Consumer Federation of America

Building a 21st Century Electricity Sector with Efficiency, Distributed Resources and Dynamic Management:

The Consumer, Economic, Public Health and Environmental Benefits

Mark Cooper
Director of Research

April 2021

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This paper argues that the infrastructure bill proposed by the Biden Administration has taken an important first step toward building a modern energy system, particularly in the electricity sector, This sector will be the core of the 21st century economy based on efficiency and renewable alternatives that create a low cost, low carbon, low pollution sector, which will create millions of new jobs and distribute them more equitably across the country.

Chapter 2 examines the technological revolutions that have taken place over the past quarter century. These revolutions, many of them led by Americans, have resulted in a bundle of alternative technologies that are least cost in the long term and cost competitive in the short term. Pursuing this transformation will result in costs that are much lower than current central station technologies fueled by natural gas, coal and nuclear power.

Chapter 3 examines projections for future costs of the four key supply side technologies that combine to make up a dynamic, integrated system: efficiency, wind, solar, and batteries. The cost trends for these suggest they will enjoy an increasing advantage. The historical path of digital communications and computing capacity which are essential in the integration of a dynamically, flexible system, reinforce this advantage.

Chapter 4 evaluates whether the resources are sufficient to meet the need and describes the tools that will be used to operate the system to ensure reliable supply. At a practical level it shows many nations have moved far ahead in this transformation without suffering significant system management problems.

Chapter 5 asks whether the transformed system, which is clearly superior economically, is also the best way to respond to the policy objectives being pursued. Five different perspectives: decarbonization, the rate and distribution of macroeconomic growth, job creation, public health, the environment, and public opinion, strongly support efficiency and renewables as the approach to meeting energy needs.

CONCLUSION

The challenge of building the physical and institutional infrastructure to support the 21st century alternative in the electricity sector are great, but so too are the rewards. Because the transformation is a process, we must be cautious in projecting benefits, but even a cautious approach to calculating benefits shows the superiority of the transformation.

The immediate impact will be to create jobs in the development and deployment of the alternatives, including system management.

- Efficiency will lower bills and deliver a mounting “respending” of the benefits.
- Over time the transformation dividend will be realized as the size of the system shrinks and the diversification and wide distribution of resources takes place.

- The full benefit will come as large, costly, central station facilities are replaced with lower cost alternatives.
    - In the long term, with replacement of all current generation, the cost savings on electricity would be over 8% of the current bill, including the transformation dividend.
    - The macroeconomic multiplier would add indirect benefits of about 7.5%.

The decarbonization and public health benefits will also be emergent as carbon emissions and pollution are reduced.

- Our analysis of energy efficiency, before carbon was an issue, puts these benefits of reduced pollution at about one-quarter of the total economic benefit, equal to about 4% of the energy bill
- The benefits of decarbonization depend on the value placed upon it. To stay within the framework of current analysis, we use Lazard's estimate of the cost of carbon ($30/ton) and the value of reduction through alternatives, identified in Figure 13.

Given the above assumptions and findings we can provide a minimum hypothetical estimate of the annual benefits per household, once the electricity system has been fully transformed into one based on efficiency, distributed renewables and dynamic integration of supply and demand. The total is at least $500 per household and could be over $1,500 when reductions in technology costs, multipliers and increases in the value of reduced pollution are taken into account.

1. BACKGROUND

PURPOSE AND APPROACH

The Consumer Federation of America wrote a letter to all the senior officials in the Biden Administration involved in the energy aspects of the infrastructure bill arguing that it has taken an important first step toward building a modern energy systems, particularly in the electricity sector,. This sector will be the core of the 21st century economy.[1] Because the electricity sector is so central to the 21st century economy, and the reduction of carbon emissions not only in the sector itself, but also to the transportation sector through the electrification of the vehicle fleet, we use the concept of the transformation of the electricity sector and the energy sector interchangeably throughout this analysis.[2] Electricity and transportation account for over half of U.S. greenhouse gas emissions. Heating and cooking in the commercial and industrial sectors, which would be deeply affected by the efficiency and cost changes described in the following discussion, could significantly reduce greenhouse gas emissions in these sectors. In total, the transformation of the electricity sector to a low-cost, low carbon sector could account for a reduction of two-thirds of total U.S. emissions.

In our letter, we pointed out that because of a series of technological revolutions, most of them led by Americans. in the past quarter century, the Biden administration is seizing the opportunity to rapidly transform the electricity sector into a low cost, low carbon, low pollution sector that creates millions of new jobs and distributes them more equitably across the country.

To do so, it must center the sector and focus its effort on:

1) increasing reliance on efficiency in consumption,

2) expanding distributed resources like onshore wind and large scale utility and community solar,

3) that are integrated in a dynamic, intensely managed system using digital communications and computing to link to advanced control technologies.

This paper provides a brief overview of the analytic basis for these conclusions. It is based on an update of the extensive analysis of two lengthy documents first published in 2017.

- The bulk of the supply-side analysis was presented in *The Political Economy of Electricity: Progressive Capitalism and the Struggle to Build a Sustainable Power Sector,*[3]
- The demand side analysis was presented in *Trump's Two Trillion Dollar Mistake: The "War on Energy Efficiency," The "command-but-not-control" approach of fuel economy and energy efficiency performance standards delivers consumer pocketbook savings, grows the economy and -protects public health.*[4]

As suggested by the above titles, we view the transformation of the energy sector as much more than an environmental policy. While environmental benefits are substantial, and decarbonization is the proximate motivation for the policy, the broader consumer pocketbook and economic benefits are much larger than the decarbonization, other public health and environmental benefits. All the benefits are important, but it is the economic benefits that mark this as a major technological revolution and make the case for transformation compelling.

In the four years since we reached those conclusions, the evidence supporting them has continued to mount in crucial aspects. The cost of alternatives has continued to plummet, while the cost of natural gas, and coal (particular with carbon capture) and nuclear power continue to be high. Confidence in the ability to manage a grid based on alternatives, distributed energy, and intense management has been demonstrated and has continued to grow at the conceptual and practical levels. Lower cost alternatives are increasingly more available and their ability to reliably meet demand has been demonstrated.

Because the transformation of the energy sector is so important in so many aspects, reduction of the reliance on fossil fuels is only part of the solution. Shifting the basis of the electricity sector from one based on large, inflexible, central station facilities (powered by gas, coal and nuclear), to one based on smaller, distributed flexible resources dynamically integrated is the other (and most important) part of the solution. This paper demonstrates not only the superior cost and environmental impact of the 21st century system, but also addresses the many tools available to ensure that the supply of electricity will be sufficient and reliable.

In making the case for the transformation, we must contrast the 21st century system to the structure that dominated the 20th century. The fuels on which the 20th century electricity sector were based could claim, or be reinvented, to achieve low carbon status, but they would still be expensive and less flexible, stimulating much less widely distributed economic growth and imposing much higher environmental and public health costs and risks.

Thus, in describing the positive aspects of the transformation of the 21st century electricity sector, we must not allow the 20th century approach to distract policy form the urgent need to transform the electricity sector. The alternatives are vastly superior today and should be the focal point of policy and markets. We believe that the alternatives will carry the electricity sector to the finish line, but even if some low carbon approaches based on traditional fuels are necessary to fill any shortfalls, it would be a mistake to allow them to frustrate the rapid transformation of the sector in the near and mid-term . If generation using these fuels, which are uneconomic today, are needed in two or three decades from now, the technologies on which they are based will be far more friendly to consumers, the economy and the environment because they will have to comply with the new rules of the 21st century system and will have been subject to the rigors of market tests.[5]

While this document reviews broad historical and national trends, citing much of the literature on technologies which is general and global, it refers to other advanced industrial democracies to highlight key findings. In addition, for some important points, analysis of individual states which have been presented in regulatory and legislative proceedings is brought forward to demonstrate what is achievable across the nation. Moreover, this is a first sweeping overview of the issues, many of which will be examined in much greater detail in future analyses.

OUTLINE

Given the economic orientation of this paper, we begin in Chapter 2 with the basic question, what are costs of decarbonizing the electricity sector? The analysis clearly shows that the least cost approach to the long term transformation of the sector is to shift to reliance on efficiency and two primary renewables, utility photovoltaic solar (utility PV) and onshore wind.

Projections of costs are discussed in Chapter 3. They show that the advantage of the alternatives are likely to increase in the mid-term.

Chapter 4 addresses equally important questions, are the resources available adequate to meet need and what tools can be used to ensure reliable power?

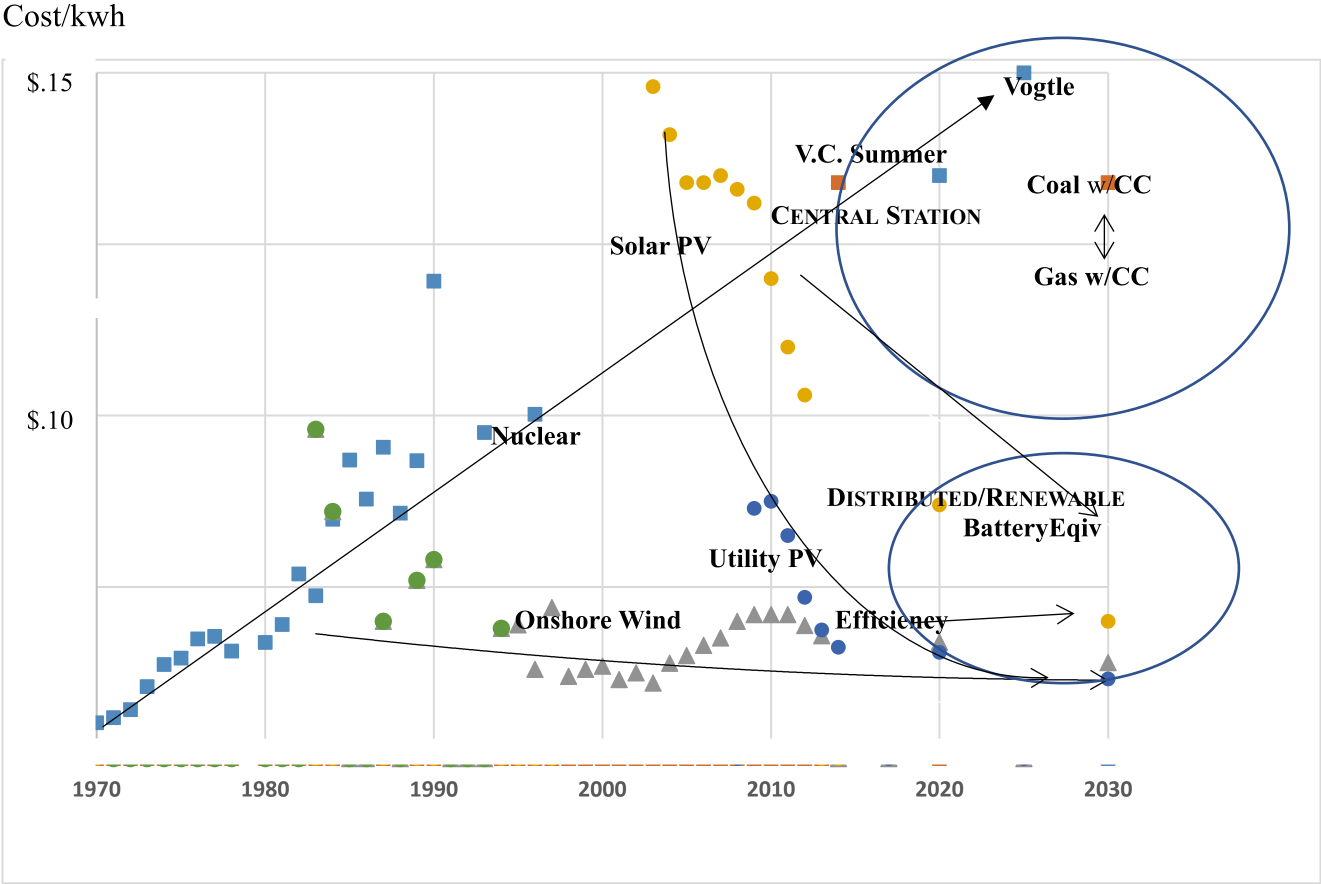
Chapter 5, then explores the other benefits and costs in terms of specific goals, decarbonization, economic policy, and enhancing public health. It shows that reliance on the key resources in the 21st century system also becomes the least cost approach for achieving these policy goals.

2. THE ECONOMIC ADVANTAGE OF THE ALTERNATIVES CREATES THE OPPORTUNITY TO TRANSFORM THE ELECTRICITY SYSTEM

TECHNOLOGICAL REVOLUTION: OPPORTUNITY TO TRANSFORM ELECTRICITY SECTOR

The potential transformation of the electricity system has been created by technological revolutions that have occurred over the past three decades. This revolution has resulted in a dramatic decline in the cost of alternative resources, as shown in Figure 1.[6]

FIGURE 1:
BROAD, LONG-TERM RESOURCE COST TRENDS



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

The cost of solar has been and is projected to decline about 5 percent per year in the 30 years from 2000 to 2030, with the key drop coming with the introduction of utility photovoltaics (PV). The cost of wind is estimated to decline by over 2 percent per year for the 50-years between 1980 and 2030. In contrast, the cost of nuclear power has increased by almost 3 percent per year over that same 50-year period. Cost trends in the decade since the publication of the data, on which the data in Figure 1 are based, reinforce and magnify those cost changes, as discussed below.

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

It is also clear that the cost of efficiency, the use of technologies to lower energy consumption and therefore the cost of operating energy consuming durable goods, has remained low for decades and there is every indication that the cost of efficiency is not rising. In fact, the cost of energy efficiency has exhibited a similar pattern for several decades. Vast quantities of energy can be saved at a very low cost, with the economically attractive opportunities expanding as new technologies convert what was known as "technical potential" into "economically attractive."

As shown in Table 1, the link between electricity consumption and economic growth has been broken. In contrast to the three decades after World War II (1950-1980) where electricity consumption per dollar of per capita GDP grew by almost 3 percent, the figure was flat between 1980 and 1995, and declined by 2 percent per year between 1995 and 2019.

TABLE 1:
ANNUAL CHANGE IN U.S ELECTRICITY GENERATION PER DOLLAR OF GDP PER CAPITA

Period	Annual % Change		Electricity/	
	Electricity	GDP/capita	GDP/capita	
1950-1980	+6.4	+3.5	+2.89	
1980-1995	+1.9	+2.2	-0.000	\
1995-2019	+1.3	+3.3	-2.0	

Source: U.S. Energy Information Administration, *Monthly Energy Review,* various, and; ***US Real GDP by Year,*** **http://www.multpl.com/us-gdp-inflation-adjusted/table.**

CURRENT COSTS

Supply-Side

The broad historic cost trends establish the general context for the potential transformation of the electricity system. More relevant for the policy choices at hand are the current costs and projections for costs in the mid-term. We begin the analysis with an update of the long-run cost of acquiring resources to meet demand (see the upper graph of Figure 2).

The analysis should begin with the long run costs because that is where the electricity sector will end up. Short-run costs matter too, especially if they differ dramatically from long-run costs. If such a difference exists, then a trade-off must be made between short-run and long-run costs. It turns out, as shown in the lower graph of Figure 2, that with respect to electricity resources at present, there is no difference and no need to make a trade off. The alternatives are competitive with the existing resources in the short run, while they enjoy a substantial long run advantage. Therefore, selecting resources that minimize long-term costs are the same as resources selected to minimize short term costs.

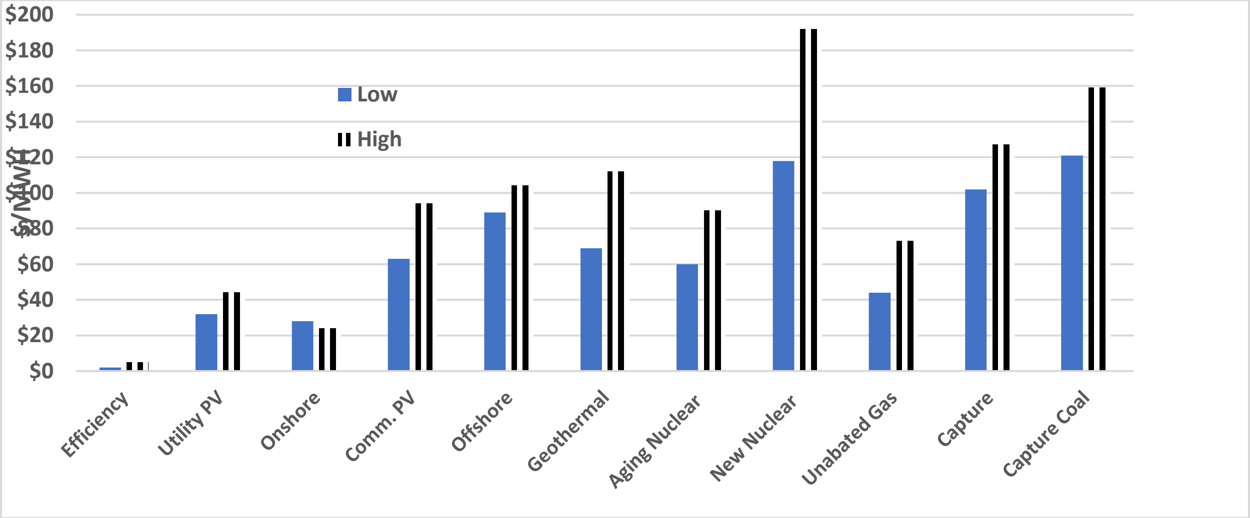
I use the electricity analysis of a Wall street financial analysis firm, Lazard here,[7] as I have done since their first publication of levelized energy costs, over a decade ago for a number of reasons.

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

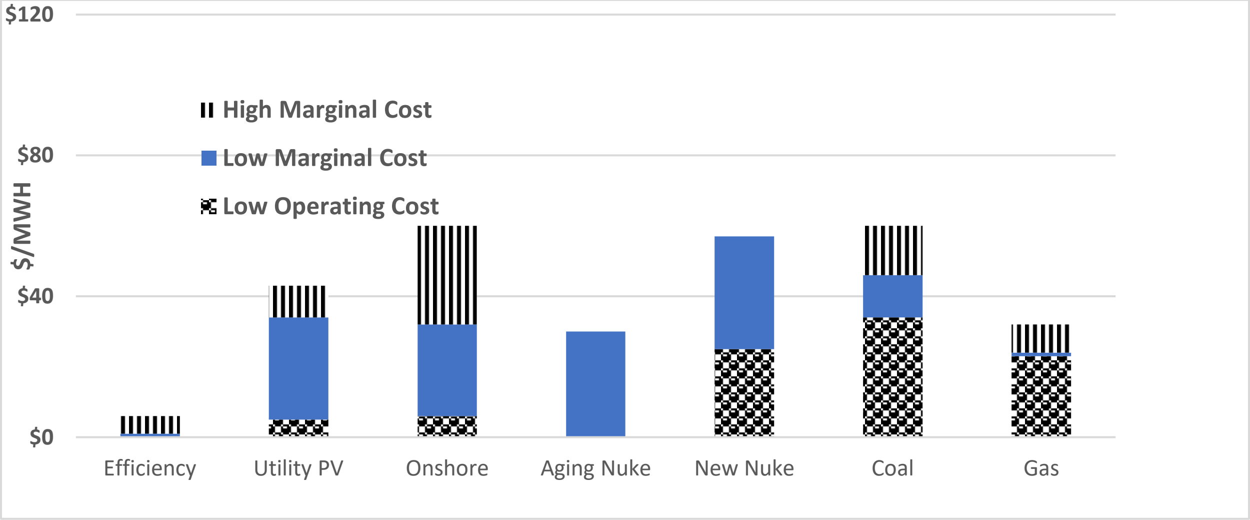
The economic dynamics of the electricity sector at the start of the 21st century have put immense pressure on nuclear power and central station generation in the United States and globally, pressure that ultimately falls on aging reactors. As Figure 2 shows, with respect to long-run costs, at present the three main resources on which the 21st century electricity system relies – efficiency, onshore wind, and utility photovoltaics – are projected to be considerably lower in cost than central station generation, even without taking the reduction of pollution and carbon emissions into account.

FIGURE 2:
COST OF RESOURCES

Long Term Costs



Short Term Costs Per MWh



Source: Lazard, *Lazard's Levelized Cost of Energy Analysis – Version 14.0,* October 2020, Long Terms Costs are from "Levelized Cost of Energy Key Assumptions. Lazard's Levelized Cost of Energy Resources – Version 14.0, with efficiency from Version 9.0, and gas carbon capture from Version 8.0. Low capture costs reflect the utilization rates that that are used in the low estimate of unabated costs (83% for coal and 70% for gas). Low cost for aging reactors is the operating cost subsidy they have demanded, while the high cost estimate include capital cost recovery. . Short term costs are from LZARD, Levelized Cost of Energy Comparison -- Renewable Energy Versus Marginal Cost of Selected Existing Conventional Generation," and Levelized cost of Energy Components – Low End," for low operating costs.

There is a one assumption implicit in Lazard's analysis that leads to an underestimation of the cost of traditional central station technologies. As is the case with almost all cost estimates, Lazard uses a high capacity factor for all three of the traditional technologies, which is well above the actual average observed in the U.S. As a result, costs are underestimated. Lazard also does not consider larger system costs, which will decline as large units, that need big backup are replaced and a closer fit of supply and demand is achieved. We call this the transformation dividend that is equal to 10% - 20%.

A similar conclusion emerges from the short-term analysis shown in the lower graph of Figure 2. Lazard compares the full cost of new build wind or solar to the marginal cost of existing conventional generation. This is a very demanding comparison, since it is a comparison of all-in costs for alternatives to marginal costs for central station technologies. Nevertheless, the conclusion Lazard reaches is that "certain renewable energy generation technologies have an LCOE [levelized cost of electricity] that is competitive with the market cost of existing conventional generation.[8]

To give a sense of a comparison that is "apples-to-apples," marginal cost for all types of resources, I have included the estimate of the operating cost provided in the long-run analysis. Needless to say, renewables are very attractive. I have also included the cost of operating aging reactors as expressed in recent subsidy proceedings, at only their cost of operation. Necessary capital costs would increase their total near-term cost by almost 50%. I also note external costs, which should be included in the short term analysis, since there are emissions. The point is that the short-term comparisons are not at odds with the long-term results. Since the alternatives are least cost in the long term and competitive in the short term there is no tradeoff necessary. The alternatives are preferable.

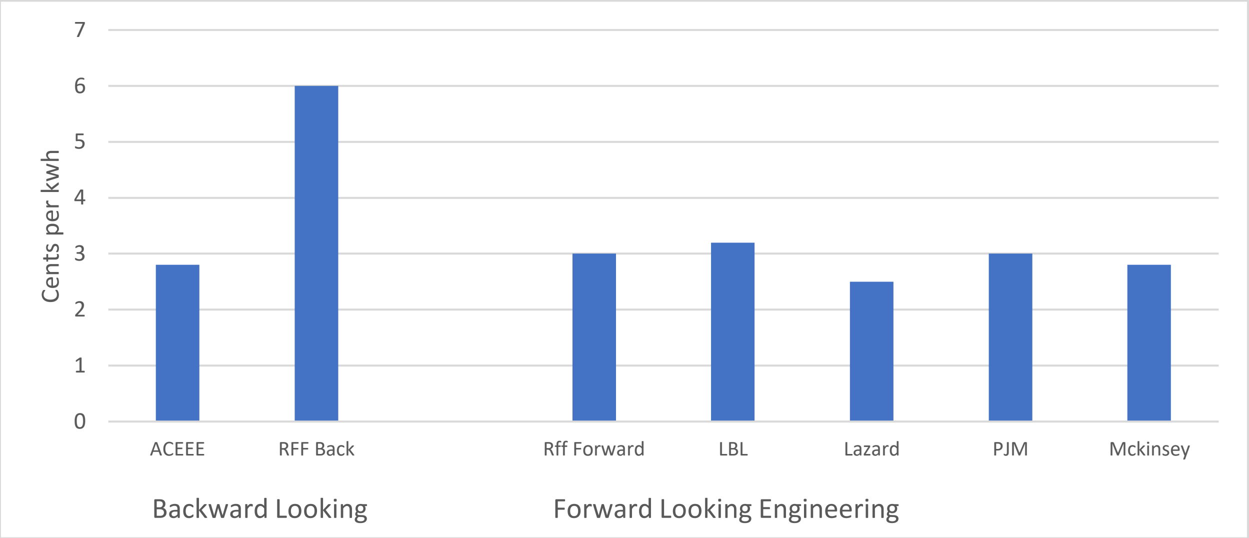
Demand Side

While the dramatic decline in supply-side costs has recently captured a great deal of attention, because the declines have been large and these resources have recently become very competitive with central station costs based on traditional sources of power, the attractiveness of energy efficiency as an investment has been recognized for over three decades. The availability of technologies to reduce energy costs, emissions and pollution at a cost that makes them attractive (less than the cost of energy used and the harm it imposes) has been the trigger for new policies.

Estimates of the large potential for efficiency have been consistent for three decades, as shown in Figure 3. The existence of these investment opportunities and the failure to pursue them represents a major market imperfection and failure. This has been a focal point of our earlier analysis and will not be repeated here, except to note that, in our economic view, the existence of the market failure is historically[9] and legally[10] the basis for pursuing policies and the economic gains that they produce. The availability of policy responses to reduce energy consumption is one of the key background conditions that justify policy action.

The forward looking cost is about $.03/kWh, below the backward looking cost.[11] The reason for the stable and slightly declining cost is learning by doing, economies of scale, and improving technology. There is also a significant reduction in electricity demand that occurs from the effect of shifting to decentralized technologies that better match supply and demand, which I call the transformation dividend. Thus, efficiency is cost competitive with the other alternatives and makes a substantial contribution to meeting need. I have prepared a detailed analysis of the potential for efficiency and renewables to meet the need in analyses of New York, Illinois and California.[12]

FIGURE 3:
THE COST OF SAVED ELECTRICITY



Source: 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).

3. COST PROJECTIONS

SUPPLY

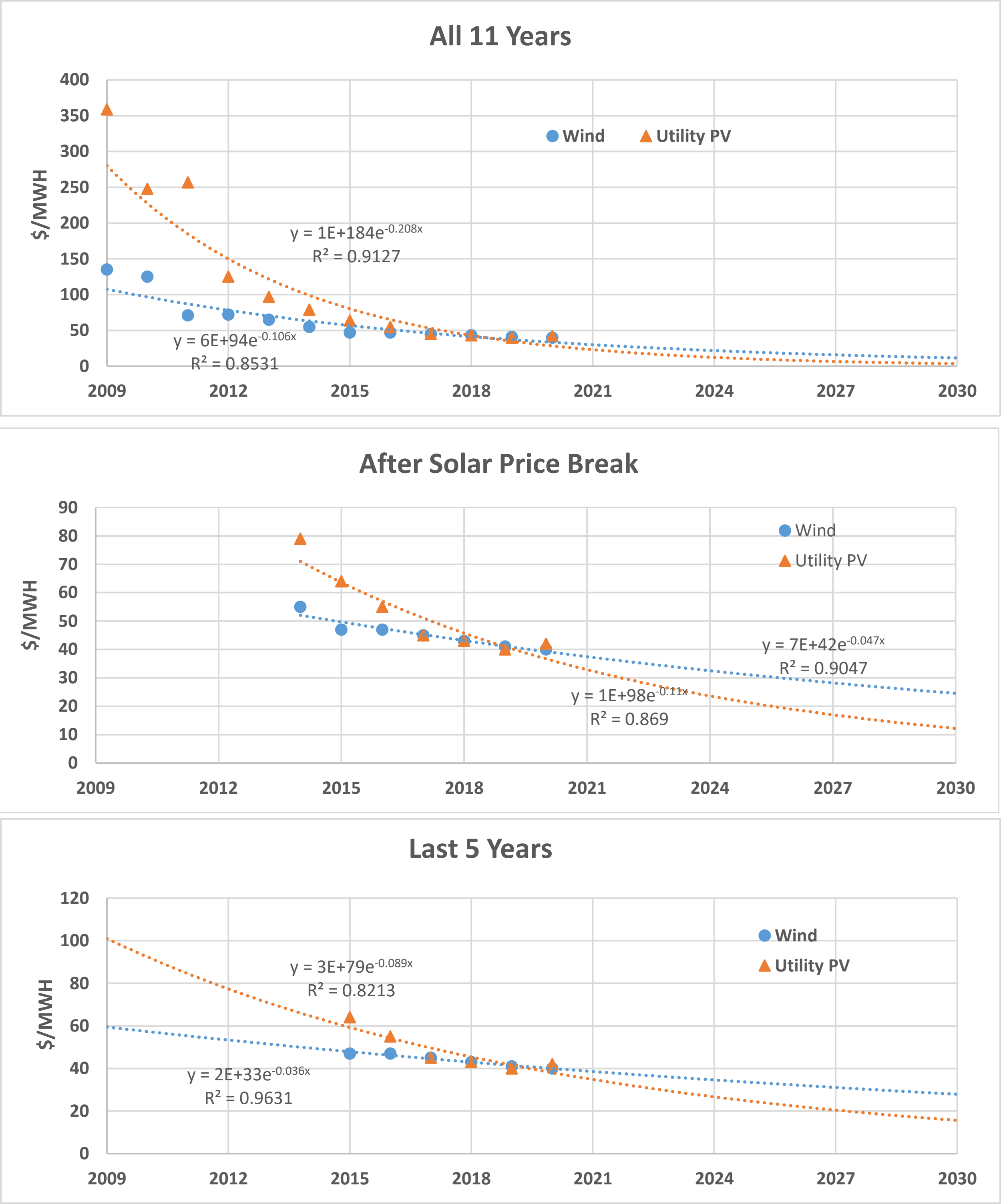
Figure 4 presents Lazard's estimates of unsubsidized cost for the main renewable resources – utility PV and onshore wind. The graphs include a projection of the next decade. In all three a simple exponential curve fits the data well. Clearly, it is reasonable to expect these costs to continue to decline. In the least optimistic view, where the early large cost declines have been exhausted, we use only the last five years as the basis for projection, we arrive at costs in the range of $20-$35 per MWH.

Projecting storage (battery) costs is difficult because of the complexity of applications. Lazard identified five functions,[13] five contexts,[14] and nine technologies,[15] for a total of over 60 combinations,[16] with high and low unsubsidized cost estimates for each.[17] Nevertheless, in 2016, he estimated that battery storage was viable or nearly so based on internal rates of return in three of the five largest grid organizations.[18] Utility management was very bullish on future cost declines for several of these, first among them lithium-ion batteries at an annual decline in cost of almost 36%.[19]

> Lazard's latest annual Levelized Cost of Storage Analysis (LCOS) shows that storage costs have declined across most use cases and technologies, particularly for shorter-duration applications, in part driven by evolving preferences in the industry regarding battery chemistry.
>
> Sustained cost declines were observed across the use cases analyzed in our LCOS for lithium-ion technologies (on both a $/MWh and $/kW-year basis). The cost declines were more pronounced for storage modules than for balance of system components or ongoing operations and maintenance expenses.
>
> Project returns analyzed in our "Value Snapshots" continue to evolve as hardware costs decline, and the value of available revenue streams fluctuate with market fundamentals.
>
> Project economics analyzed for standalone behind-the-meter applications remain relatively expensive without subsidies, while utility-scale solar PV + storage systems are becoming increasingly attractive.
>
> Long-duration storage is gaining traction as a commercially viable solution to challenges created by intermittent energy resources such as solar or wind.[20]

EIA puts the growth in storage capacity at 35% per year from 2015 to 2018.[21] It projects a declining cost for lithium-ion batteries at 10% to 13% per year for 2020-2030 with a massive increase in storage.[22]

FIGURE 4:
LAZARD TRENDS FOR ONSHORE WIND AND UTILITY PV



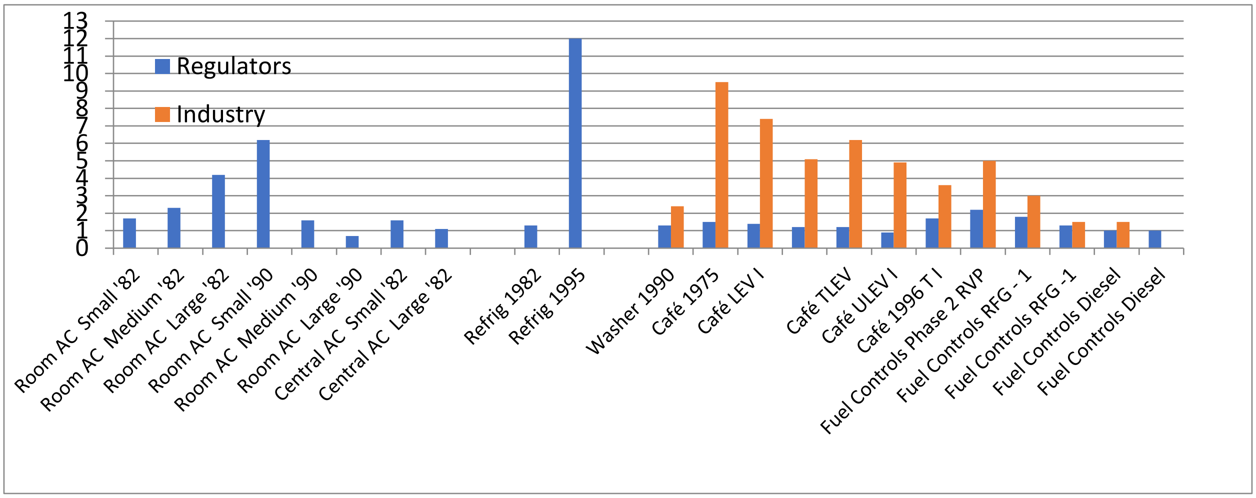
Source: Lazard, Levelized cost of Energy, Various years

DEMAND

Above we noted and explained the projection for flat cost of energy savings. Here we make two points, which counter arguments against energy efficiency – industries and regulators tend to overestimate costs in their formal proceedings and to project that the quality of goods must decline when they incorporate energy savings technologies. Both are contradicted by the record in the two primary categories of energy consuming durables, vehicle and appliances.

As shown in Figure 5, there is systematic overestimation by regulators of the cost of efficiency improving regulations in consumer durables. The cost for household appliance regulations was overestimated by over 100% and the costs for automobiles were overestimated by about 50 percent. The estimates of the cost from industry were even farther off the mark, running three times higher for auto technologies.[23] Broader studies of the cost of environmental regulation find a similar phenomenon, with overestimates of cost outnumbering underestimates by almost five to one with industry numbers being a "serious overestimate."[24]

FIGURE 5:
THE PROJECTED COSTS OF REGULATION EXCEED THE ACTUAL COSTS:
RATIO OF ESTIMATED COST TO ACTUAL COST BY SOURCE



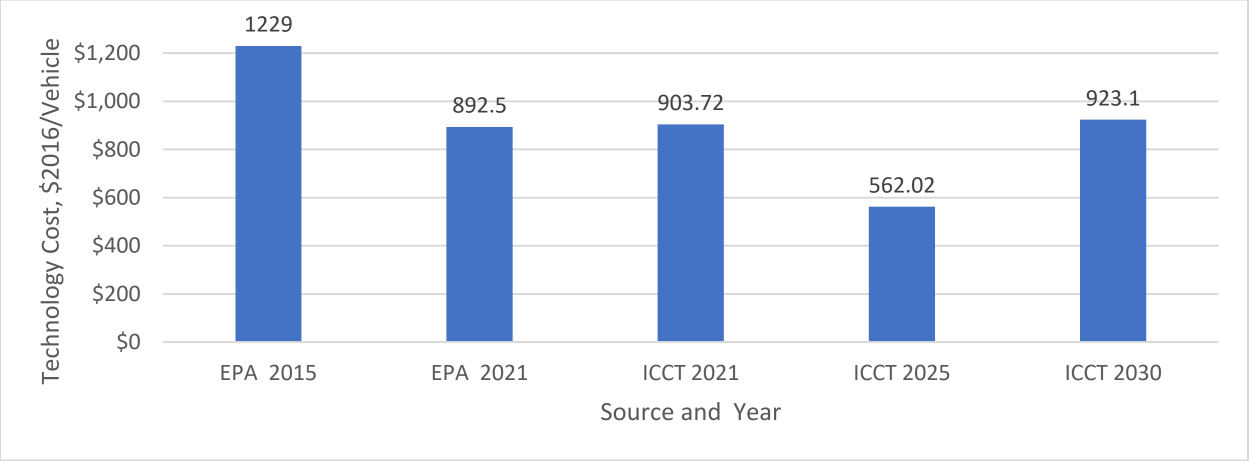
Sources: Winston Harrington, Richard Morgenstern and Peter Nelson, "On the Accuracy of Regulatory Cost Estimates," *Journal of Policy Analysis and Management* 19(2) 2000, *How Accurate Are Regulatory Costs Estimates?,* Resources for the Future, March 5, 2010; ; Winston Harrington, *Grading Estimates of the Benefits and Costs of Federal Regulation: A Review of Reviews,* Resources for the Future, 2006; Roland Hwang and Matt Peak, *Innovation and Regulation in the Automobile Sector: Lessons Learned and Implications for California's CO_2 Standard,* Natural Resources Defense Council, April 2006; Larry Dale, et al., "Retrospective Evaluation of Appliance Price Trends," *Energy Policy* 37, 2009.

EPA's analysis of the National Program (for cars and light duty trucks) demonstrates that this process is continuing to operate with respect to fuel economy standards, as shown in Figure 6. EPA found that a technology that had not even been considered is likely to have a substantial penetration, driving costs down by over 25%. Looking forward, a recent study from the International Council on Clean Transportation projects an additional 25% decline in the cost of compliance, which is consistent with the broad pattern of earlier research. Over the course of 30 years, the cost of increasing fuel economy has declined by about 2.5% per year.

Even more fundamentally, there is evidence that the decision to increase energy efficiency can stimulate broader innovation and productivity growth.

> The case-study review suggests that energy efficiency investments can provide a significant boost to overall productivity within industry. If this relationship holds, the description of energy-efficient technologies as opportunities for larger productivity improvements has significant implications for conventional economic assessments... … This examination shows that including productivity benefits explicitly in the modeling parameters would double the cost-effective potential for energy efficiency improvement, compared to an analysis excluding those benefits.[25]

FIGURE 6: COST OF EFFICIENCY TECHNOLOGY CONTINUES TO DECLINE



Sources: Environmental Protection Agency and National Highway Traffic Safety Administration, *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule*, Federal Register, 77: 199, October 15, 2012, Table I-128. Environmental Protection Agency, *Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Emission Standards under the Midterm Evaluation,* January 2017, Table ES-1. International Council on Clean Transportation, *Efficiency Technology and Cost Assessment for U.S. 2025-2030 Light-Duty Vehicles,* March 2017, Table 2.

These findings of declining cost are not merely descriptive. Several analyses have introduced controls for quality and underlying trends using regression techniques. The findings are affirmed in these more sophisticated analyses.[26] With such strong evidence of costs far below predictions by regulators who undertake engineering analyses, many authors have sought to identify the processes that account for this systematic phenomenon. For both vehicles and appliances, a long list of demand-side and supply-side factors that could easily combine to produce the result has been compiled.

On the supply-side, a detailed study of dozens of specific energy efficiency improvements pointed to technological innovation.[27] A comprehensive review of *Technology Learning in the Energy Sector* found that energy efficiency technologies are particularly sensitive to learning effects and policy.[28] This was attributed to increases in R&D expenditures, information gathering, learning-by-doing and spillover effects. Increases in competition and competitiveness also play a role on the supply side. As noted above, a comparative study of European, Japanese and American automakers prepared in 2006, before the recent reform and reinvigoration of the U.S. fuel economy program, found that standards had an effect on technological innovation. The U.S. had lagged because of the long period of dormancy of the U.S. standards program and the fact that the U.S. automakers did not compete in the world market for sales, (i.e., they did not export vehicles to Europe or Japan).

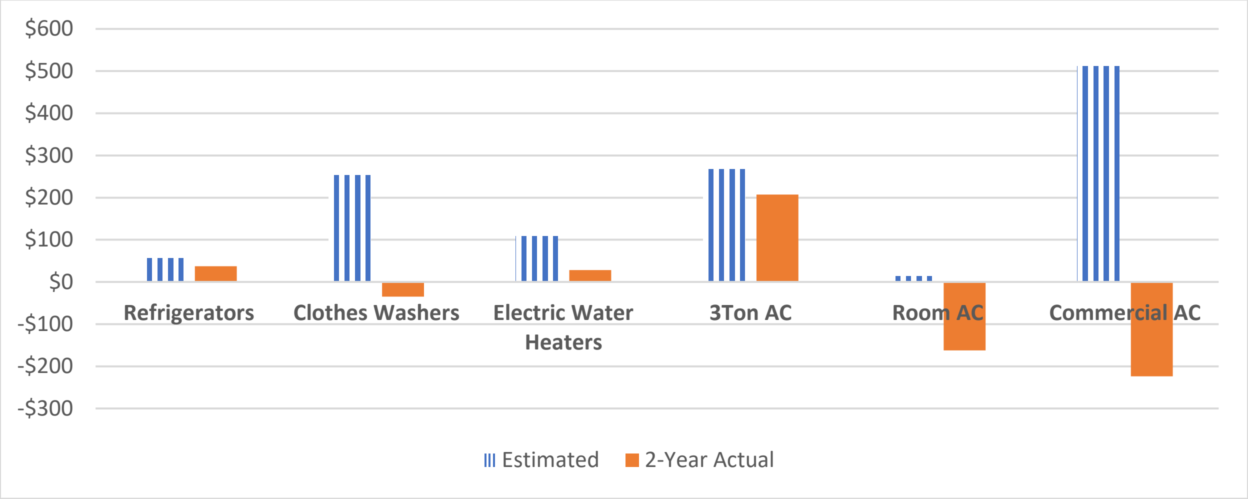
While the supply-side drivers of declining costs are primarily undertaken by manufacturers, a number of demand side effects are also cited, which are more the direct result of policy. Standards create market assurance, reducing the risk that cheap, inefficient products will undercut efforts to raise efficiency. Economies of scale lead to accelerated penetration, which stimulates and accelerates learning-by-doing. The effects of demand stimulus by increasing the growth of the economy (macroeconomic stimulus) also accelerates innovation. Experiencing increasing economies of scale and declining costs in an environment that is more competitive, leads to changes in market behaviors.

The track record of efficiency standards for household consumer durables is even more eye catching. Examining the trends in individual consumer durables suggests three important observations. First, the implementation of standards improved the efficiency of the consumer durables. Second, the failure of furnaces to improve is a demonstration of the effectiveness of standards, since the DOE has set and maintained weak standards. Third, after the initial implementation of a standard, the improvement levels off, suggesting that if engineering-economic analyses indicate that additional improvements in efficiency would benefit consumers, the standards should be strengthened on an ongoing basis.[29]

The engineering-economic analysis indicates that although the standards may increase the cost of the consumer durable, the reduction in energy expenditures is larger, resulting in a net benefit to consumers. We have also pointed to evidence that the costs of energy saving technologies tend to be smaller than the *ex-ante* analysis suggests because competition and other factors lower the cost. The experience of the implementation of standards for the household consumer durables is consistent with this interpretation. In three of the cases (refrigerators, clothes washers – second standard, and room air conditioners), there was a slight increase in price with the implementation of the standard, then a return to a pre-standard downward trend. In one case (clothes washers – first standard) there was no apparent change in the pricing pattern. In one case (central air conditioners) there was an upward trend.

A recent analysis of major appliance standards adopted after the turn of the century shows a similar and even stronger pattern (see Figure 7). Estimated cost increases are far too high. There may be a number of factors that produce the result, beyond an upward bias in the original estimate and learning in the implementation, including pricing and marketing strategies.[30]

FIGURE 7:
ESTIMATED AND ACTUAL COST INCREASES ASSOCIATED WITH RECENT STANDARDS FOR MAJOR APPLIANCES



Source: Steven Nadel and Andrew Delaski, *Appliance Standards: Comparing Predicted and Observed Prices*, American Council for an Energy Efficient Economy and Appliance Standards Awareness Project, July 2013.

4. ARE THE RESOURCES ADEQUATE TO MEET THE NEED

With the costs clearly indicating the superiority of the alternative resources and approach, the next question is, how far can reliance on these resources carry us toward decarbonization of the sector? Will there be enough resources available and how will the new system operate to ensure reliable supply?

RESOURCES

Here we begin with state specific data. Table 2 shows an analysis for New York that is taken from an earlier analysis, with one modification. The original estimated resources for 2030 and 2040, here we show the mid-point which is the average of the two. The mid-point is the target data for full decarbonization adopted by the Biden administration. There are four primary resources used to meet the need, while eliminating carbon emissions: efficiency, a transportation dividend, wind and solar. Existing hydro is flat and existing nuclear output is shrinking. In that proceeding, the acceleration of efficiency, the transformation dividend, and the growth in non-hydro -renewables were all considered well within the available resources.

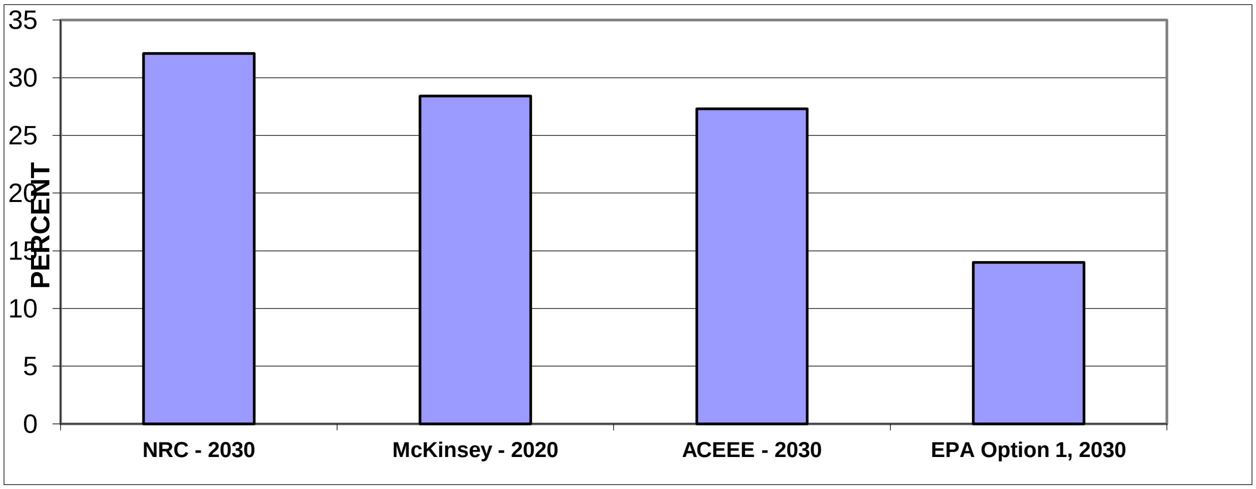
TABLE 2:
MEETING NEW YORK GOALS WITH EFFICIENCY AND RENEWABLES

Alternative Resource	2030	mid-point	2040
Efficiency			
Base case = 1.4%/year	35	43	51
Accelerated = 2%/year	51	65	78
Load @ Accelerated eff.	135	130	124
Transformation Dividend = 17%	10	13	15
Reduction in Coincident Peak (34%) >			
Effective New Load (Reduction in load 17%)	125	117	109
Resources			
Achievable 2030, Economic 2040			
New Non-Hydro	26	57	88
Existing Hydro	36	36	36
Unsubidized Nuclear	17	14	11
% Low Carbon with Transformation Dividend	63%	100%	124%

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

To analyze the adequacy of supply of renewables, we must first determine what demand will be. Projections vary, from about 15% in the EPA assumption to over 30 percent (see Figure 8). In the following analysis, we use an EPRI estimate of the amount that demand could be reduced by 2035, which is a conservative estimate of the potential and it does not take into account the transformation dividend. It assumes reduction in the range of 10 to 20 percent, with a national average of about 17 percent.

FIGURE 8:
EFFICIENCY POTENTIAL FROM MAJOR STUDIES COMPARED TO EPA OPTION 1



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

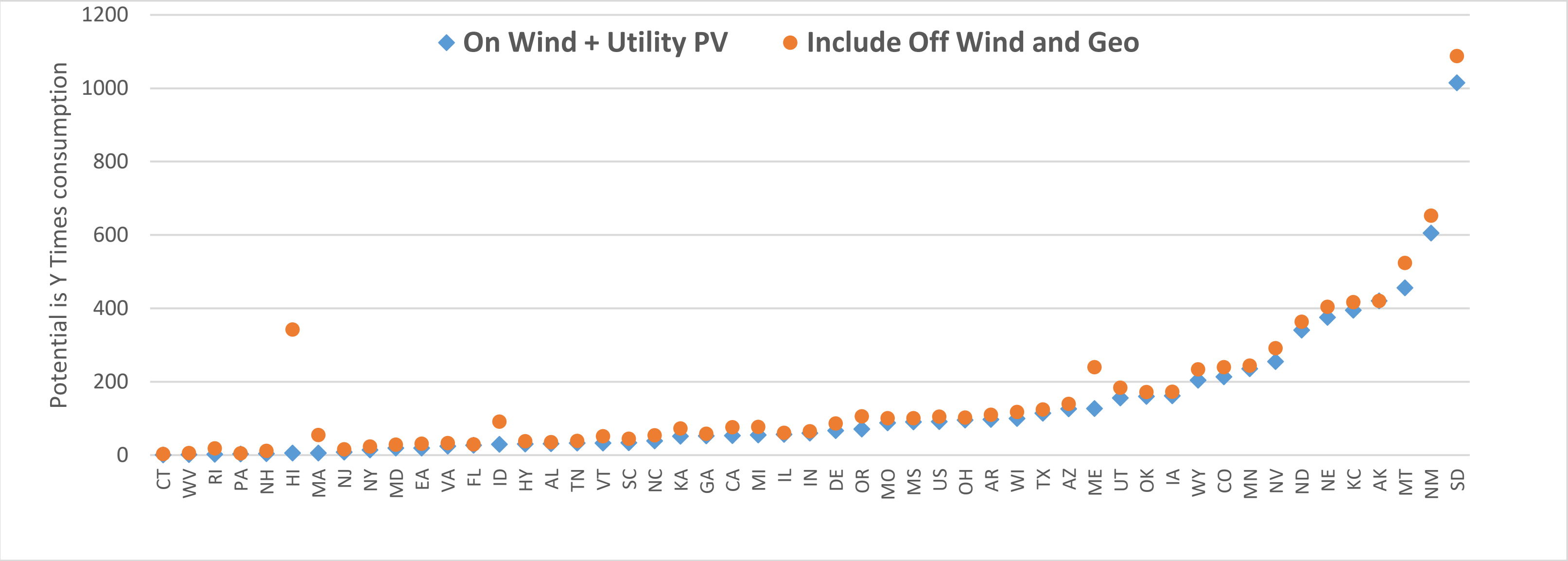
New York was far from the best performer on the alternatives, as made clear in Figure 9. The upper graph of the figure shows the potential for renewables to meet demand, based on NREL's evaluation of potential. We show the currently low cost renewables, onshore wind and utility PV separate from the more costly, but increasingly competitive, renewables, offshore wind and geothermal.

As the upper graph shows, the vast majority of states have an abundance of potential supplies of renewable resources. Only a handful have potential that is less than five times demand. And, as shown in the lower graph, meeting local demand with local supply is not the issue. Just under a dozen others export little. They are not endowed with rich, traditional resources and do not have a comparative advantage. However, the renewables are local resources and they present a new opportunity to diversify supply.

Low cost and adequate resources are two important ingredients to support the alternative system, as is the commitment to build one, but operating the system remains a challenge. The transformation is a process that does not happen overnight. However, it is clear that the tools to do so are developing and many nations have made considerably more progress than the U/S. as shown in Figure 10 shows.

FIGURE 9:
ASSESSING THE ADEQUACY OF SUPPLY

Potential Supply Compared to Demand



Potential Compared to Current Supply

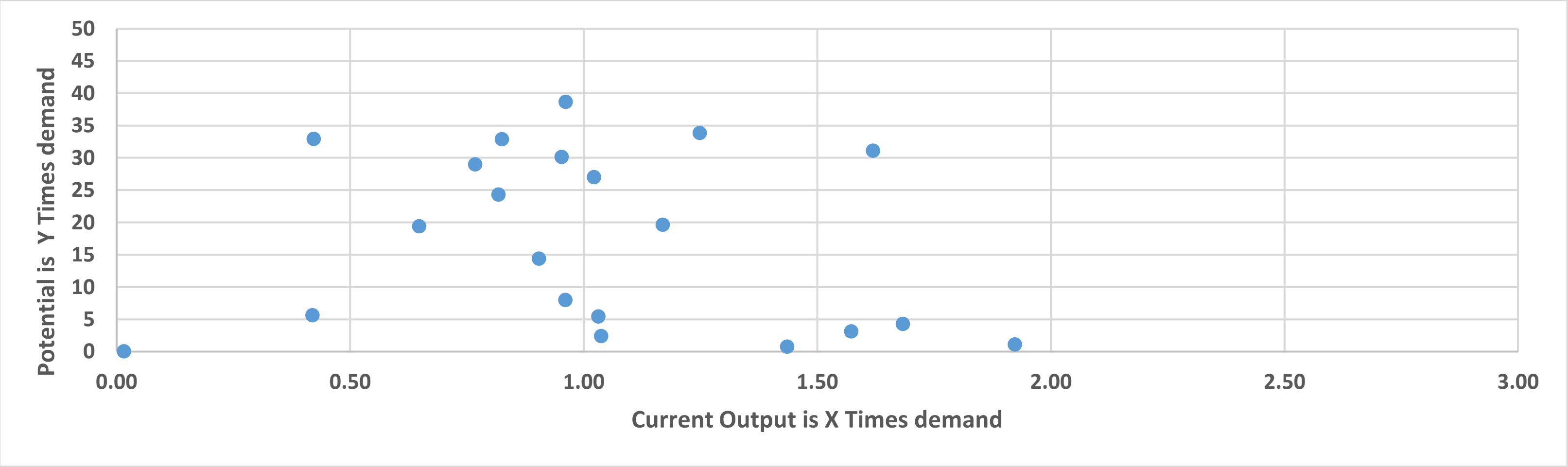
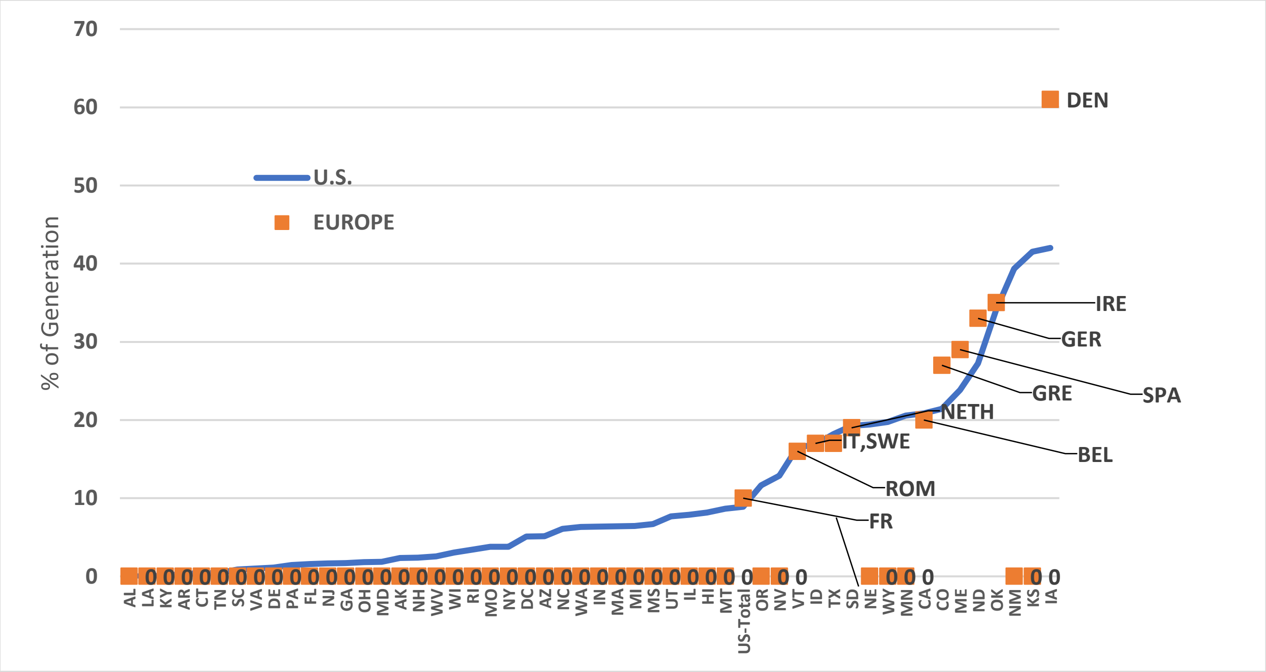


FIGURE 10:
PENETRATION OF GENERATION FROM WIND AND SOLAR



Energy Information Administration, Electric Supply Monthly, EMBER, *EU Power Sector is 2020.*

TOOLS TO ACHIEVE LOW COST, RELIABLE POWER

Figure 11 shows the many tools available to achieve low cost and reliable supply. This is based on over 250 studies.. We treat storage as a demand-side strategy. This is unarguably true for distributed storage, although less so for dispatchable storage. Both are key to balancing load and supply. The appendix gives primarily academic and trade literature citations.

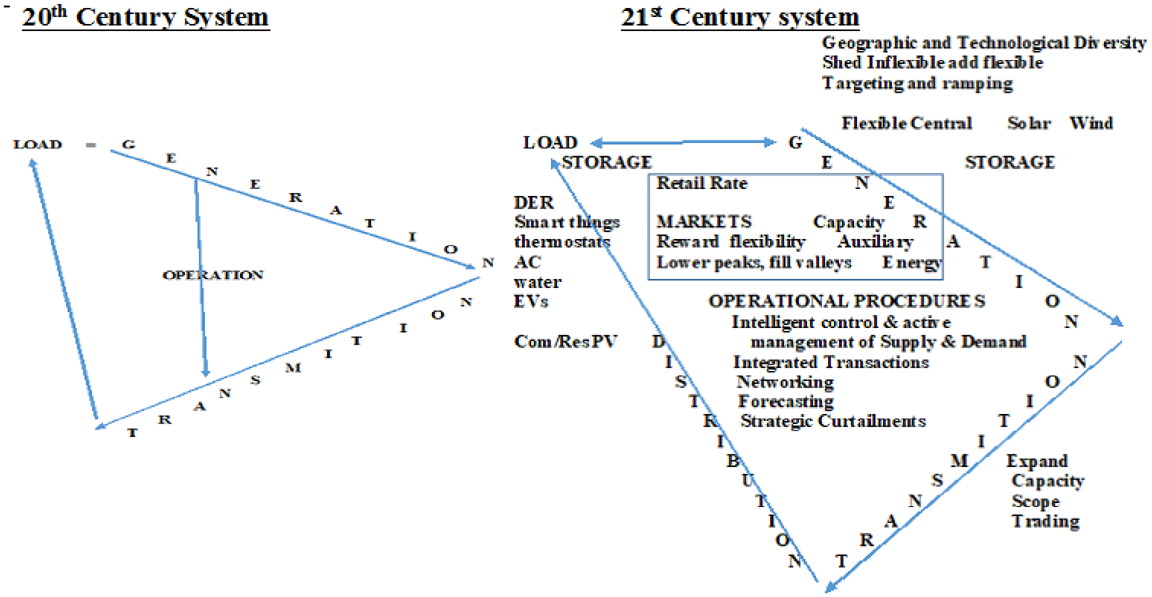
When pressed, utilities give the same answers. .A California proceeding challenged parties to think about how high levels of renewables could be integrated into the grid. Utilities offered a host of approaches and my summary concluded there were at least ten general ways to handle the challenge.[31]

The LBNL analysis shows that the technical and economic processes by which policies work to mitigate the impact of variability are straight forward.

1. Geographic diversity, particularly for wind, reduces extremes of generation, high or low output.[32]
2. Technological diversity fosters a better fit with load.[33]
3. Storage allows more energy to be captured and used when needed,[34] both by reducing curtailment[35] and by increasing demand (and therefore prices) during slack periods.[36]

4. Demand shaping allows a better balance between supply and demand.[37]
5. Flexibility is a key attribute, achieved by
    - sub-hourly scheduling to reduce the magnitude and impact of forecasting error,[38]
    - "quick start' generation,[39] or
    - a portfolio approach that uses a mix of generation assets that can reduce the need for flexibility of individual assets.[40]
6. Exploiting the best sites for renewable resources yields much larger economic value—three times the average.[41]

FIGURE 11:
CREATING THE 21ST CENTURY ELECTRICITY SYSTEMS:



Fundamental Differences between Centuries and Systems

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

Source: Mark Cooper, *The Green New Deal, Nuclear Power and Other Potholes to avoid on the Road to a Progressive, Capitalist, Least Cost, Low Carbon, Clean, Electricity Sector*, April, 2019), Chapter 6.

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 utilities started with a base case of renewables at 33 percent and set up straw men of 40 percent and 50 percent PV scenarios. Not surprisingly, they find that this extreme approach produces major problems in matching supply and demand.

Consistent with the LBNL analysis, however, the introduction of mitigating policies immediately solves the problem. The utility study identifies four "least regrets opportunities," and a number of opportunities for "research and development for technologies to address over-generation."[42] Adding in three blocks of "flexibility solutions" reduces the curtailment of PV generation to the level of the 33 percent penetration, which was virtually zero. The transformation dividend is present in the utility analysis. Pursuing downward "flexibility solutions" yield 15000MW of reduced demand, 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 the RAP finding discussed above.

This level of "flexibility solutions" is in the range of the planning reserve—an equivalence that the literature generally notes. As the penetration of relatively small-scale distributed technologies increases, the need for planning reserves may decline because, in the current baseload approach, it is the threat of the loss of large units that drives up planning reserves. The potential for a trade-off between planning reserves and "flexibility solutions" could have a significant impact on the cost of meeting the need for electricity.

While the utility study does not model the specific "flexibility solutions," it does identify the likely primary candidates, which are the same as those modeled in the LBNL analysis. The utility study finds significant challenges, but also opportunities. The four "least regrets" opportunities identified in the study include:

- pursuing a diverse portfolio of renewable resources;
- implementing a long-term, sustainable solution to address over-generation before the issue becomes more challenging; and
- implementing distributed generation solutions.
- Research and development for technologies to address over-generation are plentiful, including
    - promising technologies like storage (solar thermal with energy storage, pumped storage, other forms of energy storage including battery storage, electric vehicle charging, thermal energy storage) and
    - flexible loads that can increase energy demand during daylight hours (advanced demand response and flexible loads).
- Technical potential to implement new solutions are also available, including
    - sub-five minute operations,
    - creating a large potential export market for excess energy,
    - changing the profile of daily energy demand, and
    - optimizing the thermal generation fleet under high RPS.[43]

INTEGRATION COST AND SYSTEM VALUES

Baseload myopia, the claim that only large central station facilities can ensure reliable supply, has been rejected on the basis of cost. Can it be salvaged by the claim that it is the only means of meeting the need for power at an affordable cost? Evaluation of how much it costs to operate a reliable system suggests that it cannot. The alternatives win out on integration of resources and system values.

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. [44] It is reflected in the DOE analysis *Wind Vision,* which provides a simple explanation. The DOE *Wind Vision* analysis argues that "wind generation variability has a minimal and manageable impact on grid reliability and related costs."[45] 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. "Such challenges can be mitigated by various means including increased system flexibility, greater electric system coordination, faster dispatch schedules, improved forecasting, demand response, greater power plant cycling, and—in some cases—storage options."[46] 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.[47] These highlight the impact and necessity of changes to the grid,[48] and the prospect of achieving reliability that equals or exceeds current levels with the alternative approach is increasingly seen as quite good.[49]

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."[50] In sum, careful analysis shows that reliability is a nonissue; the conflict is about the future of the techno-economic structure of the electricity sector in the 21st century.

The DOE explicitly laid out the process in the case of transmission.[51] The *Wind Vision* analysis argues that transmission costs are constantly being incurred by the electricity system. In the early years, those costs are reallocated from supporting central station generation (which is shrinking) to supporting new renewable resources. There is only a slight net increase in transmission investment. As time goes on and the share of renewables grows, transmission costs increase. However, they are complementary to the deployment of renewables, whose capital and operating costs have been declining and are much lower than the nonrenewable, low-carbon alternatives.

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."[52] 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*. [53]

> 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. [54]

The difference between LCOE and LACE can be called "inflexibility waste" to capture the key concept.[55] The avoided cost is less than the levelized cost because resources are inflexible, i.e., unable to adapt their output to the needs of the system. The system cost would be lower if technologies that better fit system needs are used. Inflexibility waste can be lowered in two ways – reducing levelized cost or decreasing avoided costs (*i.e*., a better fit between output and system needs).

After extensively discussing the EIA system value approach to improving comparisons between alternatives, analysts at two national laboratories (Lawrence Berkeley National Laboratory and Argonne), suggested an alternative approach that rested on system costs. The 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. This approach was also advocated by a major research institution in Germany evaluating the aggressive transition to renewables being pursued in that nation.[56]

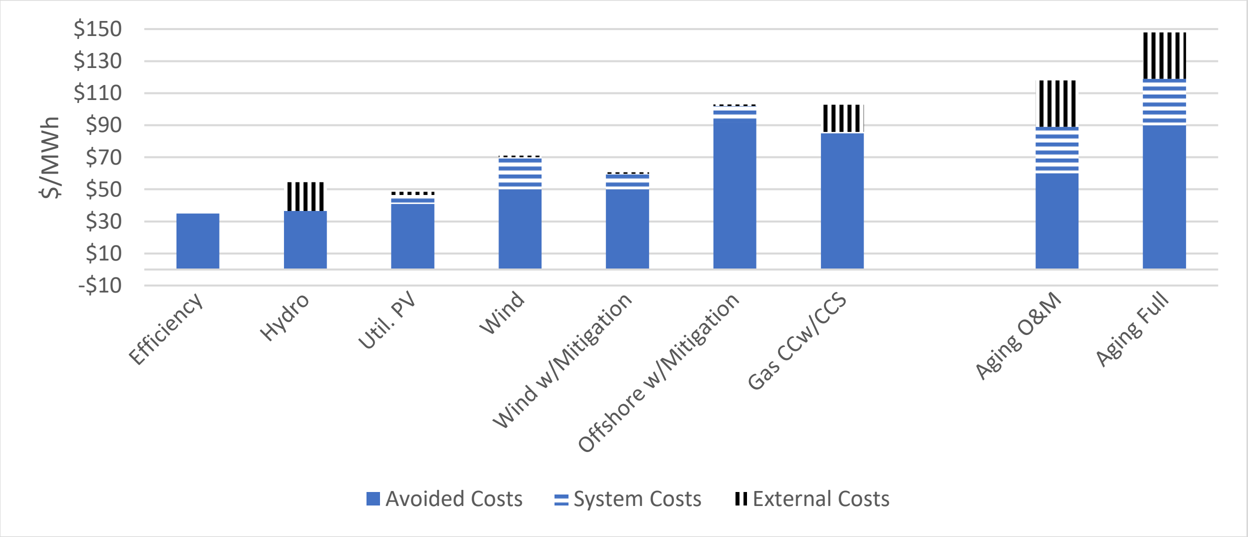
> If properly defined, the 'system cost' of VRE [variable renewable electricity] (or any other resource) combined with the plant-level technology LCOE of VRE results in a 'total system LCOE', which can then be compared (with substantial caveats) to the 'total system LCOE' of any other technology to determine which resource has the lowest total system cost. An important point to make here is that this 'system cost' perspective is related to but distinct from the system value' perspective described earlier. An analyst may choose to use the 'system value' perspective or the 'system cost' perspective, but it is important to avoid double counting. Moreover, as discussed in more depth later, all resources have 'system costs', and so an exclusive focus on VRE alone is inappropriate.[57]

Figure 12 uses Lazard unsubsidized LCOE (from 2016) and also shows the operating and full costs of aging reactors developed earlier ($6/kWh and $9/kwh), rather than new nuclear reactors. The full cost is more appropriate. To make a fair comparison between low carbon resources, I use the cost of natural gas combined cycle plants with 90% carbon capture. I have not included the cost of coal with 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, so the Figure shows avoided cost.

I also include energy efficiency with the current LCOE of $35/MWh. I attribute system costs to efficiency equal to those for hydro, which is given a slight benefit in the EIA analysis.[58] Given all of the positive attributes of efficiency discussed above, this approach is likely to underestimate its benefit in terms of system costs.

The compelling conclusion of this analysis is quite clear. The renewables are preferable by far and all of the underlying trends reinforce these conclusions.59 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.

FIGURE 12:
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. Wiser, 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.

CONCLUSION

The importance of dynamic flexibility and the total system costs raise an important point about central station facilities, especially nuclear reactors, which claim to be low carbon, . Consistent with the above analysis, an approach that tried to keep uncompetitive nuclear reactors online because they are low carbon emitters, would squeeze out and delay the growth of the alternatives for over a couple of decade. Extending the life of these facilities past the end of their economic competitiveness would delay or even forgo benefits of the transformation and still confront the problem of replacing the nuclear facilities. This would further increase the cost and risk of the electricity system.

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.

> 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.[60]

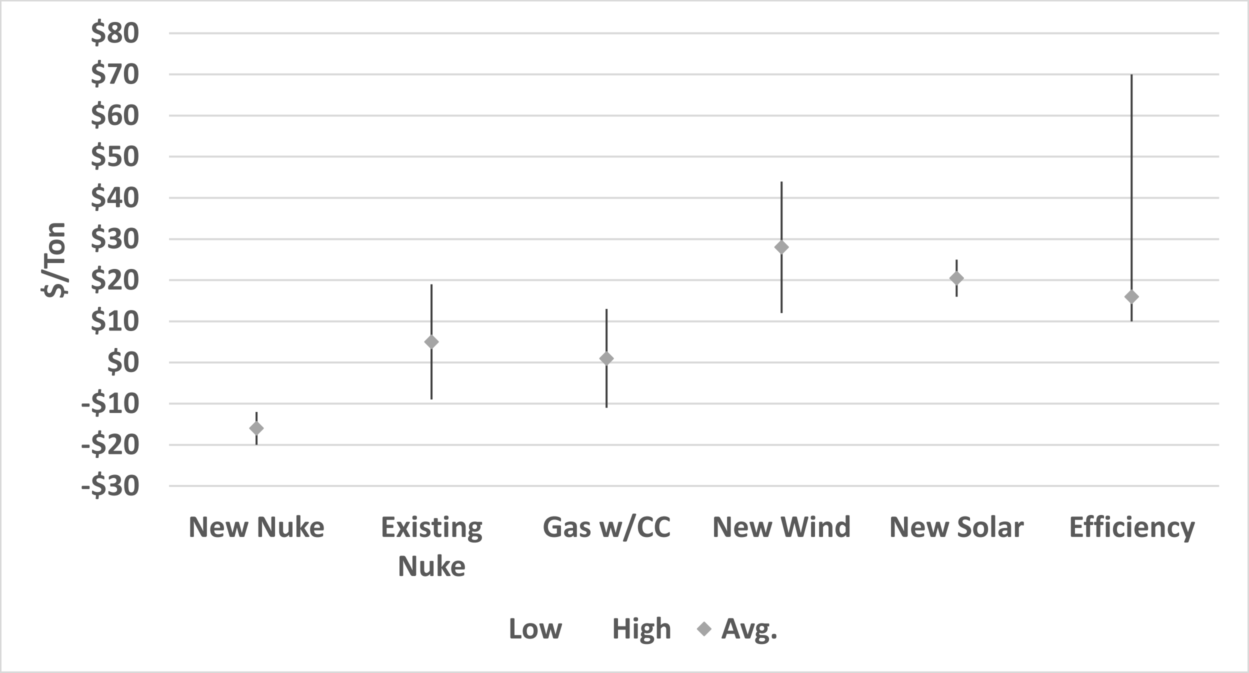
5. POLICY GOALS

Having shown the current and future economic superiority, abundant resources and practical tools to transform the electricity sector, we evaluate the impact that this transformation would have on the primary policy goals – decarbonization, macroeconomic growth, job creation, public health and the environment.

DECARBONIZATION

Figure 13 uses a recent Lazard analysis of the value of carbon reduction for an estimate of the valued of carbon abatement of the main options expressed in a comparison with coal.[61] The figure includes new builds for wind, solar, and nuclear, updating the 2019 Lazard analysis with the 2020 cost projections. It includes my estimate of the value of efficiency based on Lazard's efficiency costs. It includes my estimates of the total cost of keeping aging reactors "online" by ensuring they "make money." It includes an estimate of the cost of retrofitting natural gas to remove 90% of carbon based on a Lazard 2014 estimate.

FIGURE 13:
VALUE OF CARBON ABATEMENT



Source: Based on Lazard, as described in the text.

Three conclusions can be drawn from these estimates.

- Efficiency, wind and solar are far and away the least cost options.
- New nuclear is prohibitively expensive,

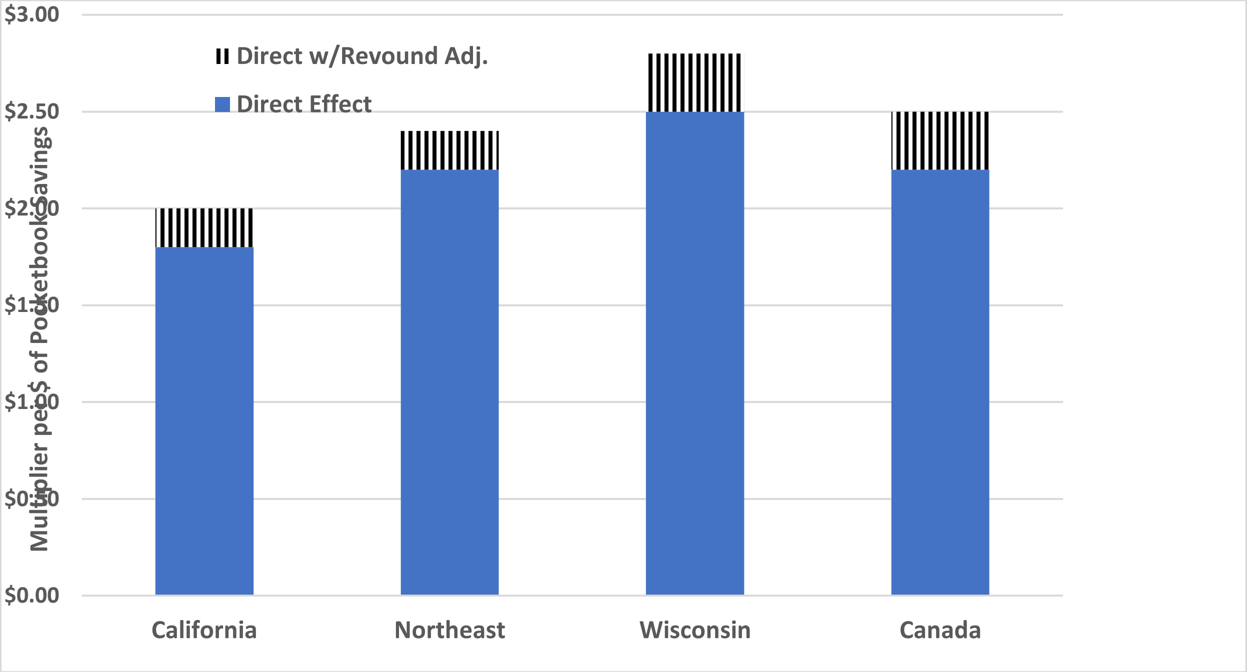
- Retrofitted gas is cost competitive with aging nuclear reactors..

Given that all low carbon resources are at least competitive with aging nuclear reactors, and three of them are much lower in cost, it is illogical to claim that retrofitting fossil fuels or keeping central station generation on line is essential for decarbonization. The strong case for the alternatives is reinforced when we examine the other externalities that might require tradeoffs in pursuit of the paramount goal of decarbonization.

MACROECONOMICS AND JOB EFFECTS

Being consumer -friendly (i.e., lower in cost) means that the alternatives have a higher multiplier when the energy cost savings are "respent." For every one dollar that is saved, as shown in Figure 14, the economy grows almost an additional dollar.

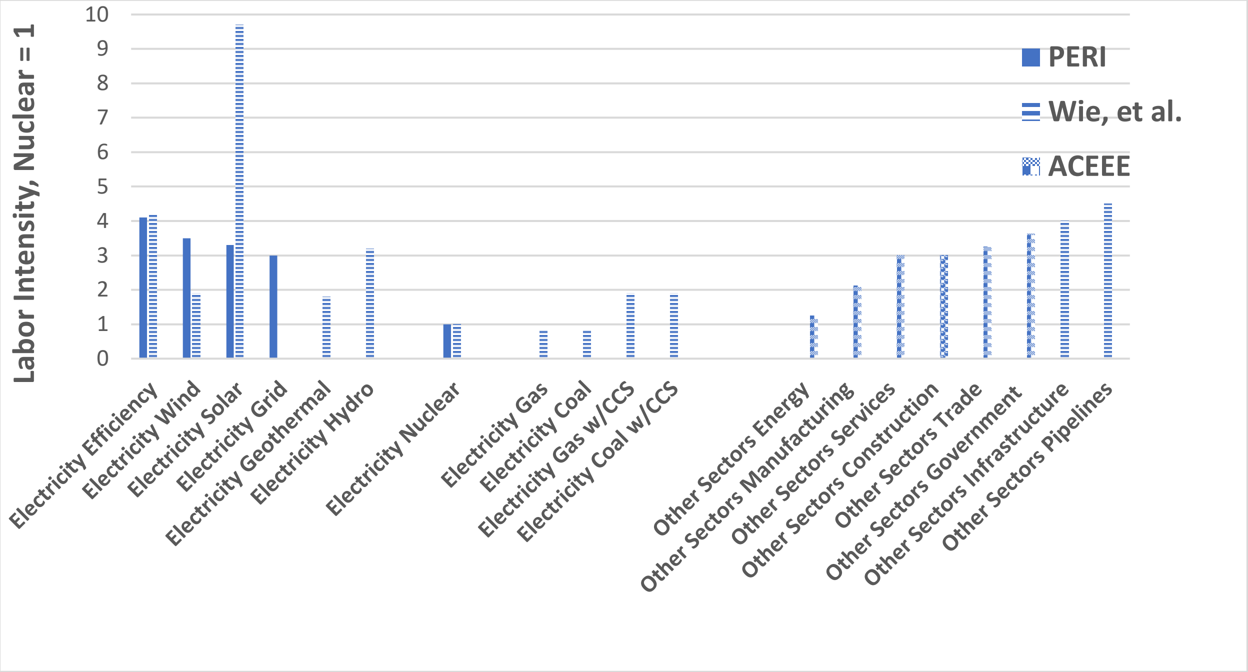
FIGURE14:
ESTIMATES OF MACROECONOMIC MULTIPLIERS



Sources: David Roland-Holst, 2016, *Revised Standardized Regulatory Impact Assessment: Computers, Computer Monitors, and Signage Displays,* prepared for the California Energy Commission, June. ENE, *Energy Efficiency: Engine of Economic Growth: A Macroeconomic Modeling Assessment*, October 2008. Cadmus, 2015, *Focus on Energy, Economic Impacts 2011–2014*, December. Arcadia Center, 2014, *Energy Efficiency: Engine of Economic Growth in Canada: A Macroeconomic Modeling & Tax Revenue Impact Assessment,* October 30, 2014.

The alternatives are also much more labor intensive, as shown in the lower part of Figure 15. The construction jobs are much more widely distributed, as are the opportunities to collect rent for land use. This is consistent with the above observation about the potential to diversify with local resources. The efficiency jobs are also dispersed.

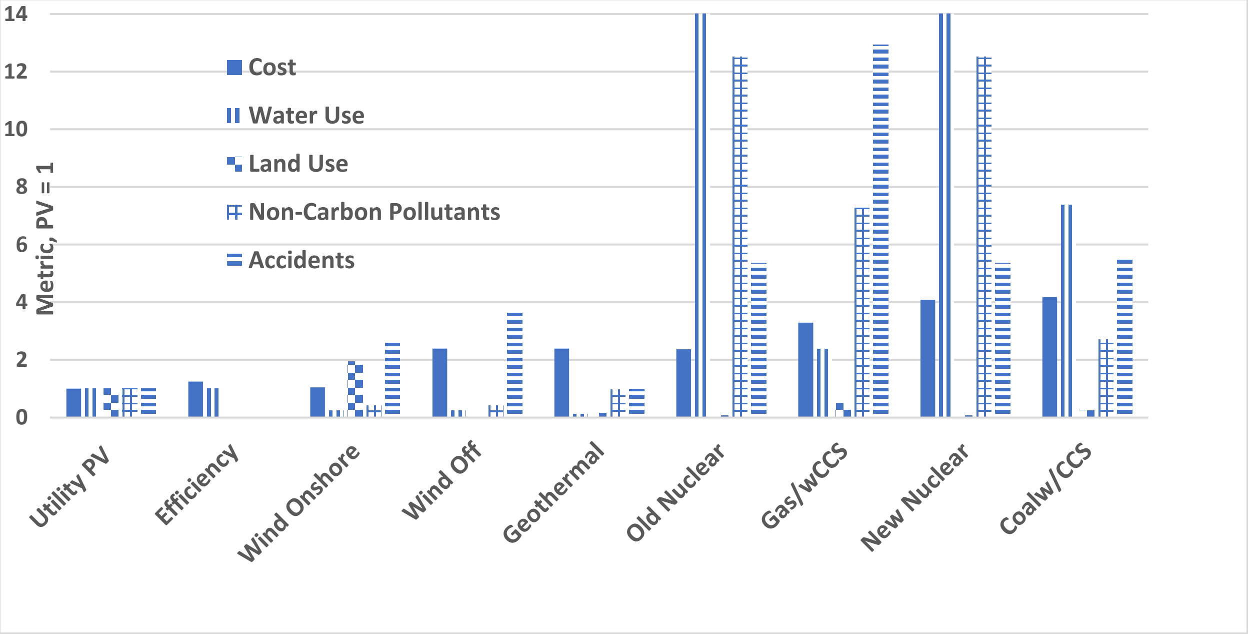
FIGURE 15:
LABOR INTENSITY OF ALTERNATIVES



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.

Other externalities are complex, but the message for the decisionmaker is the same as shown in Figure 16. Nuclear power has big issues with waste, radioactivity and accidents, which have been dealt with by insulating the industry from these concerns by socializing the costs. The industry's reliance on the use of large quantities of water is an increasing concern. Renewables have issues, too, but they tend to be smaller. Reliance on scarce materials, land use, and impact on local wildlife. The alternatives appear to have the advantage on these issues, too, but even if the comparison went the other way, it is far too small to reverse the immense advantage of the alternatives on resource costs and macroeconomic benefits.

FIGURE 16:
OTHER RESOURCE, PUBLIC HEALTH AND ENVIRONMENTAL IMPACT
(Ranked with PV =1)



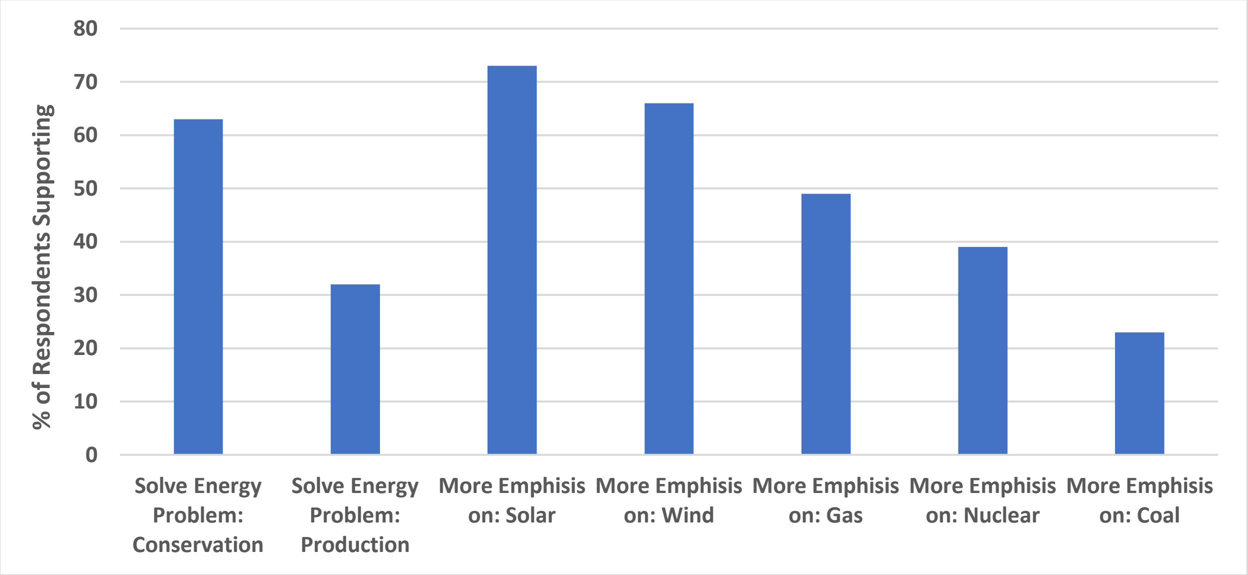
PUBLIC OPINION

Americans prefer conservation to production as a solution to our energy problems by a 2-to-1 margin, as shown in Figure 17. On the production side, they are over 1.75 times as likely to support the main renewables as they are to support nuclear. Pew surveys show similar results. Gas receives 25% more support than nuclear. Support for wind and solar are about three times the support for coal. In these Gallup polls, over 7/8ths of respondents see energy as a serious issue and 3/4 feel affordability is important. While public support for nuclear is fairly evenly split, conservative are much more likely (1.5 times) to support nuclear power than moderates and liberals (62% v. 42%). Public opinion strongly supports the alternatives on which a 21st century electricity sector will be built, particularly the public that has supported Biden.

CONCLUSION

The challenges of building the physical and institutional infrastructure to support the 21st century alternative in the electricity sector are great, but so too are the rewards. Because the transformation is a process, we must be cautious in projecting benefits, but even a cautious approach to calculating benefits shows the superiority of the transformation. Efficiency advocates have argued that efficiency alone can accomplish half the job of eliminating carbon emissions, although they do not give costs or include a transformation dividend.[62] Supply side advocates argue that wind and solar can accomplish the job of decarbonization, while lowering costs, without any increase in hydro and only modest efficiency gains, but they include a significant amount of rooftop solar,[63] which is quite expensive in the Lazard analysis. Rooftop is a personal, not a public policy option.

FIGURE 17:
PUBLIC OPINION ABOUT MEETING ELECTRICITY NEEDS



Source: Gallop, Historical Trends: Energy.

The immediate impact will be to create jobs in the development and deployment of the alternatives, including system management.

- Efficiency will lower bills and deliver a mounting "respending" benefits.
- Over time the transformation dividend will be realized as the size of the system shrinks and the diversification and wide distribution of resources takes place.
- The full benefit will come as large, costly, central station facilities are replaced with lower cost alternatives.
    - In the long term, with replacement of all current generation, the cost savings on electricity would be over 8% of the current bill, including the transformation dividend.
    - The macroeconomic multiplier would add indirect benefits of about 7.5%.
- The decarbonization and public health benefits will also be emergent as carbon emissions and pollution are reduced.
    - Our analysis of energy efficiency, before carbon was an issue puts these benefits of reduced pollution at about one-quarter of the total economic benefit, equal to about 4% of the energy bill
    - The benefits of decarbonization depend on the value placed upon it. To stay within the framework of current analysis, we use Lazard's estimate of the cost of

carbon ($30/ton) and the value of reduction through alternatives, identified in Figure 13.

Consider the following hypothetical, which presents an extremely cautious estimate of the benefits of the 21st century alternative (See Table 3). In the example, we assume that the bundle of efficiency, wind and solar lowers the consumer's bill by $10 per month. This is about 9% of the total bill and less than 20% of the generation cost. It is slightly larger than the transformation dividend, but less than half of the cost advantage of the bundle compared to the cost of natural gas with carbon capture, which is the lowest cost long-term low carbon alternative. The actual impact could be two or three times as large, but for the purpose of this hypothetical, we will use the lower figure followed by a plus sign.

TABLE 3: ANNUAL HOUSEHOLD BENEFITS OF A 21ST CENTURY ELECTRICITY SYSTEM

Benefit (and basis for estimation)	Benefit per HH per Year (assuming 100% alternatives & 150 Million HH)
Direct household bill savings	$ 120+
Macroeconomic stimulus (respending) (.9 x saving)	108+
Indirect spending on commercial electricity	108+
Public health (.25 x total economic)	57
Decarbonization (@ $30/ton)	120+
Total	513++++

The direct benefit of $120 per month has an indirect "respending" benefit of $108.

The cost of electricity in the commercial sector is about 90% of the residential sector's, which we have argued is paid for by consumers. The indirect pocketbook benefit is $108 per year. There is probably a "respending" benefit on this savings, but it is difficult to estimate. We treat it as another plus.

Historical public health benefits are about $57.

Decarbonization is valued at$30/ton, as in the Lazard study discussed above. Therefore, it equals about $120 on a per household basis. The value is expected to increase substantially over time.

The total benefit is over $500 and in all likelihood it is well over $1,500.

The energy sector has all of the key traits of classic infrastructure. It is large and effects many aspects of economic activity, setting the conditions for economic growth. Many aspects of the transition also involve "shovel ready" physical construction projects. It is also infrastructural in the sense to needing to build the institutions that will govern behavior in the sector of decades to come. This qualitative aspect of the transformation will not "cost" a lot in terms of spending on resources, but it essential to the deployment of the physical resources.

In this sense, we are not arguing that the 20th century approach was wrong; we have stated the case for moving on to a different system because the old system is too costly and inconsistent with the opportunity to pursue policy goals that been opened up by technology.

ENDNOTES

---

[1] "President Biden's American Jobs Plan Will Help Transform the Energy Sector and Kick Start Our Economy Into High Gear Transforming the Nation's Electrical Grid will Put Money Back into Consumer Pocketbooks, Boost the Economy and Reduce Harmful Emissions," April 2, 2021.

[2] Environmental Protection Agency, *Sources of Greenhouse Gas Emissions*, 2019.

[3] Mark Cooper (Praeger, 2017), (hereafter Cooper 2017). Recent updates of that analysis include: Wisconsin (XX). On New York and the Green New Deal see, Mark Cooper, *The Green New Deal, Nuclear Power and Other Potholes to avoid on the Road to a Progressive, Capitalist, Least Cost, Low Carbon, Clean, Electricity Sector*, April, 2019). (Hereafter Cooper, 2019)

[4] December 1, 2017 (hereafter 2017a).

[5] In Cooper, 2017, I concluded a Chapter entitled "The Nuclear War Against the Future" with the following observation Policy should move to quickly adopt the necessary institutional and physical infrastructure changes needed to transform the electricity system into the 21st-century approach. Policy should not subsidize nuclear reactors, old or new. In the long term, their large size and inflexible operation makes them a burden, not a benefit in the 21st-century system. Nuclear's technological characteristics combined with the industry's political efforts to undermine the development of the 21st-century system makes nuclear a part of the problem, not the solution , pp. 201-202

[6] This decline in cost is the equal of the reduction in cost that has typified key economic inputs of each of the industrial revolutions that has taken place in the past three centuries, as suggested by Figure 2.2 in Cooper, 2017.

[7] Lazard, Lazard's Levelized Cost of Energy Analysis – Version 14.0, October 2020.

[8] Id., p. XX

[9] 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. (hereafter Cooper 2014)

[10] Cooper, 2017b on OMB rules.

[11] Cooper, 2014, pp. 30-31, and the underlying studies

[12] Cooper, 2019, pp. 31-37, On California and Illinois see, Cooper,2017, pp. 169-201.

[13] Lazard, Levelized Cost of Energy Storage, 2.0, p.6.

[14] Id., p. 7,

[15] Id., p.9.

[16] Id., pp. 11-12.

[17] Id., pp. 13-16.

[18] Id., p. 23.

[19] Lazard, Levelized Cost of Energy Storage, 3.0, press release, p.2.

[20] Lazard, Levelized Cost of Energy Storage, 6.0, Additional Highlights.

[21] Energy Information Administration, *Battery Storage in the United States: An Update on Market Trends, July* 2020

[22] U.S. DOE*, Energy Storage Grand Challenge: Energy Storage Market Report,* December 2020.

[23] Hwang, Roland and Matt Peak, 2006, *Innovation and Regulation in the Automobiles Sector: Lessons Learned and Implicit on for California CO_2 Standards,* April.

[24] Harrington, Winston, 2006, *Grading Estimates of the Benefits and Costs of Federal Regulation: A Review of Reviews,* Resources for the Future, September, p. 3.

[25] Ernst Worrell, et al., 2003, "Productivity Benefits of Industrial Energy Efficiency Measures," *Energy Journal*, 11, p. 1081.

[26] Steven Nadel and Andrew Delaski, *Appliance Standards: Comparing Predicted and Observed Prices,* American Council for an Energy Efficient Economy and Appliance Standards Awareness Project, July 2013.

[27] Worrell, 2003, "Productivity Benefits of Industrial Energy Efficiency Measures," *Energy*, 28(11): This examination shows that including productivity benefits explicitly in the modeling parameters would double the cost-effective potential for energy efficiency improvement, compared to an analysis excluding those benefits. (p 1)

---

[28] Larry Dale, et al., 2009, "Retrospective Evaluation of Appliance Price Trends," *Energy Policy* 37, 2009.

[29] A multivariate analysis confirms these results.. Stricter standards as set by DOE lead to measurable improvements in appliance efficiency. This finding is highly statistically significant, with a probability level less than .0001. There is a very high probability that the effect observed is real. The underlying trend is also statistically significant, suggesting that the efficiency of these consumer durables was improving at the rate of 1.35% per year. Given that the engineering-economic analysis had justified the adoption of standards and that standards were effective in lowering energy consumption, this means the market trend was not sufficient to drive investment in efficiency to the optimal level.

[30] Sperling, Dan et al., 2004, *Analysis of Auto Industry and Consumer Responses to Regulation and Technological Change and Customization of Consumer Response Models in Support of AB 1493 Rule*making, Institute of Transportation Studies, UC Davis, June 1, emphasized the adaptation of producers in the analysis of auto fuel economy standards.

[31] Cooper, 2019.

[32] Mills, Andrew, and Ryan Wiser. Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California. Lawrence Berkeley National Laboratory, 2012, p. 24, "A portfolio with high geographic diversity leads to a higher value of wind due to a reduction in extremes: fewer hours have significant amounts of wind from all wind sites in the portfolio (reducing overgeneration and curtailment), and more hours have at least a small amount of wind generation from some sites. The benefit of increased geographic diversity is more pronounced with high wind penetration levels since wind is more likely to affect wholesale prices at high penetration levels."

[33] Ibid., 25, "The increase in the capacity value of wind with 10% PV is due to PV shifting the timing of the peak prices into the early evening, when wind generation is somewhat stronger"; 27, "As PV penetrations increase, adding 10% wind increases the marginal value of PV substantially relative to the Reference scenario. . . . The increase in the capacity value is tied in part to wind generation occurring."

[34] Ibid., 33, "The increase in the value of PV with low-cost storage is almost entirely due to the increase in the energy value of PV relative to the Reference scenario. . . . The energy value of PV increases in part due to a reduction in PV curtailment from 2.9% with 30% PV in the Reference scenario to less than 0.1% in the Low-cost Storage scenario. The strong negative correlation between PV generation and generation from storage (existing and new) at high PV penetrations indicates storage is consistently charging when PV is generating and discharging otherwise."

[35] Ibid., 32, 33.

[36] Ibid., 33.

[37] Ibid., 35, "since reductions in demand relative to historical levels at time of system need enable a balance between demand and generation rather than relying on new conventional capacity."

[38] Ibid. n Mills and Wiser, Strategies for Mitigating, the issue enters implicitly through the frequent attention to forecasting error. The other major studies give sub-hourly scheduling prominent, explicit attention.

[39] Ibid., 43.

[40] Ibid., 30, "In addition, the impact of more-flexible generation will depend on the degree of flexibility in the existing generation mix. California has significant amounts of CTs, PHS capacity, and hydropower. In comparison, we found in an earlier analysis of highly concentrated wind in the Rocky Mountain Power Area [Andrew Mills and Ryan Wiser, Solar Valuation in Utility Planning Studies. Clean Energy States Alliance: RPS Webinar, January 2013] that assuming all new CCGTs had quick-start capability increased the value of wind by up to $6/MWh at 30% wind penetration. The Rocky Mountain Power Area has much less flexible incumbent generation relative to California."

[41] Ibid., 39.

[42] 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)

[43] E3, *Higher Renewables Portfolio Standard, E3. Investigating a Higher Renewables Portfolio Standard in California.* Energy and Environmental Economics, Inc., January, 2015, pp. 31–35.

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

[45] U.S. Department of Energy, *Wind Vision*, xxiii.

[46] U.S. Department of Energy, *Wind Vision*, xlii.

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

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

[49] See for example, Martin I. Hoffert, "Farewell to Fossil Fuels?" *Science* 329 (2010); Bettencourt, Trancik, and Kaur, "Determinants of Pace"; Dalibor Petković et al., "Adaptive Neuro-Fuzzy Maximal Power Extraction of Wind Turbine with Continuously Variable Transmission," *Energy* 64 (2014); Toshiyuki Sueyoshi and Mika Goto, "Photovoltaic Power Stations in Germany and the United States: A Comparative Study by Data Envelopment Analysis," *Energy Economics* 42 (2014); Ksenia Chmutina and Chris I. Goodier, "Alternative Future Energy Pathways: Assessment of the Potential of Innovative Decentralised Energy Systems in the UK," *Energy Policy* 66 (2014); Trieu Mai et al., "Envisioning a Renewable Electricity Future for the United States," *Energy* 65 (2014); Katerina Tatiana Marques Santiago, Fernando Menezes Campello de Souza, and Diego de Carvalho Bezerra, "A Strong Argument for Using Non-Commodities to Generate Electricity." *Energy Economics* 43 (2014); Erik Paul Johnson, "The Cost of Carbon Dioxide Abatement from State Renewable Portfolio Standards," *Resource and Energy Economics* 36 (2014): 332–350; and Zheng and Daniel M. Kammen, "Innovation-Focused Roadmap." There are a growing number of scenario analyses at the global level (Jacobson and Delucchi, "Technologies"; Jacobson et al., "Examining the Feasibility of Converting New York State's All-Purpose Energy Infrastructure to One Using Wind, Water and Sunlight," *Energy Policy* 57 (2013); Delucchi and Jacobson, "Reliability"; Budischak et al., "Cost-Minimized Combinations of Wind Power, Solar Power, and Electrochemical Storage, Powering the Grid up to 99.9% of the Time," *Journal of Power Sources* 225 (2013); Mark A. Delucchi and Mark Z. Jacobson, "Meeting the World's Energy Needs Entirely with Wind, Water, and Solar Power," *Bulletin of the Atomic Scientists* 69 (2013); Cochran, Mai and Bazilian, "Renewable Energy Scenarios."

[50] U.S. Department of Energy, *Wind Vision*, xv.

[51] U.S. Department of Energy, *Wind Vision*, xxxvi.

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

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

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

---

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

[56] 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.

[57] 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.

[58] 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.

[59] 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.

[60] 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.

[61] Lazard, Version 13.0

[62] Steve Nadel and Lowel Unger, 2019, *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half*, ACEEE, Septermber.

[63] Jacobson, Mark Z., et al, 2015, "100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States." *Energy and Environmental Science* 8.