
- ¹²¹ 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. For political decision-making, the comparison of total system costs in different scenarios can be a more appropriate tool. Unfortunately, various methodological challenges persist, most importantly how to define system boundaries and how to consider externalities. Yet establishing a relevant and transparent analysis is much easier, as is the discussion of key sensitivities and implications. In the following, we describe an approach for comparing scenarios with high and low shares of renewables.... Each of these scenarios must be equal from a technical point of view. That is to say, the same level of security of supply (i.e. loss of load expectation) must be achieved and all components should be reasonably adapted to the respective mix of renewable energies. Based on an initial definition of costs, which may or may not include the costs of externalities, the total costs for power generation are calculated for each scenario. This must include costs for power generation by renewable and non-renewable technologies as well as all costs for grids and for the balancing of supply and demand
- ¹²² This is consistent with Karier, Tom and John Fazio, 2017, “How hydropower enhances the capacity value of renewables and energy Efficiency,” *The Electricity Journal* 30, Table 3 shows efficiency with much higher capacity values than natural gas. Karier and Fazio show efficiency with a 50% capacity advantage over gas and a 11% standalone advantage over 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 value suggest efficiency is a 1 on capacity and a zero on efficiency penalty.
- ¹²³ 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*, 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.
- ¹²⁴ The disruption of the transformation is one of the most important harms of extending the life of central station facilities note by Lovins, *Do coal and nuclear* (pp. 26, 28, 29).
- ¹²⁵ Comment, p. 6.
- ¹²⁶ David W. Pearce, *The MIT Dictionary of Modern Economics* (Cambridge, MA: MIT Press, 1984), 342. Wikipedia refers to Smith as “a pioneer of [political economy](https://en.wikipedia.org/wiki/Adam_Smith).” (https://en.wikipedia.org/wiki/Adam_Smith);
- ¹²⁷ Thomas Piketty, *Capital in the Twenty-First Century*, trans. Arthur Goldhammer (Cambridge, MA: Belknap, 2014), 574.
- ¹²⁸ *Id.*, Chapter 2.
- ¹²⁹ *Id.*, Chapter 5.
- ¹³⁰ *United Nations Framework Convention on Climate Change*, 1992 (hereafter UNFCCC). *21st Conference of the Parties*, 2015, (Paris Agreement).
- ¹³¹ Cooper, *The Political Economy*, Chapr 4.
- ¹³² This was the central theme frame in Chapter 1 and the Epilogue of Cooper, *The Political Economy of Electricity*.
- ¹³³ Cooper, *The Political Economy of Electricity*, pp. 5-6.
- ¹³⁴ Joseph Stiglitz, “Phony Capitalism,” *Harper’s Magazine*, September 2014 (hereafter, Stiglitz, *Phony Capitalism*).
- ¹³⁵ Stiglitz, “Phony Capitalism”; because inequality is a central source of dynamism and tension in the capitalist mode of production, Piketty’s analysis (*Capital in the 21st Century*) has elicited strongly critical reactions from right to left. From the perspective of the theory adopted in this paper, in addition to Stiglitz’s critique based on policy, Acemoglu and Robinson (“General Laws of Capitalism”) have pointed out the absence of institutional analysis and critical process of endogenous technological change. Nuno Ornelas Martins (*Inequality, Sustainability and Piketty’s Capital*, Catholic University of Portugal, Economic Working Papers, No. 5, 2014) notes the marginalist assumptions; Philippe Aghion et al., *Innovation and Top Income Inequality*, NBER

Working Paper No. 21247, June 2015, present a confirmation of the Schumpeterian hypothesis on rewards to innovation.

¹³⁶ Stiglitz, “Phony Capitalism.”

¹³⁷ Ibid., 119.

¹³⁸ Ibid., 117

¹³⁹ Ibid., 117.

¹⁴⁰ Ibid., 120, “growth faltered in the 1970s with the two oil shocks and the collapse of the Bretton Woods system. These conditions ushered Margaret Thatcher into power in the UK in 1969, and Ronald Reagan in the US in 1970, with a corresponding change in political philosophy.”

¹⁴¹ Ibid., 125. the last decade, the left-leaning government in the UK has enlarged the state, and has further extended its reach following the global financial crisis which served as a reminder that asset markets are subject to booms and busts and are not self-regulating. Greenspan, risk in financial markets are regulated by private parties,”

¹⁴² Ibid., 120.

¹⁴³ Ibid., 122.

¹⁴⁴ Ibid., 117.

¹⁴⁵ Mark Cooper, Director of Research, “Comments of the Consumer Federation of America,” In the matter of Request for Information on Reducing Regulation and Controlling Regulatory Costs, Before the U.S. Department of Energy, E.O. 13771, 13777, 13783, July 14, 2017, p. 3. I have identified these characteristics in the study of standards in a broad range of goods not limited to energy consuming durables (including light duty vehicles, heavy duty trucks, to gas furnaces) but also other goods computers and services (see Mark Cooper, “Command But Not Control: Progressive Capitalism and Regulatory Institutions for the Third Industrial Revolution: The Paris Agreement on Climate Change,” *Session on Regulation and Industry Structure The Digital Broadband Migration: The Evolving Industry Structure of the Digital Broadband Landscape*, 2016). Mark Cooper, 2014, *Energy Efficiency Performance Standards: Driving Consumer and Energy Savings in California*. Presentation at the California Energy Commission's Energy Academy, February 20, 2014; 2013; *Energy Efficiency Performance Standards: The Cornerstone of Consumer-Friendly Energy Policy*, Consumer Federation of America, October 2013. See Mark Cooper, 2017, *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Power Sector*, (Praeger), Chapter 7 and Appendix II for a more recent comprehensive review.

¹⁴⁶ Popp, Newell, and Jaffe, “Energy, the Environment, and Technological Change,” 877: “The generation of knowledge through the innovative process contrasts sharply with the negative externalities from pollution. Because of the public goods nature of knowledge, a firm that invests in or implements a new technology typically creates benefits for others while incurring all of the costs. The firm therefore lacks the incentive to increase those benefits by investing in technology. . . . Technology creates positive externalities, and so the invisible hand of the market produces too little of it.”

¹⁴⁷ Marianne Lavelle, “Green New Deal vs. Carbon Tax: A Clash of 2 Worldviews, Both Seeking Climate Action: The contest is elevating climate policy conversations on the campaign trail and in Washington. It could inspire compromises that bring together pieces of each,” *Inside Climate News*, March, 4, 2019

¹⁴⁸ Ryan Avent, “Creating the Clean Economy.” *The Economist*, June 11, 2011 Avent, “Creating the Clean Economy.”

¹⁴⁹ Ibid.

¹⁵⁰ David, Leonhardt, David. “There’s Still Hope for the Planet.” *New York Times*, July 21, 2012. Most scientists and economists, to be sure, think the best chance for success involves both strategies: if dirty energy remains as cheap as it is today, clean energy will have a much longer road to travel. . . . Still, the clean-energy push has been successful enough to leave many climate advocates believing it is the single best hope. . . . Governments have played a crucial role in financing many of the most important technological inventions of the past century. That’s no coincidence: Basic research is often unprofitable. It involves too much failure, and an inventor typically captures only a tiny slice of the profits that flow from a discovery.

¹⁵¹ Ibid., p. 675.

¹⁵² Roger Noll, “Comment,” *Energy Economics* 33 (2011), 683. Nordhaus, William. “Designing a Friendly Space for Technological Change to Slow Global Warming,” *Energy Economics* 33 (2011), represented the market side, but even he accepted the proposition that much more than price policy is necessary. Weyant, John P. “Accelerating the Development and Diffusion of New Energy Technologies: Beyond the Valley of Death.” *Energy Economics* 33 (2011): 674–682, represented the more activist side.

¹⁵³ Roger Noll, “Comment,” p. 683.

¹⁵⁴ Ibid., . 685.

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- ¹⁵⁵ Acemoglu et al., “The Environment and Dedicated Technical Change,” *American Economic Review* 102 (2012), p. 132.
- ¹⁵⁶ Gross et al., *On Picking Winners*.
- ¹⁵⁷ Ibid., p. 11. Ian Temperton, “Dining Out on Electricity Market Reform with Kylie, the Tooth Fairy and a Spherical Horse in a Vacuum,” *Climate Change Capital*, 2012.
- ¹⁵⁸ Gross et al., *On Picking Winners*, p. 12.
- ¹⁵⁹ Steve Clemmer, et al., *The Nuclear Power Dilemma: Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions*, Union of Concerned Scientists, November 2018 (hereafter, UCS).
- ¹⁶⁰ A robust, economy-wide cap or price on carbon emissions would address a key market failure and provide a level playing field for all low-carbon technologies. A national carbon cap or price could achieve the greatest carbon reductions for the lowest cost, but states can also adopt such policies. (UCS, 2018, p. 7)
- ¹⁶¹ A national carbon cap or price could achieve the greatest carbon reductions for the lowest cost, but states can also adopt such policies. (UCS, 2018, p. 7)
- ¹⁶² On average, projected operating costs exceed revenues between 2018 and 2022 for 16 nuclear plants in addition to five plants scheduled for retirement. These 21 plants accounted for 22.7 gigawatts (GW) of operating capacity in 2018. The annual average cost of bringing unprofitable plants to the breakeven point is \$814 million, for a total of more than \$4 billion over five years. (UCS, 2018, p. 2)
- ¹⁶³ UCS puts the cost at \$4 billion for five years. Tim Judson, *Too Big to Bail Out: The Economic Costs of a National Nuclear Power Subsidy*, NIRSNET, November 2016, p. 1, calculates a ten year cost at the New York rate, if subsidies are not carefully targeted, of \$280 billion. With targeting to only “unprofitable” reactors the 10 year figure is \$160 billion. Dividing in half (to adjust to 5 years), yields a figure of \$80 billion. The UCS subsidy rate is about 30% of the New York rate estimated by NIRS rate, which would yield a five year figure in an adjusted NIRS framework of \$24 billion, still eight times as high. Deciding which reactors need a subsidy and how big it should be is a critical step, one which the Aging Reactors Subsidy Program failed to take.
- ¹⁶⁴ Require plant owners to open their financial books and demonstrate need. Limit and adjust financial support for unprofitable nuclear plants (UCS, 2018, p. 8)
- ¹⁶⁵ New York also has combined an LCES with a zero-energy credit program to provide financial support only to existing nuclear plants that need it, with support adjusted as market conditions change. Along with an LCES, states should adopt complementary policies that encourage investments in energy efficiency. (UCS, 2018, p. 7)
- ¹⁶⁶ UCS complains that the NRC is being urged by the industry to adopt changes to reporting that “would effectively render it meaningless” and expresses the naïve belief,” although US reactor owners and the NEI have been pressuring the NRC for decades to reduce inspections and weaken safety and security standards. (UCS, 2018, p. 7)
- ¹⁶⁷ UCS, 2018, p. 8.
- ¹⁶⁸ UCS, 2018, p. 8.a
- ¹⁶⁹ Cooper, *The Political Economy*, p. 7.