CLEAN ENERGY DEVELOPMENT:

A Modern Approach to Government Involvement

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Contents

EXECUTIVE SUMMARY

Nuclear energy is currently the largest provider of low-carbon electricity in the United States. As reducing carbon emissions becomes a higher priority domestically and internationally, it is critical for nuclear energy to play a significant role in rapidly decarbonizing the energy sector. As a result of rapid changes in energy markets over the last 10-15 years, nuclear energy has been largely unable to compete in wholesale energy markets. Falling costs in solar, wind, and natural gas have undercut the profits of nuclear. Government incentives for renewable generation have succeeded in rapidly growing generation from the energy sources and reducing costs, giving them an edge in wholesale markets.

Though a growing market share for renewables is generally looked on favorably by environmentalists, the growth has, at times, undercut the more central goal of reducing carbon emissions. Wholesale energy markets operate under the tenets of the Public Utility Regulatory Policy Act (PURPA) and the Energy Policy Acts of 1992 and 2005. These pieces of legislation set the stage for the deregulation of energy markets, incentivizing cost reductions using market based principles for energy sale. However, electricity's trade as a commodity creates price distortions not present in many other market goods. Similarly, structural incentives for renewables from PURPA combined with solar and wind specific subsides have quickly altered electricity markets. Purchase mandates for renewable energy and the growth of non-utility generators of electricity has increased the frequency of negative pricing spikes, i.e. baseload generators (coal and nuclear) paying consumers to use their electricity.

Energy demand in the United States is expected to grow to as much as 28% by 2050. The growth of non-utility generators and utility scale renewable projects is expected to continue, while nuclear energy is projected to decline. Nuclear energy has enjoyed support from the Trump, Obama, and G.W. Bush administrations, yet none have taken sufficient steps to prevent the slide of nuclear energy. The growth of nuclear energy is a fundamental assumption from the Intergovernmental Panel on Climate Change, and is an important part of preserving American energy independence and aligning the energy sector with public policy goals. The Federal government needs to take immediate steps to establish deployment incentives for nuclear energy to encourage growth in the sector and prevent the loss of nuclear leadership internationally.

The decline of nuclear energy is not inevitable, but current trends should not be ignored if the United States is to meet its energy goals. Rather than extending renewable specific tax incentives past their 2021 expiration, this program should be expanded to include all low-carbon technologies. Generalization will reduce market distortions by aligning tax incentives with the overall policy goal of decarbonizing the energy sector and allowing technologies to compete with each other in a more natural form. Capping specific low-carbon technology investment must also be a priority to increase diversity in the energy sector and reduce waves of rapid investment in systems which create challenges for electricity markets.

Similarly, the success of renewable energy specific market protections at the state and federal level have allowed renewables to gain a significant market share that is only projected to grow. Reforming PURPA to update standards for avoided cost and qualifying facilities to match current market trends would more accurately price wholesale electricity. Finally, assessment of energy subsidies is critical for understanding their impact on markets and setting future policy priorities for lawmakers regarding government investment. An in-depth analysis from an independent commission to quantify and understand impact would set the groundwork for a national energy policy to reduce financial risk long term and spur investment.

The rapid implementation of these steps would allow nuclear energy to gain a foothold in the energy markets and lay the groundwork for nuclear energy expansion in addition to renewables. Decarbonization of the electricity sector is a high priority internationally and domestically, and has risen in popularity in American public opinion. As support for these initiatives grow, so too should support for nuclear energy as the United States seeks a robust, diverse, and clean energy sector.

FOREWARD

About the Author

Erik B. Olson is a senior at Utah State University in Logan, Utah. He will graduate in May, 2019 with a B.S. in Mechanical Engineering and a minor in Political Science. He currently serves as the student representative for the USU College of Engineering, and is looking forward to continuing his advocacy for engineering students to the College and University. Outside of his work in student government, he has been heavily involved in political advocacy and his fraternity, Sigma Phi Epsilon, in addition to his active membership in the American Nuclear Society and Tau Beta Pi. Upon graduating, he seeks to continue taking on large problems and advancing innovative solutions to complex systems. Erik is an avid skier and musician, and can usually be found on a mountain in northern Utah or playing guitar with his friends. He happily volunteers in the Big Brothers, Big Sisters program as a Big Brother, and is continually inspired by his Little Brother.

Acknowledgements

The WISE program is one of intense personal development. This summer, I have been pushed to grow, connect, and think critically about the issues facing the United States. I express my gratitude towards the Nuclear Energy Institute for providing an intellectually stimulating work environment and Dr. Gilbert Brown for providing so many meaningful experiences in Washington, D.C. I thank those who worked to establish and sustain the WISE program and to those at IEEE who keep it running today. I would like to thank Dr. Alan Levin specifically for his mentorship, advice, and challenge throughout the summer that will guide me for years to come. Finally, I recognize my fellow interns for sharing in this experience with me. Thank you all for bringing your diverse backgrounds and personal passion for striving towards more – you have each inspired me and made this opportunity one I will never forget.

About the WISE Program

Founded in 1980 through the collaborative efforts of several professional engineering societies, the Washington Internships for Students of Engineering (WISE) program has become one of the premier Washington internship programs. The WISE goal is to prepare future leaders of the engineering profession in the United States who are aware of, and who can contribute to, the increasingly important issues at the intersection of science, technology, and public policy. Each summer, the WISE societies select outstanding 3rd or 4th year engineering/ computer science students, or students in engineering/ computer science graduate programs, from a nation-wide pool of applicants. The students spend nine weeks living in Washington, D.C. during which they learn how government officials make decisions on complex technological issues, and how engineers can contribute to the legislative process and regulatory public policy decision making.

Terms/Acronyms

UN: United Nations
US: United States
EIA: Energy Information Administration
DOE: Department of Energy
EPA: Energy Policy Act
FERC: Federal Energy Regulatory Commission
PTC: Production Tax Credit
NEI: Nuclear Energy Institute
LWR: Light Water Reactor
AEC: Atomic Energy Commission
NRC: Nuclear Regulatory Commission
ERDA: Energy Research and Development Agency
FPC: Federal Power Commission
PURPA: Public Utility Regulatory Policies Act
NUG: Non-utility generators
IPP: Independent Power Producer
PUC: Public Utility Commission
LCOE: Levelized Cost of Electricity
CWIP: Construction Works in Progress
ISO: Independent System Operator
RTO: Regional Transmission Organization
LNG: Liquefied Natural Gas
DER: Distributed Energy Resources
ITC: Investment Tax Credit

INTRODUCTION

In 2017, more than 6.4 million Americans worked in the energy and energy efficiency sectors [1]. Though it comprises less than 5% of the overall workforce, the energy sector is responsible for creating, maintaining, and innovating technology for one of the most fundamental tools in modern society, electricity. Nearly 14% of all job creation in 2016 occurred in energy, making it an important driver of US economic growth. Since the development of tools for the generation and use of electricity, it has assisted in driving commercial innovation and improving the quality of life for billions of human beings.

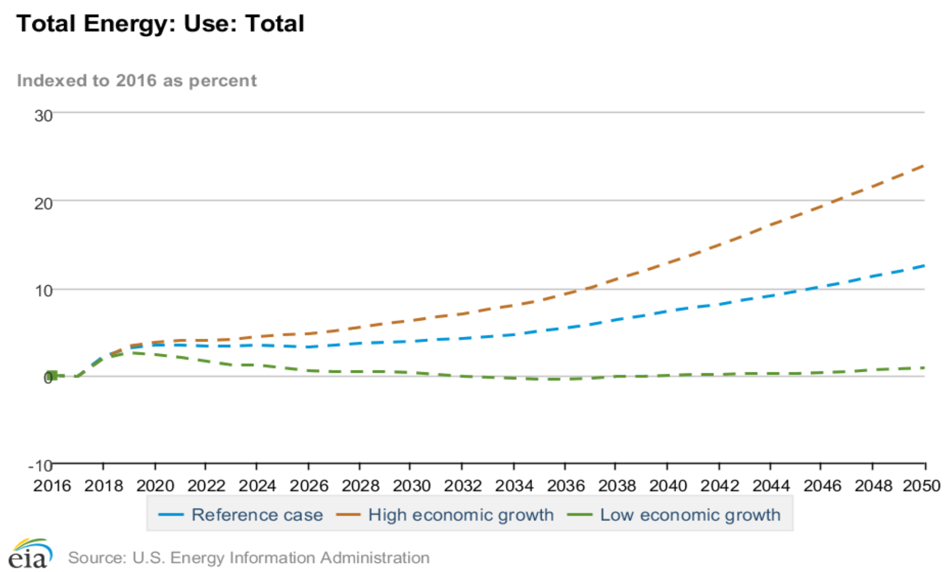

Figure 1: Total energy projections to 2050 demonstrated as a percent of current levels.

In the United States (US), electricity demand is expected to grow. Figure 1 from the Energy Information Administration (EIA) demonstrates projections that US energy use 2050 will be limited to 24% growth from current consumption assuming high economic growth [2]. Much of this energy use will be electricity, as electrification of the transportation sector grows in prominence. Despite these expectations, the US does not have a long term energy plan supported by the branches of government and American public. Though not having a current national energy policy, the United States now favors a diverse energy portfolio that minimizes reliance on foreign powers while reducing energy costs and increasing reliability [3]. As is the case globally, the US is also seeking to reduce carbon emissions. There is a growing call from lawmakers for clean energy investment by the Federal Government and the broader national lab and university research infrastructure. More than 29 states have adopted Renewable Portfolio Standards, mandating their state to reach a certain percent of renewable energy production [4]. Similarly, 8 states have put in place non-mandatory targets for renewables while public support for stricter clean energy standards and priority for non-fossil fuel based technology has greatly increased [5].

Both the federal and state governments play an instrumental role in energy. Through regulating, appropriating research funding, and developing policy that governs how energy is produced and distributed to consumers, the Federal government deeply influences trends in the industry. The Department of Energy (DOE), with $5.6 billion of its annual budget, seeks to make energy generation cheaper, more diverse, and cleaner [6]. State utility commissions are the primary regulators for a geographic area, and provide approval for specific projects under their jurisdiction. With Federal regulators and DOE, these entities determine how and where growth occurs in the sector.

The Federal government has been inconsistent on energy technology action and has largely not had a unified policy since the passing of the Energy Policy Act (EPA) of 2005. The EPA of 2005 defined strategic priorities that had been outlined by the G.W. Bush administration in response to growing energy needs [7]. Since the passage of the act, energy production from wind and solar has greatly increased. Solar energy now produces seven times more electricity than in 2005, and wind energy consumption has grown by an order of magnitude, shown in figure 2 [8]. Though the majority of solar energy gains have taken place at the large utility level, the public has also driven the residential solar market, as falling costs and government incentives have driven investment in both. Growth in wind has taken place almost exclusively at the utility level due to the large land footprint required. Over the same period of time, techniques for extraction and processing natural gas have advanced, resulting in falling prices and natural gas surpassing coal as the primary electricity generation source. With such rapid growth in solar, wind, and natural gas, the traditional mix of energy sources (coal, oil, gas, nuclear, and hydro) has been changing, bringing significant challenges for policymakers and energy regulators. What is the ideal mix of energy? How should the US balance clean energy goals with preserving resiliency and energy independence? And of particular importance to this paper, what role does nuclear energy play? How can the Federal government preserve, sustain, and grow the sector in accordance with energy priorities?

There are no simple answers to these questions. The American energy sector is one of the strongest assets of the US, providing high paying jobs and an avenue for economic growth. However, the changing energy market has had negative consequences on two traditionally strong sources of energy, coal and nuclear. Regulatory decisions in electricity

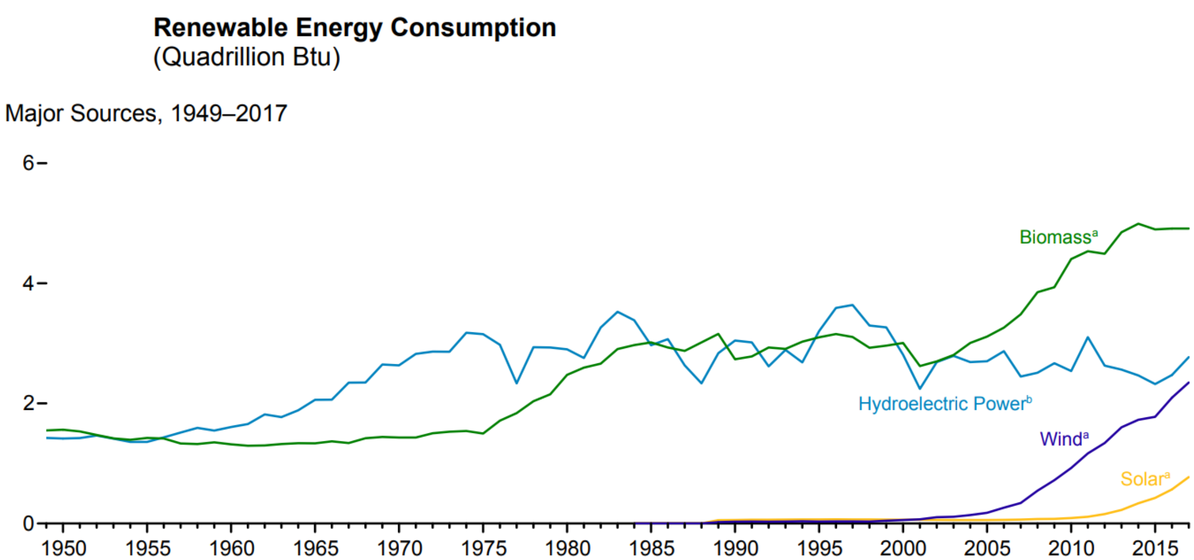

Figure 2: Renewable energy usage in Quadrillion Btu over time from EIA

markets are driving down costs and improving quality of transmission [9]. Falling prices are causing declines in profits for coal and nuclear plants, leading to closures of struggling plants by the utilities that operate them. The Trump administration has made it a priority to preserve the strength of these sectors, and recently directed DOE in a controversial move to keep several plants open that were slated to close. Under the authority of Defense Production Act of 1950, the plants were to remain open by obligating grid operators to purchase their electricity to preserve national security interests [10]. A similar move was rejected by the Federal Energy Regulatory Commission (FERC) earlier in the year with the same intent of preservation. The DOE order has created a renewed interest from the public on the merits of preservation of nuclear power the future of the technology in US energy.

The energy market has direct effects on the finances of every American. The average customer pays well over $1300 per year in residential electricity bills, and citizens are aware of the cost and outcomes of this market [11]. Due to the ubiquity of energy demand, virtually all interest groups, industries, and policymakers have a vested interest in the energy debate. Decision makers must factor in long term trends and implications when considering electricity rates. Our fossil fuel driven economy can change subject to geopolitical factors, as was evidenced by the energy crises of 1973 and 1979. Diversity in energy has value, and energy demand can change rapidly. If one energy source was unable to be used, or was directed for other purposes, increased demand would create significant spikes in prices. One such incident happened in the polar vortex in the northeastern US in 2018. Natural gas normally used for generating electricity was instead drawn to heat homes, creating an all-time high in price for consumers [12]. The utility company responsible for delivering electricity then burnt oil, only used as a backup due to its high cost, for electricity to prevent price spikes. If this cold spell had continued, significant measures would have to be taken to ensure heating and electricity could be provided to homes in extreme cold. Preventing similar scenarios requires policymakers to consider the benefits associated with diversity and reliability of delivery. Though short term price decreases are better for ratepayers, there are long term drawbacks to fewer sources of electricity being present. Understanding and valuing these tradeoffs is no simple task. The Federal government has tools to alter markets in way to reflect market shortcomings, but they often drive political debate.

The energy sector is subject to significant government intervention. Table 1 presents estimates the level of total government assistance in the sector to be higher than $1 trillion from 1950 to present day [13]. As renewable energy sources have begun to make up a larger share of the energy sector, some have questioned the large extent government has played in supporting their growth. This criticism has also been directed towards fossil fuels [14], nuclear [15], and biofuels [16]by varying groups. Renewable assistance in the form of subsidies and disbursements is the bedrock for the cost reduction and growth in recent years and has totaled more than $118 billion. In contrast to renewable growth, the nuclear sector has stagnated. In the same period (2005-present) that renewables grew by a factor of 12,

Table 1: A Summary of Federal Energy Incentives from 1950-2016
(Billions of Dollars)

TYPE OF INCENTIVE	ENERGY SOURCE							SUMMARY	
	Oil	Natural Gas	Coal	Hydro	Nuclear	Renewables[2]	Geothermal	Total	Share
Tax Policy	218	122	40	14	-	84	2	**479**	47%
Regulation	138	5	11	6	18	1	-	**179**	18%
R&D	9	8	43	2	85	32	6	**185**	18%
Market Activity	8	3	3	78	-	4	2	**98**	10%
Gov't Services	38	2	19	2	2	3	-	**66**	6%
Disbursements	3	-	-4	3	–27	34	1	**10**	1%
Total	**414**	**140**	**112**	**105**	**78**	**158**	**11**	**1,018**	
Share	40%	14%	11%	10%	8%	16%	1%		100%

several utility companies have canceled nuclear plant construction, suspended license applications, or have called on federal and state governments to take unprecedented measures to preserve nuclear plants at risk of closing. Renewables are not unique in their receipt of government assistance. Nuclear energy receives its own assistance, primarily in the form of research and development funding. Investment in renewables is generally considered successful as costs have fallen and deployment has rapidly increased. Nuclear energy has had its own victories; two new reactors are under construction and many others have received renewed licenses. However, the investment in nuclear has not yielded such dramatic results in growth and, more importantly, price reduction.

Why has government assistance failed to make nuclear energy competitive in electricity markets? What steps can be taken to ensure that new nuclear plants are built? Are subsidies being allocated effectively? This essay analyzes the intricacies of these questions and the landscape of government involvement in the energy sector. Policy recommendations are provided with the intent of improving the effectiveness of government assistance in meeting the energy goals of lowering electricity prices, decarbonizing energy production, and preventing the diminution of US leadership in nuclear energy.

THE ISSUE

The US has been the global leader in developing civil nuclear technology for power production since its inception in the 1950s, and early plans foresaw the construction of hundreds of nuclear power plants. Despite high expectations and promises of a new age of nuclear energy, however, that vision was never fully realized. Consequently, over time, US leadership began to wither. Currently, of the 94 GW of nuclear energy under construction globally, only 2.3 GW is in the United States [17]. Despite significant federal investment in mining operations, research and development, loan guarantees, production tax credits (PTC), and liability limits, several utility companies are considering prematurely closing nuclear plants due to lack of profitability. Federal assistance has proven insufficient, and state initiatives in New Jersey, Ohio, and New York seek to provide economic assistance [18]. Despite these measures, plant retirements and premature closures is driving the US towards producing nearly 20% less electricity from nuclear by 2030 assuming little change in the current market (e.g., no carbon tax, natural gas prices remain low).

American strength in nuclear has been a slow decline while retaining support in government and public opinion. Nuclear is waning, but not primarily due to political or social fallout, coordinated campaigns from special interest groups, or concerns of environmental hazards from radioactive spent fuel. Rather, nuclear energy is the accidental victim of economic forces that have come about from policies crafted over the last several decades. Unlike the stated goal set out in national and international environmental agreements to phase out fossil fuels from energy production, the US has never sought to specifically make nuclear power unattractive. In addition to the central debates on Federal government involvement in sustaining nuclear energy, the debate considers what is "clean", and what tradeoffs are acceptable as part of the cost of reducing our carbon footprint.

The Myth of Clean Energy

There are no sources of "clean" energy. Power production will inevitably bring negative consequences in the form of resource consumption and waste into the environment, among other effects. The damaging impact of fossil fuels from carbon dioxide and other environmental toxins is established as having a role in global climate change. Nuclear energy produces spent fuel that must be monitored and kept secure for hundreds of years and even thousands of years. Yet consider solar and wind, advanced as the energy source of choice by environmental advocates. Waste from solar panel manufacturing energy generation is not accurately tracked, but is estimated to total between 6,000 and 24,000 tons in 2016 alone. The production of windmills relies partially on rare earth elements from China, and produces significant amounts of toxic waste as a result. Estimates from MIT state that up to 2450 tons of rare earth materials were used in 2012 for windmill construction. Just one ton of these elements can generate up to 19,000 gallons of highly acidic wastewater [19]. These points do not, and should not, discredit the critical role wind and solar need to play in the US energy mix, but illustrate that all solutions pose challenges.

This discussion on energy requires a perspective through which to view those challenges. In recent years, anthropogenic climate change has gained a significant amount of interest from citizens, lawmakers, interest groups, scientists, and industries in addition to being considered one of humanity's greatest long term threats. Increased greenhouse gas emissions from widespread adoption of fossil fuel based energy production is well documented as the source of this global trend. As mitigating the mounting threat of climate change is the paramount goal of many environmental organizations, clean energy in this essay will refer to energy sources that do not generate greenhouse gases as an immediate result of electricity generation.

The Absence of Planning

The fate of nuclear energy is one of the most important debates occurring in the US. Even in the circumstance that nuclear energy is completely phased out of power production, the sequestering spent fuel and decommissioning plants will be a critical policy debate. Global nuclear production is set to increase, and 13 nations are beginning to develop or purchase nearly 50 reactors for power production in the next ten years [20]. Most concerning in this debate is the lack of an overarching plan for nuclear energy in the US. Since the stagnation of construction in the late 1980s, the US has not developed an effective strategy for its future that has withstood changing energy markets. The point bear reiteration: this was not planned by the US government. As the financial landscape shifted for utilities invested in nuclear, it was no longer a prudent investment. Energy consumption continued to increase as a whole in the United States primarily in the form of fossil fuels. The government did not drive the growth of nuclear, though it supported it. Nor did the government call for an end, though it crafted the policies that would undermine the profitability of nuclear energy.

Internationally, the US fares no better. The United States is one of the relatively few nations that has privatized nuclear power development and operation. Most other nations operate their nuclear fleets in government owned and controlled sovereign corporations -- nuclear is a national effort *by design*. Cost overruns do not lead to bankruptcy and cancellation of projects. More important, each project in those nations is under the direction of a single entity with operations overseen ultimately by the national government. Russia's Rosatom has been successful in leveraging this ability to export its nuclear technology to twelve nations. The geopolitical implications of Russian influence in nuclear technology cannot be understated: billions of dollars and guaranteed influence in a foreign nation for 60 - 100 years. National ownership and control of nuclear allows growth to be less concerned with economic forces, and more with national energy strategies and goals. Without a US strategy (aside from proliferation prevention) for nuclear, US technology is not allowed to be exported without adherence to very strict standards that are often not present from other exporters. This issue is currently being highlighted by US negotiations with Saudi Arabia over uranium enrichment.

Weakness domestically and little involvement internationally paints a grim picture for the future of US nuclear energy. Yet, in spite of this poor national planning, nuclear energy enjoyed support from recent presidential administrations and generally has bipartisan and bicameral support. President Bush signed the Energy Policy Act of 2005, increasing research and development (R&D) funding and ensuring access to $18.5 billion in loan guarantees for nuclear energy. President Obama cited expanding nuclear energy as a major part of the US Climate Action Plan and called for $900 million in R&D investment and continued use of $12.5 billion federal loan guarantees from DOE [21]. President Trump recently directed Secretary of Energy Rick Perry to embrace significant measures to prevent premature plant closures. All three presidents valued nuclear energy for different reasons, and took steps to support American nuclear power production.

None of the measures address the need in the nuclear industry for growth or addressed the policies that created the poor market for nuclear energy in the first place. As licenses have expired from construction in the 1960s, 1970s, and 1980s and few new plants are being constructed, the industry will decay. Suppliers of nuclear technology and American expertise in the sector will atrophy, and new nuclear construction will have larger and more expensive hurdles to implementation. Even with the assistance above, the nuclear sector has weakened. The absence of planning has yielded its results, and nuclear now faces an uphill battle to regain solvency and contribute to US efforts to decarbonize the electric power sector.

Financial Hurdles

Despite the significant financial hurdles to current systems, more than sixty companies in the US and Canada are working to develop and implement advanced reactor technology. Despite the purported benefits of these reactors, raising the necessary capital to finalize designs and test concepts poses a significant challenge. Strategic goals from Nuclear Energy Institute (NEI) estimate that 1-2 advanced non-light water reactors (LWR) designs may be deployed between 2030 and 2035 [22]. Financing the necessary capital, which can exceed $7 billion, poses a significant risk for unproven technology, and investors are hesitant [23].

There are several reasons for this financial gap. Nuclear energy plants are held to very stringent design and regulatory standards which raises cost of compliance. Regulatory structures and fees significantly delay going from blueprint to breaking ground. This time delay increases raises interest and risk over time, driving up the cost of any borrowed money. Though limited assistance from the government guaranteeing loan prices even when cost/time overruns occur is available, this benefit is not significant enough to overcome the risk for most investors. The upfront cost of nuclear construction prior to making and profit on electricity sale creates a difficult market for utilities, and companies have responded by designing new systems that require less of an initial investment.

Capital costs of nuclear are very significant, but are not the only financial threat to the industry. Electric power generation is the only source of income for the vast majority of nuclear plants. Despite some advanced reactor companies expanding beyond this model, profitable production of electricity remains the primary focus of utility companies and the financial modeling of newer reactor types. Over time, profits have decreased as electricity markets have changed, and nuclear utilities have been pushed to operate on razor thin margins [24]. If nuclear power is to be part of the energy sector and assist in producing low carbon electricity, these hurdles must be overcome.

Moving Forward

What, then, is the value of nuclear energy being a significant part of energy portfolio in the United States and in the world? The United States allocated more than $700 million to nuclear energy related R&D in FY 2018 and well over $85 billion since 1950. Additional subsidies in the form of liability insurance, production tax credits, and investment tax credits totaled from than $100 billion since 1950 [13]. The investment was successful early on, and nuclear power grew rapidly to 10% of American electricity production quickly and eventually to 20% by current day. Despite early growth, continued investment in nuclear has not yielded continued results, with the industry seeking to prevent its decline due to early plant closures.

In the same period, traditional renewables have received more than $158 billion in R&D, tax incentives, and disbursements (grants) from the Federal government, with 95% of the funding coming after 1975. This funding has helped solar, biomass, and wind to grow to be 7.6% of the electricity production market in 2017. With this much assistance in the sectors expected to continue over time, renewable energy sources are set to produce up to 20% of electricity production by 2050 [2].

The fossil fuel industry is one of the largest recipients of government sponsored benefits of all types. They will not be discussed in this paper. Though meaningful steps are being taken to increase efficiency and affordability of carbon capture/prevention methods, these benefits are largely not involved with attempts to decarbonize the energy sector. Though reining in these benefits is a necessary and meritorious discussion, it will not be conducted here.

Combined, the solar, nuclear, wind, and biomass energy sectors take up nearly a quarter of all energy related government funding [6]. With the promise of jobs, economic growth, low carbon electricity, and cheaper electricity, the Federal government has seen fit to invest the country into these sources of energy. As with many forms of government assistance, proponents will vigorously defend their own form of energy production and justify the benefits of the assistance. Policymakers face the task of understanding the breadth of these benefits and choosing how they can best be allocated to accomplish the goals of the Federal government.

HISTORY

Nuclear energy occupies a unique place in the history of politics and energy. An early goal of the civil nuclear industry was to pass development and operation onto the private sector [25]. The Atomic Energy Act of 1954 stated: "the development, use, and control of atomic energy shall be directed so as to promote world peace, improve the general welfare, increase the standard of living, and strengthen free competition in private enterprise [26]." Even at this stage, nuclear energy struggled to receive immediate financial support from private industries, which considered the energy source as a high risk investment due to the massive sums of capital required. The AEC had the difficult responsibility to promote the benefits of peaceful nuclear technology while also being its primary regulators and conducting weapons tests. The growth of the environmental movement in the late 1960's alongside historic cases of mismanagement combined with the untenable position of promoting and regulating led to broad disapproval of the AEC [25]. As a response to these trends, the AEC was abolished by the Energy Reorganization Act of 1974 and its duties were split into the Nuclear Regulatory Commission (NRC) (regulatory) and Energy Research and Development Administration (ERDA) (research, development, and promotion) which would later become the DOE.

This current NRC/DOE regulatory and development framework is what defines the nuclear sector today. The majority of growth took place in the 1970s and 1980s -- growing from 2.4% of electricity production in 1971 to 19.5% in 1988 [25]. After the high profile accident at Three Mile Island, in addition to significant cost overruns, the construction of many power plants was canceled and the industry's growth halted. Since 1988, little motion towards construction has taken place in the domestic nuclear energy sector. Significant capital costs and reduced demand in electricity leading to lower profits made nuclear an unattractive investment for private financiers. Despite these issues, there have been several revivals of interest in nuclear technology. Expansions in government support in 2005 and 2009 under the Bush and Obama administrations led to 4 planned nuclear reactors in South Carolina and Georgia as part of the growth in US clean energy and calls of a nuclear "renaissance." Global recession beginning in 2009, declining natural gas costs in the 2010s, and construction cost overruns on the planned projects led to the cancellation of two reactors and further challenges on the remaining two [27].

The "renaissance" faltered, even as new, more advanced, designs of reactors were being thought up. NEI estimates that between 15 and 20 of the 99 total plants are at risk of closure in the near future because of market concerns and a lack of competitiveness with natural gas [28]. Once operation ceases at a plant, it is highly unlikely that they will begin again. Meanwhile, only one company is going through the licensing procedure for a new, small type of reactor with plans for commercialization in 2025. These are economic, and not regulatory, decisions by the utility companies. The sector is in a critical period of decision making, and is seeking respite from any source. In 2018, President Trump is attempting to address the threat of premature closures through an order to Secretary of Energy Perry [10].

The history behind nuclear energy is important for understanding the current state of the industry. Economic struggles have stifled growth since the 1980s and falling electricity prices in modern day markets has rendered nuclear energy uncompetitive. Many plants built in the construction boom from 1970 to 1988 operate on extended licenses that will be up for extensions in a difficult economic setting if not closed prematurely. While fundamental design innovation has begun, timelines place commercialization to be at least 20 years away for the majority of designs. Historical trends with nuclear technology must also be recognized in the policy framework of energy in the United States.

BACKGROUND

Understanding the challenges nuclear energy faces requires knowledge of the fiscal and regulatory environment surrounding the technology. The economics of power production are distinct from many other markets in the United States. Modern energy market structures create unique challenges due to the high capital investment and poor valuation of non-financial attributes of nuclear. Government sponsored assistance is heavily intertwined with energy markets, and is used to foster technological innovation and achieve public policy goals. Public policy has a drastic effect on the success or failure of nuclear energy and must be considered when evaluating the future of the sector.

Electricity Markets

The production and sale of electricity operates on one primary principle, demand for electricity must equal the supply of electricity being produced at any one time. Energy is expensive to store, and technical challenges have prevented large, commercial, adoption of energy storage technology. Therefore, electricity must be produced at the time it is needed and distributed to the entity desiring to use it - an office building, home, or factory, for example. Immediacy of need is the physical basis of the electricity grid, the constraint that drives pricing and forms electricity rates. Economic forces of supply and demand coupled with the physical constraint of transmission leads to fluctuating prices over seasons and

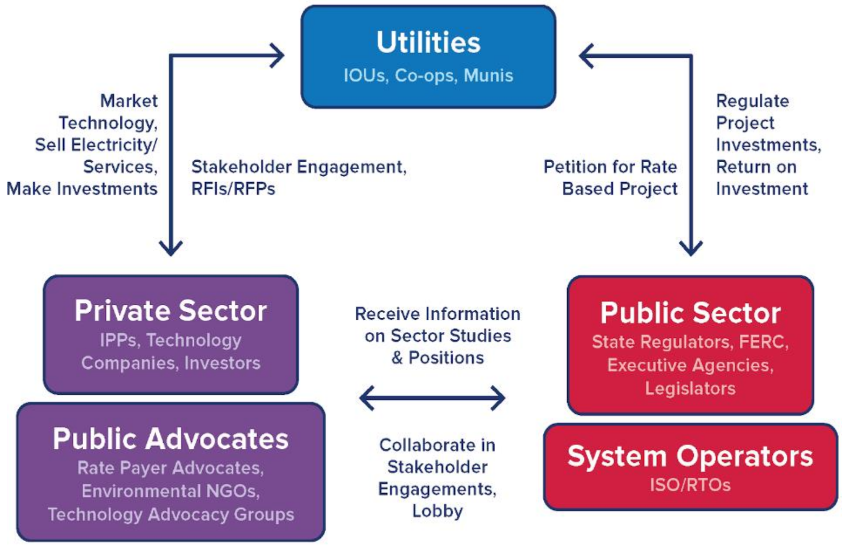

Figure 3: Representation of the stakeholders in electricity markets and types of interaction between them, Yale Center for Business and the Environment.

even over the course of a day. As demand for electricity changes in a day, prices change in response. Government plays a role in setting prices and ensuring equitable pricing and transmission for consumers.

The relationship between the Federal government and energy production goes back to the early 1900's. The first government regulation came after the passage of the Federal Power Act of 1920. Prior to this act, energy production was not considered to be under the jurisdiction of the Federal Government. Conflicts over hydroelectricity production between industries and states led to the bill's passage and the creation of the Federal Power Commission (FPC). The Federal Power Act of 1920 set the stage for Federal regulation and oversight of electricity markets [29]. As utility companies developed, expanding to interstate markets happened quickly due to high startup costs and but relatively low cost of development.

Over time, the FPC's role quietly became more important as the American energy grid grew. Increasing regulatory requirements became cumbersome, and the energy industry began to shift. Government restructuring of electricity regulation led to the FPC being dissolved and transferring its responsibilities to the new FERC. FERC's primary purpose is to regulate the wholesale sale of electricity and natural gas in interstate commerce and regulates the transportation of oil by pipeline in interstate commerce [30]. FERC oversees the interstate and wholesale energy markets and ensures those markets are equitably and efficiently distributing and pricing electricity. Private stakeholders in addition to utility companies often interact with the Commission, as shown in figure 3 [31]. Transferring of information, advocating for regulatory changes, and driving investment all occur between the main players in energy. While states and other government entities play a role in electricity transmission and regulation, FERC has the largest impact on a national scale by impacting pricing and approving regulatory decisions. FERC gained an even greater role in energy markets with the passage of the Public Utilities Regulatory Policy Act of 1978 (PURPA). This act altered the structure of the energy market, ending the provision that all energy companies operate most efficiently as a monopoly [32].

Prior to the passage of PURPA, the majority of utilities operated as a vertical monopoly. This economic term means that the same entity that produces electricity is also responsible for transmitting and ensuring that electricity reaches customers within their market. Moreover, they are protected as a monopoly and are the only entity legally *allowed* to do this Vertical monopolies are protected by the government in markets where costs of producing a good or service requires significant initial investment, making competition unlikely once one entity has developed the necessary infrastructure to provide that good or service. In energy markets, the electricity provider (utility) is the only option for power providing in a region and must be regulated by the government to ensure rates are fair for consumers while also allowing reasonable profit for the utility.

Vertical monopolies were the standard for most electric power production until the 1970s. Over-reliance on oil for American energy needs coupled with increasing energy use over time drove the US into two energy crises when oil prices spiked in the 1970s. These crises drove the Carter administration and Congress to enact in the Department of Energy Organization Act of 1977 (DOEA) and the PURPA. DOEA created the FERC from the skeleton of the FPC. PURPA created energy efficiency standards and provided incentives for lowering energy consumption. The legislation also tackled the issue of non-utility generators (NUG) or independent power providers (IPP) in energy markets. NUG/IPP (used interchangeably) are entities that generate electricity but do not own transmission lines. Prior to PURPA, utility companies were the only significant owners of power producing entities, with little private capital funding NUG/IPP since the electricity they produced would not be bought [32].

PURPA's passage had a remarkable impact on the energy generation landscape. As prices for solar and wind energy began to decrease with greater government incentives and research funding, solar and wind projects became more competitive on a traditional market. Private development of new NUG/IPP renewable projects began, and state and regional utilities were now obligated to buy electricity from these projects. Section 210 was the first step to breaking down the vertical monopoly previously held by utility companies [32].

The Energy Policy Act of 1992 continued deregulation steps and opened the door for electricity to be treated like a commodity in the market. Monopolies were broken and regulatory authority was transferred to FERC as electricity began to be sold on a "wholesale" basis. Consumers now had options as to where they received their electricity from rather than being obligated to a specific utility company. In these areas, prices tend to be lower and the markets operate more efficiently because consumers have the option to choose the utility which provides the lowest rate [9]. Competition has driven down costs and has altered the environment in which energy sales take place. In these markets, utilities seek to lower nominal costs that make their rates as low as possible.

It is important to note the distinction between federal, state, and regional authority over energy markets. FERC controls interstate and wholesale markets, but state public utility commissions are, in most cases, the primary authority in regulated energy markets. These Public Utility Commissions (PUC) negotiate rates with utilities operating in that state. At times, these commissions operate at a regional level, varying across the nation. These entities typically operate using the same guiding principles and align with FERC, but there are noteworthy exceptions. PURPA and EPA of 1992 applied equally to state and regional commissions, and they were left responsible for determining whether an NUG/IPPs met the guidelines for a qualifying facility. Differing state authorities and interpretations of rules has led to conflicts and uncertainty in many regions. Each state regulator is responsible for overseeing the implementation of PURPA and can influence the deployment of renewable energy in regulated markets.

PURPA, the Energy Policy Act of 1992, and subsequent orders gave FERC the critical role of shaping access to markets and the ease of which a power providing entity has access to that power market. The avoided cost rule has particularly impacted regulated markets, as wholesale markets were exempt from the purchase obligation by the EPA of 2005, prior to the widespread growth of renewables. However, wholesale markets incentivize low prices in the near term, while not reflecting benefits that are difficult to quantify in a financial market.

Nuclear Energy's Economics

The nuclear industry is inherently tied to electricity markets. Though some advanced reactor companies are looking into diversifying sources of revenue, the near future will be dictated by how effectively nuclear technology can supply electricity at competitive cost. The most common measure to compare costs of producing electricity is known as the levelized cost of electricity (LCOE). The LCOE aggregates all cost spent on all steps necessary to produce electricity (actual dollars spent) compared to the electricity produced over the lifetime of that source, providing an estimate of cost per kilowatt hour (kWh) over the life cycle of a power producing entity. While this measure does allow for simple comparison, it is not without weaknesses. The LCOE tends to be more accurate for energy sources supplying dispatchable power, i.e., power that can be produced at any time, rather than intermittent sources from renewables [33]. Renewable energy sources are non-dispatchable, and cannot adjust their power output to meet demand. Prices of electricity are shown below for the major energy sources in the United States in table 2 [34]. Nuclear energy has one of the higher LCOE's -- only lower than coal and offshore wind.

Table 2: Tabulated prediction of LCOE of various energy sources entering service, EIA.

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit[1]	Total LCOE including tax credit
Dispatchable technologies								
Coal with 30% CCS[2]	85	84.0	9.5	35.6	1.1	130.1	NA	130.1
Coal with 90% CCS[2]	85	68.5	11.0	38.5	1.1	119.1	NA	119.1
Conventional CC	87	12.6	1.5	34.9	1.1	50.1	NA	50.1
Advanced CC	87	14.4	1.3	32.2	1.1	49.0	NA	49.0
Advanced CC with CCS	87	26.9	4.4	42.5	1.1	74.9	NA	74.9
Conventional CT	30	37.2	6.7	51.6	3.2	98.7	NA	98.7
Advanced CT	30	23.6	2.6	55.7	3.2	85.1	NA	85.1
Advanced nuclear	90	69.4	12.9	9.3	1.0	92.6	NA	92.6
Geothermal	90	30.1	13.2	0.0	1.3	44.6	-3.0	41.6
Biomass	83	39.2	15.4	39.6	1.1	95.3	NA	95.3
Non-dispatchable technologies								
Wind, onshore	41	43.1	13.4	0.0	2.5	59.1	-11.1	48.0
Wind, offshore	45	115.8	19.9	0.0	2.3	138.0	-20.8	117.1
Solar PV[3]	29	51.2	8.7	0.0	3.3	63.2	-13.3	49.9
Solar thermal	25	128.4	32.6	0.0	4.1	165.1	-38.5	126.6
Hydroelectric[4]	64	48.2	9.8	1.8	1.9	61.7	NA	61.7

Nuclear energy has a high LCOE despite having one of the lowest operation costs, i.e., the cost of producing electricity once the plant is built. Fossil fuel plants tend to be cheaper to build, but more expensive to keep running. This tendency is heavily dependent on the current cost of the source of fuel, which can greatly shift for a variety of economic and geopolitical factors. Renewables have low operation costs once installed, and, similar to nuclear, incur the majority of their costs at the onset construction and installation phases. The relatively low operation costs for renewables and nuclear means that the longer a unit produces power, the lower the LCOE becomes [33]. Large nuclear plants (1000-1500 megawatts) have estimated construction costs of $7-9 billion prior to producing electricity. Plants of this size are most common, and capital costs are heavily dependent on the funding agreement. Some utilities are allowed to charge for the cost of construction works in progress (CWIP) – interest on money borrowed to pay for construction in their rates. In this case, capital costs may be reduced because interest is not included in the capital costs [18 C.F.R § 35.25]. Without such an agreement, nuclear powered electricity becomes quite risky in a constantly shifting regulatory and financing environment. One major draw for investors is options for loan guarantees which provide assurance that the Federal government will "cover" a portion of the loan if the entity defaults on its own capital. This reduces the risk to investors as the amount of money they are responsible for is lowered. This does not mean the Federal government is providing the funding, but lowers the pressure and encourages investment to overcome a significant finance gap. Another significant part of nuclear electricity economics involves the subsidies present for production once the plant is established. If the margins of profit between operation costs and price of electricity are not high enough while producing electricity, a financier is much less likely to invest in a plant.

Funding decisions regarding electricity rates are critical for nuclear power utilities. As described before, state regulators are the primary authority in regulated markets. Making decisions on allowing a CWIP, for example, can determine whether or not a nuclear utility project will be financed. Policies on choosing state utility commissioners and the decisions they make regarding oversight and rate structures can be drastically different. This difference was in part highlighted by the construction on two projects in Georgia in South Carolina. Regulatory processes and decisions and the political nature of South Carolina's selection of commissioners have been pointed to as partially at fault for the canceling of the nuclear project in the state [35]. In regulated markets, state-by-state variance in PUC governance is the primary authority, and will impact decision making surrounding nuclear utility projects.

The performance of nuclear plants in regulated and retail electricity markets has varied dramatically. In retail markets, nuclear power plants often cannot compete with low natural gas prices in the region [36]. If a plant cannot sell electricity at a competitive rate, that plant will have fewer customers purchasing electricity, compounding losses for a utility owned nuclear plant. Retail markets are the greatest threat to the current nuclear fleet due to the unforeseen cost reductions in renewables and natural gas. Direct incentives for renewables in market pricing structures and subsidies can result in a power plant paying to have its electricity used, significantly undercutting its own profits. As regulated markets have more consistency in rates, nuclear plants have less risk. Market deregulation has been successful in reducing prices to the point that nuclear energy is much less competitive than when plants were built in the 1970s and 1980s [36]. Price reductions are a beneficial market change, but the unintended and rapid threat to nuclear energy has led to lawmakers considering options to prevent the loss.

The Role of Government in Markets

The energy market is subject to significant government impact. The generation of electricity for personal and industrial uses has developed hand-in-hand with governmental relationships. As Thomas Edison and Samuel Insull's General Electric began to grow to commercial scale, they faced the threat of municipalization, the seizing of private investments in a certain industry to be controlled by a local government. To prevent this, Insull pushed for the regulation of the electric power industry as a natural monopoly and public utility (similarly to railroads) [37]. In time, the Federal government exerted greater control as discussed with the FPC, FPA, FERC, and PURPA.

The government's vested interest in electricity production has had many important outcomes in energy policy. Subsidies are one tool used to develop or incentivize an entity, industry, or field that aligns with the national or state goals, but would not be viable in private markets alone. Electricity is the form of energy most desirable for many household purposes such as refrigeration or lighting, and is proven to increase the quality of life as access to it increases. As such, the government faced the challenge of increasing access to as many Americans as quickly as possible. The government's role as a regulator and acknowledgement of electricity production as a monopoly led to prices being somewhat fixed, with a certain profit ratio for utility companies [38].

The government has played a role in every major industry in the US. From tax credits to loan guarantees in every sector from mining to art, the market is rarely allowed to be truly free. However, government assistance oftentimes is critical for getting an industry off the ground and making advancements in technology that serves the government's interests. The reasons for government involvement in an industry are varied, and the methods employed are even more greatly varied. National security or protection of American industries is often tied to the reasoning behind creating or continuing a subsidy. For example, subsidies that make rare earth mining a better investment in a rural community will bring jobs (income and tax dollars) to that community while also ensuring the US is less dependent on foreign sources of those elements for military grade lasers. Applied to energy, the creation of an ITC for solar power will increase the share of electricity independently produced in the United States, while also having the benefit of not emitting carbon. However, some methods of government assistance are much more difficult to quantify and track impact. Whereas subsidies have a specific dollar amount associated with them, government research into aircraft engines leading to spinoff technology in the commercial sector is less clear. This is not a "subsidy" in the strict sense, but does greatly impact the industry.

Subsidies, then, serve as one tool for the government to advance a goal. The price of a commodity does not necessarily reflect those goals unless the government alters the market in some way.

POTENTIAL SOLUTIONS

As nuclear energy is predicted to decline, the industry is looking into many options to prevent the slide. Since the Economic Recovery and Stimulus Act in 2011, spending on renewable energy subsidies has decreased by more than $4 billion a year [13]. Similarly, direct federal intervention and subsidies (excluding technology research and development) for nuclear power has decreased from $1.5 billion in FY 2010 to $365 million in FY 2016 [39]. In order to keep nuclear a viable part of the clean energy mix of the United States, more direct funding towards nuclear energy would be valuable. However, the political likelihood of such a step is low. Therefore, potential solutions to regain nuclear solvency must be limited to the benefits already being provided to clean energy sources.

One solution commonly advanced by clean energy producers is a fine or tax on carbon emission. Though generating a significant amount of public discussion in recent years and even garnering support from ExxonMobil [40], this solution is unlikely to have a significant amount of backing to push it through the political process. Disagreements on amounts and the specific nature of a program like this spark debate and would be the source of controversy. This program would then need to go through a Republican-controlled government that has been lackluster on such solutions. Additionally, fines discouraging any behavior tend to be less desirable by most corporate entities and have had limited success as a public policy tool [41].

Recent efforts to promote nuclear energy have also focused on the renewable energy mandate system put in place by many states. These mandates require that a certain percent of a state's electricity be purchased from traditional clean energy sources (solar and wind) in a certain timeframe. Many in the industry have cited this policy as being counterproductive in reducing emissions because of the fact that these policies may also lead to premature closure of nuclear plants that are not included in the mandates [42]. By expanding these standards to include all forms of clean energy, states could more aggressively decarbonize their electricity sectors. Though these measures have promise, they are largely dictated at the state level as no unified emissions plan is currently enacted in the United States. Under President Obama, the Clean Power Plan was put in place to require the nation (divided into regions under the plan) to reduce emissions by a certain target amount. This plan was allowed to be developed internally by a state or region. If no plan was developed by a state, the EPA was to develop and implement its own plan for emissions reduction in that state. With President's Trump election, the CPP is in the process of being formally repealed and a less stringent replacement emissions plan is being implemented [43]. This places the adoption of federally-driven mandates of any kind to be doubtful.

There have been calls for the government to abandon the deployment-based approach to nuclear assistance and instead move towards innovation support similar to DOE's Gateway for Accelerated Innovation in Nuclear (GAIN). The government has played a significant role in allowing emerging markets and technology to take root. Two main approaches to government management as it relates to nuclear have emerged to assist the industry. The Breakthrough Institute advocates taking the example of other commercialized industries with similar challenges and applying those regulatory and government support structures that foster innovation at the startup level [44]. There are others who advocate complete control on innovation, and moving nuclear towards sovereign control present in other nations. They maintain that the benefits of nuclear are difficult to quantify using market forces alone, so the government should ensure that nuclear survives by expanding its own role in financing and operations. Innovation would take place at the national lab level and only certain technologies would be chosen to be deployed in this approach [17]. Both approaches require significant regulatory and/or market intervention, and were not considered due to the required magnitude of change. Additionally, the government's abilities to select industries and technologies for development and implementation is not held in high esteem. "Picking winners and losers" is deeply unpopular politically and has had, at best, mixed results.

The United States needs to take action to correct mistakes in political priorities and take meaningful steps to secure the future of US civil nuclear power production. Preservation of the current fleet is important, but the health of the sector depends on future growth and production, which means addressing the financial chasm for current reactor operators and fourth generation reactor startups and making new nuclear a stronger investment for private capital. Though mentioned as a priority many in the industry and in government, previous efforts have been, and will continue to be, insufficient.

REOMMENDATIONS

For the nuclear sector to gain immediate benefit from the government, and its intrinsic value to be recognized, there must be several major changes to the structure of renewable and nuclear energy R&D, tax expenditures, and direct expenditures. These changes must be deployment-focused to preserve the nuclear supply chain and incentivize investment in the sector. For nuclear to regain a competitive edge domestically, several funding programs must be altered.

Allow the Solar ITC and Wind PTC to Expire

Wind energy currently receives one of the largest subsidies in the form of the Renewable Electricity Production tax Credit (PTC). The credit was established in 1992 as $0.015 per kWh (1993 dollars) and has been extended several times in 2005, 2009, 2012, 2015, 2016, and 2018. However, stepwise decreases have begun to take effect and the credit is currently at $0.019 per kWh (2017 dollars) and will be reduced even further to 40% of 1993 level, expiring completely in 2021 barring further extensions [45]. These production credits have been used to greatly expand wind energy's growth, and should be allowed to expire as wind now has a significant foothold in the energy market. Benefits should not be extended at their current levels in order to free funding that may go to other low carbon technologies that can serve to diversify and expand the American energy sector. Limiting these subsides solely to wind power stifles the funding available for other investment. Though wind energy has been shown to have other competitiveness issues on price alone, it is a significant part of the American energy sector and will be continue to be as the R&D continues and renewable portfolio standards are put in place.

Similarly, the solar based Investment Tax Credit currently provides up to 30% of cost savings to any entity (commercial or residential) in the form of a tax credit [46]. This tool has been a significant resource for the growth of solar energy due to the reduction in up front capital costs associated with solar investment, spurring financiers to invest in solar. The benefits of this credit are well established, and have allowed significant investment in solar energy to take place as prices have fallen into competitive levels. Even without the subsidy, which was set to expire in 2016, and was then extended to 2021, some sources predict that cost increases from the removal of this credit to be as low as 2.5% of current cost [47]. For such a perceived low benefit, this subsidy is responsible for almost a quarter of all renewable energy spending ($1.25 billion), 680% more than similar subsidies for nuclear energy [13]. Solar now represents 1.9% of the US total electricity market and is predicted to grow to 8.2% of all electricity production by 2050 [2].

Allowing these credits to expire without future extensions will provide options to lawmakers to reassess low carbon energy investment. Extending current credits adds on to the already significant market benefits and regulations not present for other sources of low carbon energy. Incentives that spur investment and growth in a technology are beneficial, provided that they are phased out once an energy source matures. Then, funding should be generalized to achieve a policy goal of the government, such as investing in low carbon energy sources.

Consolidate Low-Carbon Credits

As mentioned previously, decarbonization, as well as energy diversity, is one priority for many policymakers as well as low-carbon energy industry advocates. One way the industry can incentivize low-carbon-emission energy sources in addition to promoting diverse technologies would be generalize subsidies currently focused on wind, solar, and biomass to all low carbon technologies. Subsidies should be based on deployment cost of the technology applying for the credit and should be generalized to include all low energy technology provided they meet certain criteria. The option should be given to take the credit in the form of an ITC or PTC based on the needs of the developer. The length of a PTC credit should be based on the expected lifespan of the plant, whereas an ITC should be based on the overnight cost of construction. Providing options allows clean energy sources to adapt to changing markets in order to encourage continued investment. To prevent one type of utility company from gaining too much of an edge no energy type should receive more than half of the entire subsidy amount each year, assuming this amount is capped. This levels the playing field for all competitive forms of electricity and thereby can allow the market to operate more naturally while still pursuing clean energy.

Cap Technology Specific Investment

Tax incentives should be capped to limit the total amount given to any single state, region, or entity. The tax credits for wind and solar are prudent because they encourage financiers to invest and provide critical start-up capital and make the investment less risky to renewable projects. However, not limiting the subsidy to a specific amount of new power productions has led to growth in areas where distribution challenges and overall competitiveness as part of the grid has not been considered. The nuclear energy production tax credit is limited to the first 6000MW of generation brought online, meaning that only early nuclear plants will benefit from the price reduction. Similar caps for any specific technology qualifying for the low-carbon credit should be implemented. Caps on actual output allow for predictable growth in the energy sector and ensure that no singular energy source will grow at unsustainable levels at the expense of other energy sources. Capping the investment allows money to be freed to invest in other sources of clean energy. This would allow the current incentive to scale down on schedule while allowing other funding to take place. A cap on incentives ensures that growth occurs in desirable sectors with a reduced potential for over-subsidizing specific electricity sources. The caps can be set on strategic targets for emissions reductions and grid reliability. This requires no greater funding to be allocated, but is a more efficient allocation of tax subsidies.

Extend Time Frame for Nuclear Production Tax Credit

One benefit the nuclear energy industry currently receives comes in the form of the PTC for advanced nuclear power plants. Originally conceived as part of the EPA of 2005, the PTC was extended as a part of HR 1892, the Bipartisan Budget Act of 2018. This tax credit provides a price reduction of $0.018/kWh for the first 8 years of service of that nuclear plant [48]. This credit, while having a modest impact, does not make a large enough impact on the futures of a nuclear energy plant. Similar credits for wind energy vary in amount depending on the date (see above) but continue for 10 years. Wind turbines can have varying lifespans, but performance generally decreases over time. The average turbine lasts between 20 and 25 years [49]. This means that the wind PTC is present for around half the lifespan of a wind turbine. For a similar relationship with nuclear energy, the advanced nuclear PTC should last 20 years [50] and, if extended the PTC should be extended retroactively to cover the first half of a nuclear plant's life. Extending the PTC provides more certainty to long term financing as natural gas and renewable prices fall. By extending this credit, new nuclear projects in the near term becomes more desirable and advanced reactors can benefit as their industry grows.

Reform Section 210 of PUPRA

Lawmakers should take steps to reform the problematic sections of PURPA, specifically the mandated purchase of renewables if avoided cost is competitive. Renewables are now a significant part of the energy portfolio, and oil is down to 1% from 15% in the 1970s [51]. Requiring purchases of renewables undermines long term funding models that nuclear energy electricity producers depend on. Section 210 of PURPA outlines what defines a qualifying facility for being allowed electricity purchase priority. Several technical criteria for qualifying facilities outlined in PURPA do not reflect the current energy market. Altering these criteria to reduce loopholes would prevent exploitation by energy companies seeking to take advantage of the regulations. Reforms of these purchase mandates have undercut nuclear technology profits and are driving plants towards economic shutdown. PURPA's goal is to increase overall electricity generation and encourage development of low carbon electricity. Requiring the purchase of renewables under legislation written decades ago, prior to explosive growth in renewables is archaic. These legal facets contribute to the shutdown of a low carbon nuclear plant, undercutting energy goals and the stated purposes of PURPA.

Expand Understanding of Subsidies

Due to significant government intervention at all levels of the energy market, there is little consensus as to what defines a subsidy. Different sources find wildly varying estimates of the total amount given, and what effect that has on the viability of an energy source. Without a clear understanding of exactly how the government provides assistance and what impact this has provides no clear options for sound alignment with public policy goals. Though the reduction or removal of a subsidy is very contentious politically, understanding the full picture would be valuable for policymakers. The Federal government should establish a blue ribbon commission to analyze the full effect of subsidies on the energy market and gain consensus on the quantities of government benefits in the sector and the effects this money has had. No efforts have been made so far to develop a basis for subsidy analysis at high levels of government. The Energy Information Administration provides documentation on its estimates of direct government assistance in energy with their own objectivity standards [39], but no specific body has looked at the larger picture of government involvement and its total economic effects. The EIA's reports provide a basis for money allocated each year, but do not look into its effectiveness or impact on the sector as a whole. An economic focused blue ribbon commission could use this data to begin an analysis of the government's true effect in energy markets, and begin looking deeper than annual appropriations.

CONCLUSION

Nuclear energy's future in the United States is not dim. Public support for action on climate issues is increasing and has become a top priority for environmentally minded lawmakers on both sides of the aisle. Federal support for advanced sources of energy is strong, and has weathered calls for reductions in R&D. The Federal Government's investment in the energy sector is critical for continued growth. Subsidies, taxes, and loan guarantees all serve the purpose of advancing the government's goals of a strong and reliable energy sector that is clean and affordable. This action is not limited to the Federal government. Several states have recently passed legislation crediting low-carbon energy sources, nuclear energy included. These efforts have preserved the profitability of nuclear energy and served to ensure its presence as part of a diverse energy mix. Though conflicted at times, the Federal government has continued to support clean energy. The recommendations listed above provide a roadmap for ensuring the government advances its goals quickly and that the most prominent low carbon energy source in the United States does not wither as it attempts to pursue cleaner and cheaper energy.

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