US Electricity Policy 2009

STUDENT ANALYSIS AND RECOMMENDATIONS

A Report by
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at The University of California, Santa Barbara

Table of Contents

About this Report

Power Shift 2009 is a student convergence in Washington, D.C. meant to promote the creation of a green economy based on renewable energy. With upwards of ten thousand young people from all over the country united in the nation's capital behind this cause, the student voice cannot be ignored. The report seeks to broaden the impact of this movement by presenting concrete recommendations derived from rigorous research and trend analysis to illustrate the economic and social advantages of shifting energy policy toward the aggressive stimulation of clean electricity on a large scale. The authors seek to engage government officials rationally, with professionalism and respect, to show that the nation's youth are dedicated to working with decision makers, rather than against them, in the pursuit of a sustainable economic future. The insights provided herein are meant to encourage fiscally responsible improvements of federal policy by providing new perspectives from the student constituency.

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The Environmental Affairs Board, a branch of UCSB's Associated Student Government, is the largest environmental group on campus. EAB engages environmental issues at every level, from campus and community activities to statewide and national policy. EAB was UCSB's 2007-08 student organization of the year.

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Executive Summary

This student-written report reflects values and concerns held by youth from all over the nation regarding the state of US energy policy in the shadow of anthropogenic climate change. It focuses specifically on electricity supply by source, highlighting economic, social, and environmental trends associated with each to argue that a concerted effort toward emissions mitigation, achieved by expanding renewable electricity capacity, is both feasible and necessary. This report does not make rash demands for policy change, nor does it ascribe to any particular liberal or conservative agenda. Instead, it presents objective evidence related to electricity generation from coal, nuclear, solar, and wind, respectively, to form recommendations for the stimulation of a functional US economy powered by clean energy.

The report begins with a discussion of coal-fired electricity production. This method of generation, generally accepted as the cheapest option, supplies more than 50% of US electricity demand each year. Though the market price associated with coal power is attractively low, this cost fails to incorporate significant externalities that are ultimately borne by the consumer. From resource extraction to consumption and waste disposal, coal is extremely harmful to human and environmental health alike. Coal miners suffer serious and costly health impacts from exposure to coal. This report will show that a large portion of the healthcare costs associated with this exposure is ultimately paid for with taxpayer dollars. Similarly, efforts to restore areas damaged and polluted by strip mining and mountaintop removal come at a significant public cost. The picture gets no better at the point of electricity production. Coal burning accounts for 36% of CO_2 gas released into the atmosphere in the US each year. This form of generation also produces massive amounts of other harmful emissions that are linked to serious respiratory conditions and early death. Estimates regarding health impacts associated with coal-fired electricity reveal a stunning $268 billion external cost levied on the American people each year. Though ‘clean’ coal technology has the potential to mitigate at least some of this cost, problems associated with extraction and solid waste disposal remain unsolved. The integration of gasification and sequestration systems, furthermore, changes the economic picture for coal drastically. With estimated cost increases of at least 35% and commercial application of the technology still more than a decade away, inherently clean alternatives become much more attractive.

Nuclear generation, though beneficial in that this source of electricity is nearly emission-free, faces significant economic barriers that are at present masked by public subsidization. Fission-based electricity, once touted as “too cheap to meter,” is now described by experts and economists as “too expensive to matter.” Nuclear power plant construction is unpredictably costly and slow. Of the 75 plants in operation in 1986, all were well over budget and behind schedule in coming online. Even with billions of dollars in public handouts to the industry over the last half-century, cost estimates remain remarkably high and inaccurate. In the last year alone, these estimates have jumped 50% from an already significant $4,000 per kilowatt of installed capacity to an unrealistic $6,000. Cost is not the only obstacle facing widespread nuclear power generation. Radioactive waste, though not a substantive contributor to climate change, is not by any means environmentally friendly nor easily stored. Yucca Mountain, the largest proposed (and still incomplete) waste depository, would reach capacity with the addition of only a few large-scale nuclear generators. This facility is currently projected to begin operation at a cost of more than twice what was originally estimated. If more nuclear generators are to come online, extensive cost overruns like this will inevitably be reflected in rising market prices. This again suggests that renewable sources are poised to penetrate the market, especially if future policy is geared to allow them to do so.

Solar electricity production, though at present more expensive than coal to produce, is advantageous in that associated externalities are minimal. Furthermore, the industry is experiencing rapid growth and concurrent cost reductions that are expected to put solar in a competitive position with coal by 2015, before expensive sequestration technologies are even part of the commercial equation. Currently, the US exports 58 MW of photovoltaics each year. This exportation foregoes potential domestic emissions reductions while shipping high paying jobs in installation and maintenance overseas. To keep these jobs and those associated with manufacturing at home, it is imperative that policies are developed to stimulate the industry toward economies of scale that will keep US solar technologies competitive with those that are rapidly being developed abroad. There are significant and distinct benefits associated with both centralized and distributed solar. Centralized photovoltaic and concentrated solar facilities can be sited more advantageously, though this at present poses problems, as the current grid infrastructure is inadequate for their large-scale deployment. The ideal location of these generators is in non-arable desert areas where solar incidence is at its highest and land allocation is not an issue. Distributed photovoltaic systems such as rooftop arrays, though generally less efficient than their centralized counterparts, do not require additional grid infrastructure. It is estimated that 15-50% of US electricity demand could be supplied by residential and commercial rooftop installations. The potential for rapid deployment of these systems on a large scale makes them a great intermediary technology, especially considering the 58% cost decreases expected in 2009 with the introduction of third generation thin film modules. All indications suggest that solar will be an economically and environmentally ideal electricity source within the next five to ten years.

Wind, like solar, is a power source with few serious associated externalities. Costs in this industry are already competitive with those of dirty coal, and public confidence in wind generation technology is overwhelming. In 2007, $34 billion of private capital were invested in wind energy worldwide, with $9 billion of this injected into US markets. In contrast, no private capital was invested in nuclear in the same period. Though the wind industry has seen serious expansion in the last few years, accounting for 35% of total added capacity in 2007, an analysis of per capita wattage capacity reveals that the US is far behind a number of industrialized countries in terms of emissions mitigation. Wind farming has the potential to reverse this trend while providing serious economic stimulus to struggling agricultural communities and farm owners at risk of foreclosure. Land leases for wind development, with average lives of over twenty years, provide $2,000 to $5,000 per turbine per year. This consistent source of revenue comes at little cost to the lessor, as turbine farms cover only 3% of the land across which they are distributed. Farmers and ranchers can therefore continue to cultivate their properties around the turbines as they always have, but with a little extra revenue to keep them afloat in rough years. Though utilization of the most abundant US wind resources will require extensive infrastructure expansion, this should be seen as an opportunity rather than a challenge, as the antiquated grid is in desperate need of modernization in the very near future as it is. This modernization, encouraged by President Barack Obama, will create thousands of new jobs and steer the country toward a more competitive, globally respected, and sustainable economic future. These incentives should not be overlooked.

The final section of the report briefly discusses other considerations relevant to electricity policy. The first is energy efficiency and conservation, perhaps the most important and cost-effective approach to emissions mitigation. This subsection takes a close look at various strategies for demand reduction, including Architecture 2030 founder Ed Mazria’s 2030 Challenge Stimulus Plan, which advocates a fiscally viable strategy for reducing carbon footprints in the building sector while simultaneously curbing the current recession. Next is an analysis of the pros and cons of expanding electricity supply using natural gas. One considerable problem for this sector is fuel cost in the face of increasing global demand. It is also important to recognize that natural gas consumption is not by any means carbon neutral. A final consideration is the potential of storage systems to facilitate and accelerate the integration of renewable systems on a large scale. With further development, these technologies can play a large role in reducing costs associated with current grid instability. These costs are often overlooked, but are substantial nonetheless.

The report concludes with a number of final recommendations:

- Prioritize conservation and energy efficiency in federal energy policy
- Comprehensively analyze subsidies in the electricity sector and phase-out incentives for more problematic technologies
- Analyze and consider external costs in the form of social and environmental harm by source when forming future energy policy
- Accelerate the phase-out of coal and nuclear facilities in a fiscally and socially responsible manner
- Develop new infrastructure that is compatible with renewable sources of electricity
- Invest public money in the renewable sector to eliminate existing market distortions created by years of neglect of external costs

It is the responsibility of decision makers to ensure that future generations inherit an America that is healthy, functional and economically prosperous. This report provides informed youth input as to how this future can be realized.

Coal

In the United States today, coal-based electricity production accounts for more than 50% of the total electricity generated each year.[1] Though coal is predominately a domestically produced resource, its extraction, burning and disposal present significant economic, social, and environmental problems. When considering the cost of mitigating these harms, not to mention those associated with climate change, the economic outlook for coal becomes disheartening.

1. Market Cost

Currently, end-user electricity is supplied at an estimated average price of 8.9 cents per kilowatt-hour (kWh).[2] In 2004, end-user electricity generated from coal-powered plants was about 5.3 cents per kWh,[3] 40% less than the retail average. In analyzing the derivation of the market price of coal, however, a number of significant considerations for the long-term economic viability of generating electricity from this source must be recognized.

2. Social Externalities

Not included in the market price of coal-based electricity are the health impacts associated with its extraction and combustion. As a direct result of extraction, almost 1,500 miners die annually of Black Lung, a condition induced by prolonged exposure to coal dust.[4] Most who die are already retired, their health damaged and lives shortened significantly by their time spent in the mines.

Some estimates suggest a premium of 13.5 cents per kWh for coal-fired electricity production. This equates to a $268 billion external cost to the public each year

In addition to the costly loss of productivity from health-related retirements and early death, a huge sum of money has been swallowed-up by the Black Lung Program, a government entity that offers healthcare to those affected by the condition. Since 1969, more than $41 billion have been allocated for this program. Although it was originally intended to be industry funded, mining companies have borrowed $8.7 billion from the Federal Treasury since the program's inception.[5] This taxpayer-funded shortage is expected to increase to $68 billion by 2040.[6] With 960,800 claims filed,[7] it is clear that black lung compensation, a cost associated directly with the operation of the coal industry, is a serious expense borne by the public. This expense does not show up on the utility bill, but is paid for by consumers nonetheless.

The burning of coal has broader and more profound negative health implications. The American Lung Association estimates that there are 24,000 premature deaths from power plant pollution each year.[8] To further quantify such impacts and other debilitating effects on the population, the Environmental Protection Agency explains that prolonged exposure to particulate matter of 2.5 microns and smaller ($PM_{2.5}$), a large portion of which comes from coal plants, shortens the average lifespan by 14 years.[9]

Princeton University professor Robert Williams has also estimated some of the health-related costs associated with coal-based electricity production. Using methodology established by the European Commission's ExternE project, he calculates that the mean cost premium per kWh due to pollution from the average US coal plant is an additional 13.5 cents in the US, nearly three times the current end-user price of coal.[10] Given that in 2006, 1.99 trillion kWh of electricity were generated from coal,[11] the mean external costs from this methodological estimation totals over $268 billion in just one year.

Although the ExternE model has a high degree of variability, Williams points out that it "represents the state-of-the-art in estimating costs of externalities for energy production systems." It is important to recognize here that the 13.5-cent mean discussed above considers only the negative effects of SO_2, NO_x and particulate matter emissions. It does not include public health costs associated with mining, other emissions such as ozone, or the release heavy metal particulates like mercury, a deadly neurotoxin.[12]

World Bank estimates about external costs associated with coal are not far from those predicted using the ExternE model. A 1997 report on China indicates that in a business-as-usual scenario, health costs stemming from *just* particulate matter released during coal-firing will total $516 billion by 2020, a full 13% of China's projected GDP.[13] Though China's emissions standards are more lax than those in the US, this proportion is nonetheless eye opening. The $268 billion annual cost (which includes more pollutants than $PM_{2.5}$) estimated by Williams represents only about 1.8% of US GDP. In this light, the integrity of the ExternE estimate is again validated.

A recent study from California State University Fullerton further quantifies the damage that $PM_{2.5}$ has had on the population of the San Joaquin Valley and the southern coast of California. Consistent with the estimates above, the study concludes that the 20 million people in these areas face a total health cost of almost $27 billion per year due to $PM_{2.5}$ alone.[14] The likely source of California's $PM_{2.5}$ problem is predominantly petroleum-related emissions. Nevertheless, this indicates an urgent need for analysis of $PM_{2.5}$ in coal-affected regions throughout the U.S., which cover a much larger population area.

The costs of these dramatic social externalities have been and continue to be placed on the shoulders of American workers, children, and the elderly. If added back to the market price of coal-fired electricity, the economic picture would be radically altered, leaving standard coal-based electricity as a financially unfeasible option.

3. Trends in Labor Cost & Productivity

In a further attempt to keep coal prices low, labor costs for the industry have been cut significantly since 1985, while productivity has nearly tripled in the same period. Currently, coal miners work for real wages that are 20% lower than those paid in 1985 despite such dramatic increases in productivity.[15] The Bureau of Labor Statistics reports that this job is among the most dangerous in the US, with 49.5 deaths per 100,000 in 2006.[16]

Economic theory dictates that dangerous, undesirable jobs like underground mining should garner high wages, but this is not the case in the coal industry. Approximately 83,000 coal miners put their lives at risk every day to feed American demand for cheap energy. They do so at a wage that does not reflect this risk, a strong indication that fuel costs in this industry are exploitatively low.

4. Environmental Externalities

The external costs associated with coal production and consumption are not limited to human impacts. Ecosystems in mining regions of the country have been all but destroyed, as displaced earth and exposed chemicals alter the landscape irreversibly. A study by the Environmental Protection Agency of a mining region in Appalachia reveals that 6.8% of the 12 million acre study area has been or may be negatively impacted by recent and future mountaintop mining. This includes the direct pollution of 1,200 miles of headwater streams as well as the destruction of 400,000 acres of temperate forest.[17] The costs associated with this harm, like those related to human health impacts, are not considered in the market price of coal-based electricity.

> Coal miners work for real wages that are 20% lower than those paid in 1985, despite a tripling of worker productivity in the same period

In addition to environmental degradation from mining, accidents add another element to the real cost equation. On October 11th, 2000, over 300 million gallons of toxic coal sludge from a mine spilled throughout 100 miles of waterways of Martin County, Kentucky, causing more environmental damage than the Exxon Valdez Oil Spill of 1989. The dangers posed by over 700 mine slurry impoundments throughout the nation certainly need to be evaluated, especially in light of the fact that the Martin County Coal slurry spill was in large part due to the local Mine Safety and Health Administration's ignoring the recommendations of a 1994 memo that warned of a need for a reevaluation of the slurry's integrity.[18]

Other hidden costs associated with mining have been quantified to a certain degree. The Office of Surface Mining Reclamation and Enforcement (OSM) has spent over $3 billion since 1977 to clean up dangerous abandoned mine sites, primarily those that harvested coal. The OSM has successfully eliminated "safety and environmental hazards on 314,108 acres since 1977, including all high-priority coal problems."[19]

This restorative effort undeniably benefits the surrounding environment. The costs associated with these cleanups, however, are not paid for by those responsible for the environmental degradation that is mitigated. These costs are a factor when considering the scope of the burden the coal industry has and continues to place on taxpayers.

Coal's negative environmental effects, like its effects on humankind, are not limited to those associated with extraction. Each year, coal plants produce about 130 million tons of solid waste, nearly three times the annual municipal waste produced in the United States.[20] Ash waste that is collected and stored is not by any means removed from the picture when considering the environmental degradation associated with coal. A very recent example is the Tennessee Valley Authority's ash spill, in which over 1 billion gallons of ash sludge spilled into the local community.[21] There are over 1,300 coal ash dumps throughout the country. As of yet, no federal regulation exists for these toxic impoundments because coal ash is not considered 'toxic waste.' This is primarily due to coal industry influence, which has stifled EPA efforts at regulating such waste. In response to the TVA spill, however, Representative Nick Rahall (D-WV) recently introduced a bill to counteract this influence.[22] It is estimated that the enactment of new regulations such as this may add an additional $11 billion per year to the coal mining industry's operating costs.[23] The TVA spill indicates that these costs are necessary to secure the integrity of the environment, public health and the private property of the American people. Any increases in cost due to regulation for safety purposes should be reflected in the cost of production rather than in the form of environmental disaster. This is currently not the case.

> There are over 1,300 coal ash dumps throughout the country. As of yet, no federal regulation exists for these toxic impoundments because coal ash is not considered 'toxic waste'

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Coal-generated pollution is extremely pervasive, as it is deposited into the atmosphere, the earth, and into water systems around the world. This has serious effects on global wildlife. As habitats are destroyed, so too are the species that rely upon them. When plants and animals of all sizes are forced into smaller and smaller areas, significant pressure is placed upon the ecosystem. Eventually, ecological balance becomes impossible, and entire species perish. This is yet another serious concern associated with the burning of coal for electricity that is neglected entirely in its market price.

5. Subsidies

Instead of taxing the coal industry to fund mitigation efforts for the external costs discussed above, current government policy enables the price of electricity from this source to remain artificially low by providing massive subsidies to the already profitable industry. A number of examples can provide insight into the scope of this problem. The Government Accountability Office reports that in 2007, the fossil fuel-based electricity industry, largely composed of coal producers, was granted $2.75 billion in tax exemptions.[24] Additionally, 2007 Research and Development subsidies for the coal sector totaled $527 million.[25] The GAO also identified areas of possible subsidies that were not included in their calculations, some of which are likely beneficial to coal. These include low-cost financing options, USDA electricity related programs,[26] and the projected $68 billion (total cost by 2040) in federal assistance to the Black Lung Program discussed above.

Subsidies are hidden in a variety of ways, and efforts to comprehensively quantify them are difficult. Nevertheless, a recent OECD report provides a mean estimate of $8 billion per year in federal support for the coal industry.[27] It is also important to bear in mind that there are subsidies provided at the state level, which in many cases add a great deal to the equation. While coal continues to inflict massive external damage to the environment and human health alike, state and federal governments ignore these negative consequences, and instead provide financial aid to the industry.

6. Clean Coal

The term “clean coal” designates a broad array of electricity production processes that have the intention of reducing either the toxic pollutant levels or the carbon dioxide levels (or both) of coal-based electricity. One point of particular importance is that none of these improvements on coal-based electricity production do anything to mitigate the harms or costs associated with mining. These include worker health and safety, mine slurry disposal, and the associated landscape degradation discussed above. Furthermore, as coal gets “cleaner” in the combustion process, more ash will accumulate in containment ponds. The 2008 TVA spill is an example of the consequences this can have. Decision makers must not ignore these socially relevant and costly harms.

One moderately promising technology that both reduces toxic emissions and sequesters a portion of CO_2 is Integrated Gasification Combined Cycle (IGCC) generation. IGCC uses heat and pressure on coal to create a pressurized synthetic gas, removing impurities in the process. Williams’ estimate of external costs from IGCC plants is much lower than the unfiltered US coal plant, with a mean of 0.24 cents per kWh compared to 13.5. Though still about one-and-a-half times the external cost of natural gas, this is a significant improvement nonetheless.[28]

Externalities aside, clean coal technology faces another considerable barrier: cost. Although coal-based power is currently the cheapest form of electricity production, the capital investments, infrastructure upkeep, and energy inputs of *clean* coal represent a significant increase in operating and maintenance costs. Recent studies considering cost and future viability of commercial deployment of these technological innovations indicate significant challenges. The GAO estimates, for instance, that the cost of electricity production would increase by 35% for newly constructed IGCC plants with carbon capture and storage technology (CCS). The GAO also points out that “studies by the IEA, DOE, and the National Coal Council cite a number of compelling factors, such as the relative cost of IGCC plant construction and the limited operational experience worldwide with this relatively new technology, which may limit commercial deployment of IGCC technology.”[29]

The cost of electricity production would increase by 35% for newly constructed clean coal plants (IGCC) with carbon capture and storage technology

Estimates for new construction of *standard* coal plants with CCS indicate per kW cost increases of about 77%.[30] The picture looks even worse for retrofitting existing coal plants. The DOE estimates that capturing 90% of an existing plant’s CO_2 emissions would increase the cost of electricity by nearly 7 cents per kWh.[31]

The final consideration related to clean coal technology concerns the uncertain future of its commercial-scale implementation. A 2001 GAO report notes that many projects aimed at emission mitigation and clean coal research and development “experienced delays, cost overruns, bankruptcies, and performance problems.”[32] In addition, the Electric Power Research Institute estimates that IGCC plants could take as long as 15 years to move from pilot testing to commercial-scale viability.[33] There are similar estimates of viability around 2020 for pulverized coal plants with CCS as well.[34] Even if it is possible to be a cost-competitive part of mitigation, clean coal still must play catch up with the other, undeniably cleaner technologies that will be discussed later in this report.

The Electric Power Research Institute estimates that IGCC plants could take as long as 15 years to move from pilot testing to commercial-scale viability

7. Resource Supply

Although the Energy Information Administration estimates 491 billion short tons of coal are buried within the borders of the United States, a large portion of these reserves are at present economically unrecoverable. The EIA report estimates that only 264 billion short tons are feasibly extractable. With over 1.1 billion tons of coal used in the United States each year,[35] this amounts to about 240 years of coal reserves at current consumption rates.

Although this number may seem attractive for long-term supply, many geologists consider the above-mentioned estimates to be overly optimistic, in part due to the fact that they are based on research conducted in 1974. In contrast to such numbers, a 1993 Department of the Interior Study of coal reserves in Kentucky found that only 7.5-22% of the available reserves in the area were economically recoverable at current market prices. The study concludes that if similar data emerges in other coal producing regions, it is likely that we will experience resource depletion problems "far greater and much sooner than previously thought."[36] As confirmation of this prediction, consistent estimates have been reported in a number of coal producing regions. Examples include the Powder River Basin of Wyoming, the Colorado Plateau, and the coalfields of Illinois.[37]

These findings suggest that domestic coal supply at current prices may be less stable than once thought. Combining this with other economic costs discussed above, the economic picture for coal becomes even more daunting.

8. Conclusions and Recommendations

A broad yet brief analysis of coal-based electricity production yields a conclusion that is particularly damning. When taking into account the external costs of coal levied on society, this form of generation is far from economically preferable. Attempts to mitigate even a portion of these externalities reveal costs that are problematic as well, although perhaps not insurmountable. Policy decisions should be made in consideration of trends in the alternative energy sector, which reveal a much brighter economic outlook.

Congress and administrative bodies need a comprehensive analysis of coal-based electricity that effectively considers the multi-faceted nature of its economic viability. Issues that must be addressed include the following:

- Worker rights, safety and health
- Society-wide health implications
- Environmental degradation and associated costs
- Federal and state subsidy analysis
- The economic and time-sensitive viability of harm mitigation methods for clean coal
- Supply integrity

Nuclear

Nuclear power generates about 19% of US electricity supply.[38] Although commonly touted as an important contributor to US energy independence and a solution to climate change, more substantive analysis of its economic outlook, hidden costs and environmental impact indicates that nuclear, like coal-firing, is far from an optimal electricity production technology.

1. Economic Outlook

A significant factor that is missing from most recent discussions of nuclear power in popular media is cost. Energy experts who realistically consider the economics of nuclear, however, understand the significance of this barrier. The lackluster enthusiasm from private investors is another indication of cost concerns. As far back as 2001, *The Economist* noted that although nuclear was initially claimed to be "too cheap to meter," it is more likely to be remembered as "too costly to matter."[39] A recent comprehensive and rigorous analysis of this issue comes from renowned energy experts Amory Lovins and Imran Sheikh.[40] They point out that on almost every economic front, nuclear power faces an uphill battle, and will require a huge amount of government subsidy to remain cost-competitive with other technologies. Such fiscal resources could be better used to promote more promising energy technologies.

Mid-range estimates for newly constructed nuclear plants have costs of about 16 cents per kWh, nearly twice the current end-user market rate

The most daunting problem facing the nuclear power industry is its high capital cost. Although operating expenses are not particularly steep, plant construction costs have been extremely expensive and timetables unpredictable. Of the 75 plants online in 1986, all exceeded initial estimates by a range of 209-381%.[41] Current estimates have been on the rise as well. In 2007, estimates for plant construction were in the $4,000 per kilowatt range. More recent estimates, however, put plant construction costs at around $6,000 per kilowatt, fifty percent higher than projected just a year before.[42] These price increases will affect the market price of electricity borne by consumers. Lovins and Sheikh point out that a $5,200 per kilowatt plant would have costs of about 16 cents per kWh, *not including* the cost of distribution. This alone is almost twice the end-user market rate (which includes distribution).[43]

The dramatic increases in construction cost estimates described above have two important causes: manufacturing shortages of expensive special parts and lack of construction expertise. In the reactor parts manufacturing industry, high capital costs create barriers to entry that bar competition and allow for monopoly pricing of needed supplies. Japan Steel Works, for example, is the only manufacturer of specialty 600-ton steel ingots. This company currently has a production capacity of about 4 of these per year. Although it plans to double its capacity, world demand for nuclear parts far exceeds supply. This keeps prices high and prolongs construction time, which in turn adds more to construction costs.[44]

Regarding construction expertise, nuclear education programs have been and continue to be on the decline, from 65 programs in 1980 to around 29 today. This decline may limit industry capability so much that it will be unable even to offset retirements or account for staff growth in currently existing plants, let alone to staff new plants entirely. Before any new plants can come online, especially on a massive scale, many new training programs for operations and construction must be established.[45]

Nuclear received *zero* private investment worldwide in 2007, while renewable technologies received over $71 billion

Although an increase in interest for nuclear electricity production may help to decrease costs and spur education in the field, the technology will face difficult hurdles to remain competitive with solutions that have established growth momentum. In the meantime, the industry will require extensive government support in order to instill a sense of investment security for Wall Street. Furthermore, even if investors can be convinced that nuclear is a profitable option down the road, other technologies that have more promise and more distributed, lower costs (and thus higher profitability) will compete for much needed capital input. A clear indication of this problem can be seen by the fact that nuclear received *zero* private investment worldwide in 2007, while renewable technologies received over $71 billion.[46] These market trends suggest an ominous future for the industry.

2. Reliability

Another issue related to cost and market feasibility for nuclear has to do with its reliability. A typical criticism of alternative energy technologies that rely on solar and wind is that they are intermittent and therefore undependable. Though many believe that nuclear does not have these problems, a closer examination reveals that this is not the case.

Of the 132 nuclear plants built and licensed to operate in the United States, 21% were permanently shut down because of reliability or cost issues and 27% of the rest have suffered from outages of more than one year

The reliability of nuclear is called into question when one considers the rate of long-term generator shutdowns in the past. Of the 132 plants built and licensed to operate in the United States, 21% were permanently shut down because of reliability or cost issues and 27% of the rest have suffered from outages of more than one year.[47]

Another important factor that has recently emerged concerns the water supply necessary to keep reactors cool. If water temperature from local sources is too high or if the resource becomes unavailable, reactors have to temporarily shut down or reduce output. The Associated Press documents that 24 of the 104 plants in the United States are in areas "experiencing the most severe levels of drought." In addition to this problem of short-term reliability, repeatedly starting and stopping a plant will likely exacerbate wear and tear, since these base-load plants are not designed to run intermittently.[48]

Despite $84 billion in government support for research and development, nuclear remains unable to compete with current and emerging technologies

Furthermore, starting and restarting nuclear plants is very time-intensive. This was exemplified during the emergency shut down in the Northeast Blackout of August 2003. From shut down to full operation, a process that took over 12 days, the average capacity of nuclear plants was 53%.[49] Nuclear plants must also be shut down for refueling. The average time period for this process is 37 days every 17 months.[50]

Though somewhat problematic, the grid was designed to handle many of the above-mentioned intermittency issues. The impact of contingencies and expectations of shutdowns are much lower as a result of sound planning. Similar planning techniques can and will play a role in incorporating other alternative sources of electricity, such as wind and solar, into the grid on a large scale. The argument against renewable electricity generation as intermittent and therefore not feasible fails because proper planning can resolve such issues. This will be discussed in more detail later in the report.

3. Subsidies

Consistently ignored in the mainstream discussion of nuclear is the heavy financial support the industry receives from taxpayers. Government subsidies, far greater even than those for coal, have propped up the nuclear power industry for decades, allowing it to artificially compete with other technologies. Fee assessments for waste management are underpriced as well, possibly leaving the federal government with an even heavier financial burden. Adding these costs into the equation makes an already expensive option look even worse.

The long and well-documented record of subsidies to the nuclear power industry can be summed up by recent publications from Public Citizen. It estimates that direct public subsidies to the nuclear power industry from 1947-1999 total over $115 billion.[51] A portion of such funding has come in the form of handouts, tax credits, loan guarantees, and payments for regulatory delays. The bulk of this expense, however, has come in the form of direct public 'investment' in nuclear research and development. The Congressional Research Service documents R&D expenditures from the same period at $84 billion in 2008 dollars.[52] Despite these billions of research dollars, the nuclear power industry remains unable to compete with current and emerging technologies.

The picture gets even worse when less obvious forms of subsidy are taken into account. One major indirect subsidy comes from the limited liability of nuclear operators. The Price-Anderson Act limits financial liability for operators in cases of nuclear accidents at $10.5 billion, even though some estimates for total damages in the case of an accident or attack put the cost at $600 billion or more.[53] The federal government would pay for the vast majority of costs should a nuclear accident occur. This policy was enacted in 1957 to stimulate a new electricity industry by securing investment in an uncertain technology. The industry, however, is no longer in its infancy. There is no legitimate reason today why nuclear power producers should not have to pay their full insurance costs. After incorporating indirect subsidies such as this, Public Citizen puts the 1947-1999 public funding total at $145 billion.[54]

The Government Accountability Office has documented more recent subsidies to the nuclear industry. The 2002-2007 estimate for DOE expenditures for nuclear totaled $6.2 billion.[55] Although the GAO identifies no tax expenditure subsidies to nuclear during this period, they cite several other possible ways in which the industry is braced by subsidization. These include: low-cost federal financing, the Price-Anderson limitation on liability, decontamination and decommissioning costs for nuclear fuel manufacturing facilities, and nuclear waste storage.

4. Storage

Nuclear waste storage is a topic that merits more discussion. In analyzing the presumed-yet-incomplete repository, Yucca Mountain, the GAO explains, "the federal government has potentially assumed risks of cost over runs and schedule delays for the repository."[56] Currently, there is a 0.1 cent per kWh fee for electricity generated from nuclear facilities to pay for nuclear waste processing and storage.[57] Though earlier estimates from the DOE for nuclear storage found this to be financially sound,[58] such estimates are based on an assumed cost of $51 billion for a monitored geologic repository.[59] Recent estimates for the Yucca Mountain storage facility, however, have steadily increased over the last few years to a *current* $96.2 billion, almost twice the cost upon which the DOE made its fee estimate.[60]

The expected limit of even an expanded Yucca Mountain repository will have the capacity to hold the waste of only a few additional reactors

An increase in nuclear fuel use will result in more nuclear waste than Yucca Mountain is designed to handle. As of now, the project is expected to hold around 77,000 tons of waste. This may be expanded to hold even more, but even an expanded facility could only hold the waste of a few additional reactors.[61] Any substantive expansion of nuclear capacity will inevitably require another expensive and controversial repository. With this in mind, it becomes abundantly clear that the current excise tax is not nearly enough to cover an expansion of nuclear on a large scale. To facilitate such expansion, costs will inevitably increase. This will be reflected by the additional allocation of taxpayer dollars to repository efforts or by an increase in the rate users pay. Either way, the public will bear a heavy burden for nuclear electricity.

More daunting for the Yucca Mountain repository are recently documented management challenges. The GAO points out that the project has faced "quality assurance" problems with its data, software and models that are intended to supply scientific support for the licensing process.[62] Even more problematic is the fact that the Department of Energy has "inconsistently tracked progress with problems."[63] Yucca has suffered more basic management problems as well, such as confusion over "roles and responsibilities."[64] This does not bode well for the efficient implementation and operation of this nuclear waste disposal project and others like it. Increasing cost estimates and prolonged start-up dates are some of the worst symptoms of this management dilemma.

5. Mining

Another serious economic and environmental problem that is often overlooked in public discussion of nuclear energy is uranium mining. As described in the section on coal, mining of any material is environmentally hazardous. Uranium, however, has especially horrible consequences. It goes without saying that any substantial increase in nuclear power generation will result in an increase in uranium extraction, either in the United States or in exporting countries around the world. This mining will release radiation that is seriously detrimental to human and nonhuman health alike.

Problems abound for uranium mining, as Federal oversight for the mining process itself has been far from responsible. Just one example relates to exploitation of the Navajo people, whose land has been extensively mined and degraded for uranium ore. In a hearing for the House Committee on Oversight and Government Reform on October 23, 2007, Chair Henry Waxman (D-CA) succinctly described the situation of uranium mining on the lands of the Navajo people as "an American Tragedy."[65] Poor oversight and regulation of private mining companies has led to environmental contamination and ill-health effects for many of the people who live near the mining and milling areas. As with coal mining, few clean-up procedures and mandates are in place to ensure environmental quality and human safety. Once mining was complete, the Navajo were left exposed to hundreds of abandoned mines and tons of toxic materials. The Navajo Nation's Executive Director of Health, Anslem Roanhorse Jr., laments that the number of abandoned mines totals over 500, with a total volume of contaminated materials of about 870,000 cubic yards.[66]

> "Those looking to mine uranium to fuel future reactors face a desolate landscape littered with abandoned mines and mill sites, still generating unknown levels of health and environmental damage." *Representative Tom Davis (R-VA)*

During the hearing, representative Tom Davis (R-VA) notes, "serious cleanup is underway at only one of the more than 500 mines EPA found on Navajo lands."[67] Exactly quantifying the long-term costs of this neglect may prove to be difficult, but it certainly cannot be overlooked. As Davis points out, "Those looking to mine uranium to fuel future reactors face a desolate landscape littered with abandoned mines and mill sites, still generating unknown levels of health and environmental damage."[68]

Any future policy that encourages more uranium mining must certainly be done in consideration of cleanup, safety and environmental factors, regardless of the immediate internal cost to mining companies.

6. Conclusions and Recommendations

The economic picture for nuclear energy is rather bleak. Costs may prevent the technology from ever gathering market momentum, even with the lavish government subsidies that the industry has received. In addition, serious environmental and human health concerns remain for the mining and disposal process of radioactive materials. If any discussion of Nuclear energy policy is to proceed, Congress must ensure that it makes decisions in light of the following information:

- Subsidies to the industry
- Plant construction costs and implications for competitiveness with other technologies
- Reliability issues for the technology
- Environmental harms associated with uranium mining
- Projected costs and public burden for storage of waste

Policy makers would do well to shift appropriations to the more cost-effective and environmentally friendly electricity options that already exist (discussed below). Despite 60 years of experience and handouts, the nuclear industry has failed to meet its promise of cheap and clean energy.

Solar

With the solar photovoltaic (PV) industry burgeoning on a global scale, it is important that the US develop a political and technological infrastructure to keep the nation in a position of economic and environmental leadership.

1. Market and Cost Trends

Though photovoltaic technology is not yet cost-competitive on a wide scale with the artificially low costs of coal discussed above, it has the potential to be in the near future. A number of important indications suggest that 'grid parity,' or cost-competitiveness with the US average, is on the horizon. In the past decade, for every doubling of capacity in the solar industry, prices have dropped 20%. With a per annum growth rate of 29%, such doublings occur every 2.4 years.[69] The Department of Energy has an R&D goal of making solar cost-competitive with other technologies by 2015.[70] Industry is optimistic about this possibility as well, predicting grid parity in some states by 2012, and almost all states by 2016.[71] Indications suggest that this could be achieved even sooner. Recent analysis of a new 10 MW plant in Nevada, for example, revealed a cost of 7.5 cents per kWh, 16% lower than the national average.[72]

Industry is optimistic about the cost-competitiveness of solar, predicting 'grid-parity' in some states by 2012, and almost all states by 2016

Despite these trends, many are led to believe that solar electricity is not economically feasible because the average price per kWh of photovoltaic electricity is generally significantly higher than that of the conventional competition. In order for such a comparison to be valid, however, how and when the generating source operates must be considered. Since solar insolation (sunlight) is highly correlated with peak electricity use, when prices are at their highest, the comparative cost of base-load power to solar is not immediately relevant, as solar impacts primarily peak-load demand. Whether centrally deployed or distributed, solar photovoltaic technology has the potential to reduce a significant portion of this peak demand, and can therefore help the grid to run more smoothly, avoiding shortages. Peak electricity relies on flexible generators (such as natural gas plants) that are generally more expensive than base-load plants to operate, as they must shut down and restart according to demand, and are highly dependent on fluctuating fuel costs. This generation, representing about 30% of total electricity supplied each year, is much more costly than base-load production.[73] As a primarily peak-load-responsive technology, therefore, PV must only initially compete with this more expensive 30%. Grid parity in this sense is nearly a reality, and costs continue to drop. While economies of scale ramp up in the face of global competition, momentum is steadily building toward the ultimate goal of generation that is less expensive than conventional base-load power. This, as previously pointed out, will likely be possible within the decade.

Domestic development and installation of solar photovoltaic systems has advantages beyond simply being a clean source of electricity. Widespread acceptance of this technology will create thousands of new jobs, from technical product design and development to local manufacturing and installation. According to the Center for Energy Efficiency and Renewable Technologies, solar PV development generates seven times more jobs per megawatt than natural gas. Currently, the United States exports 58 megawatts of photovoltaics each year.[74] In the process, many potential jobs are also shipped overseas, as installation projects and maintenance positions that could have employed many Americans at home are lost to global competition. There is great promise in the future of solar, but only for those countries that encourage development and innovation today. It is imperative that the United States establish itself as a leader in this field.

Coal-fired electricity appears to be on an upward price slope. The Energy Information Administration estimates that 2.6% growth in electrical production capacity will be required each year to meet growing demand.[75] The International Energy Agency predicts that satisfying world demand from 2003 to 2030 will require capital investment of nearly $18.5 trillion by utilities around the world, much larger than investment in previous decades.[76] As existing infrastructure continues to need replacement and growing demand necessitates costly expansion, significant upward pressure will be placed on the cost of conventional electricity. As discussed in the Coal section above, costs will see an even more substantial rise with the implementation of IGCC with CCS or other mitigation techniques. Solar photovoltaic generation, on the other hand, will see significant price *drops* in the near future and beyond. This market momentum should be encouraged by government policy, especially in light of the imminent threat posed by anthropogenic climate change.

2. External Costs

Externalities associated with solar electricity production are dramatically less than conventional generation methods, an important factor when considering the comprehensive cost of electricity by source. It has been shown that the coal industry keeps costs low by reducing workers' standards of living and placing the brunt of the cost of health and environmental deterioration on the public. By contrast, the solar industry remains on an experience curve that will allow for future cost decreases with minimal harm to society. These will be achieved with the emergence of key economies of scale, increases in efficiency of materials use and installation, and new design. Externalities are not placed on workers in dangerous and deleterious environments, nor are they exacerbated or induced in the form of health risks to nearby stakeholders. To stimulate the development and concurrent slashing of costs for this clean source of electricity will require investments and policies that allow for market penetration. Just as the US government has invested heavily in coal and nuclear electricity development in the past, so too must it now encourage growth and stability in the solar industry.

The International Energy Agency estimates that buildings in industrialized countries have enough rooftop space to provide between 15% and 50% of demanded electricity

3. Central & Distributed Solar

There are many distinct advantages associated with both centralized and distributed photovoltaic arrays. According to the International Energy Agency, very large-scale centralized photovoltaic systems covering just 4% of the world's desert land could provide electricity to meet total global demand.[77] Solar power plants are advantageous in that they can be strategically located in areas of extremely high and consistent solar incidence. These facilities, averaging between 10 MW and several GW, do not compete for land resources, as they make use of desert land that presently remains unutilized by society.[78] Furthermore, unlike nuclear and coal, these systems can be built incrementally, allowing for rapid and flexible capacity expansion in response to demand.

International examples suggest that deployment of very large-scale photovoltaic fields will likely streamline the production and installation of PV technology, not to mention the development of valuable economies of scale. Such productive growth will decrease costs, thus further expanding the feasible market for clean energy consumption. According to many economists and experts in the PV industry, investing in large-scale solar now will begin an autocatalytic cycle of growth in the large-scale photovoltaic industry, as reduced costs will lead to further expansion, and further expansion will lead to even greater reduction in costs.[79] The photovoltaic industry is poised to penetrate the electricity market. Its niche must be developed and expanded as soon as possible, for the longer significant market entrance is delayed, the harder it will be to remain globally competitive in the industry, let alone to play a role in reducing emissions to safe levels.

Distributed solar, too, has great potential to help 'green' the US electricity grid while reducing costs associated with infrastructure maintenance and expansion. By placing solar installations on the rooftops of homes and large buildings, concerns about grid capacity and development timelines to meet rising demand become moot. The International Energy Agency estimates that buildings in industrialized countries have enough rooftop space to provide between 15% and 50% of demanded electricity.[80]

Rooftop solar obviates the time and capital input needed for grid expansion, and is therefore an ideal intermediary technology in the shift to sustainable electricity production. The industry has excellent prospects for growth that will come at little cost to utilities as they struggle to renovate the grid.

Grid-connected installations on residential and commercial buildings have a very different cost structure than that of conventional electricity generators. While the price of fossil-based and nuclear power is strongly tied to the costs of fuel and maintenance, over 90% of the lifetime cost of the average PV system is incurred at the point of installation.[81] Historically, this has acted as a significant barrier to market entry for producers of photovoltaic cells, but this trend appears to be dissipating. To remain competitive with the large-scale thin-film manufacturing capacity that is expected to come online in 2009, silicon-based solar panels must decrease in cost by 58% in the very near-term. Consumers will benefit from this reduction.[82]

A federal financing program for renewable energy like the ones discussed in the following section could make widespread installation of distributed solar a reality. Such policy has the potential to create thousands of jobs, ease time constraints on infrastructure expansion, and begin to steer the market toward a more socially and environmentally sensible supply of electricity.

4. Foreign Policies

Federal energy policies in Germany and Japan illustrate the potential that government has to develop a niche for photovoltaic electricity production. Since the early 1990s, both countries have seen huge growth in their respective domestic renewable industries, and today are world leaders in PV development and deployment.[83] The common elements in their rise to leadership in renewable electricity production are long-term and consistent fiscal policies and programs aimed at promoting industry growth. This market encouragement has led to cost decreases that have moved solar closer to feasibility as a main source of electricity. Much can be learned from the examples of the enabling policies developed by Germany and Japan.

Germany has only a fraction of the solar incidence of the United States, but is nonetheless a leading installer of PV systems globally. With the 1990 passage of an energy law focused on safe and reliable electricity production, a multi-billion dollar industry and tens of thousands of new jobs were created in the span of a decade.[84] By guaranteeing a minimum price for renewably generated electricity over a long period of time, German officials created a market confidence that encouraged and protected investment in solar systems across the country. Subsidies were introduced early on then gradually phased-out as capacity expanded and prices dropped. This long-term pricing strategy, applied to both domestic consumers and utilities, found widespread support and stimulated the market in a fiscally responsible manner that addressed the environmental advantages of new forms of electricity production. Germany's 'Feed-In Tariff' and '100,000 Roofs Program' have been significant steps toward emissions reduction. According to the Energy Information Administration, the country produced a significant 7% of its electricity from renewable sources in 2004.[85] The German economy has benefited greatly from this orchestrated boom.

Japan has also seen significant increases in solar photovoltaic production and installation in the last two decades as a direct result of enabling government policies. The World Watch Institute reports that, "With far less land area and about half the solar insolation of California, Japan now has three times as much PV capacity as the United States."[86] Though it is true that this is largely a consequence of the extremely high cost of conventional electricity in the country, it is also the result of a concerted government effort to clean up and secure domestic electricity supply. Japan's "New Sunshine" and "Solar Roofs" programs promoted PV through low-interest loans, education programs to raise public awareness, and rebates that started high then gradually declined as capacity increased.[87] These wisely planned programs, the last one ending in 2002, exceeded all expectations

Smart policies in Germany have led to the emergence of a multi-billion dollar industry and tens of thousands of new jobs, all created in the span of a decade and catapulted Japan to the top of the global PV industry. Like those in Germany, Japan's long-term economic guarantees and efforts to increase public understanding of the benefits of solar electricity have led to significant cuts in cost resulting from the emergence of new economies of scale, increases in demand, and development of valuable market experience. In both countries, the PV industry has successfully established itself as a competitor in the field of electricity production.

In the US, no such focused and long-term policy has been implemented to date, though the recently extended Production Tax Credit is a step in the right direction. This credit, however, has been far from stable. Since 1999, it has expired three times,[88] discouraging necessary long-term investment. With no guarantee that government support would continue long enough for manufacturers to establish the productive scale requisite for the industry to penetrate the market and compete, investors were slow to provide the funds necessary for companies to do so. All indicators suggest that the PV market has the potential to be competitive with conventional electricity in the near future. More consistent government encouragement of this industry, as demonstrated by Germany and Japan, will stimulate the domestic economy while simultaneously pushing it toward environmental and social conscientiousness.

5. Grid Impacts

Electricity supply and distribution in many regions of the United States depend on the functionality of an antiquated grid that is largely inefficient and unreliable. This dated infrastructure, much of which was designed and installed in the 1940s and 50s, is responsible for costly shortages and blackouts, as its capacity is limited by 30-75 year-old technology and equipment. This is indicative of a general tendency to focus on short-term profits and forgo adequate maintenance of infrastructure.[89] Currently, about 2% of the grid is replaced each year, providing the opportunity for gradual modernization.[90] In redesigning our energy infrastructure in the years to come, solar photovoltaic technology can and must play an important role.

According to a report submitted by the National Renewable Energy Laboratory, photovoltaic technology has the potential to supply about 15% of total electricity demand without necessitating changes to base-load infrastructure.[91] Since this total is far below the present proportion of electricity provided by solar photovoltaics, less than 1%, there is ample time to work on infrastructure flexibility to allow for a greater percentage of clean, though intermittent, sources. Scientists at NREL explain, "now is the time to begin thinking creatively about ways to begin moving toward a more flexible and PV-friendly electric power system."[92]

6. Thermal Solar

Another valuable form of solar electricity production uses mirrors to concentrate sunrays, heating a working fluid (usually water) that is used to power heat engines that generate electricity. Large-scale collector fields, found in the deserts of the American Southwest as well as throughout the European continent, are advantageous in that the heat collected by these systems can be stored in thermal energy insulating tanks for later use. Such storage, though currently above grid parity, allows the operation of the plant to continue in periods of cloudiness and after sunset, an important feature that makes this technology extremely valuable to utilities. These generating systems, like those dependent on fossil sources, are highly flexible. Thus, they can be deployed to meet a large portion of base-load demand without the emission of the harmful pollutants characteristic of conventional generation.

> "Now is the time to begin thinking creatively about ways to begin moving toward a more flexible and PV-friendly electric power system."
> *The National Renewable Energy Laboratory*

In California, 354 MW of grid-connected electricity generating capacity using parabolic trough concentrators were installed in the 1980s.[93] All plants are still in operation, a testament to the integrity of the technology. To date, these plants have accumulated 15 TWh of clean solar electricity. The success of this form of generation, fluctuating fossil fuel prices, as well as increasing concern regarding the dire consequences of climate change have led to the commission of many new plants in the past two years. Most of these plants will be erected in the European Union, however, as incentive programs in the EU make development more financially appealing abroad.

There is little reason why this proven technology should not be developed and installed on a very large scale. Energy analyst Fred Morse estimates that with appropriate economies of scale, thermal solar with molten salt storage, capable of operation for more than 8 hours without sunlight, can reach costs of around 11 cents per kWh.[94] Further market growth may drive these prices down even more. These systems have the potential to supply a large portion of US demand at close to, if not less than grid parity. It is generally accepted that in order to prevent catastrophe related to climate change, emissions reductions must start now. Integration of solar concentrating facilities is a good place to start.

7. Conclusion and Recommendations

There is a great deal of momentum behind the solar photovoltaic and thermal concentration industries. In order for these renewable sources of electricity to reach an environmentally significant scale, however, productive capacity must be further developed, and a place in the market must be established. The following recommendations have the potential to speed this process:

- Look into the necessary policy tools for de-centralized solar. Options include easily accessible low-interest federal loans, feed-in tariffs, and incentives for small-scale commercial installation.
- Consider incentive programs to encourage the establishment of renewable portfolio standards at the state level.
- Analyze job market trends in the renewable energy sector and make fiscal policy decisions to reinvigorate the US economy by creating new, green jobs.
- Work to establish a long-term vision for renovating the electricity grid to accommodate solar development.

It is imperative that action is taken now to begin to shift the country away from pollution and environmental degradation. Solar technology has the potential to facilitate this shift, but only if its development is encouraged now.

Wind

Electricity generated from wind turbines is already cost competitive with conventionally produced power. The wind resource in the United States is abundant, and can be 'extracted' with lower external costs to the environment than fossil-fuel and nuclear generation. Though there have been concerns regarding bird and bat deaths associated with utility-scale wind farms, smart placement of these farms and better technology have been proven to minimize this threat.[95] Wind turbine technology continues to harness the wind more and more efficiently. Its potential to mitigate emissions damage from conventional electricity production is truly remarkable.

1. Market Trends

In 2007, $33.4 billion in private capital were invested in the wind industry worldwide, with $9 billion of this injected into US markets.[96] This trend illustrates the momentum of the industry, and suggests that the public recognizes the social and environmental advantages, not to mention the economic feasibility, of wind as a source of electricity. Over the last two years, the United States has installed more wind capacity than any other country. Domestic installation now exceeds 25,000 MW,[97] recently surpassing Germany.[98] This ranking is impressive at first glance, but per capita calculations reveal that, where Germany has about 280 watts of wind generating capacity per person, the United States has only 82, more than three times less.[99] This indicates that the US lags behind other industrialized countries in its efforts towards carbon mitigation. It is important that this country take a position of leadership in tackling climate change, especially considering the size and global influence of the US economy.

In 2008, wind accounted for an estimated 42% of all added electricity capacity in the United States. This makes it clear that a phase-out of new generating facilities fueled by dirty sources is feasible

In 2008, wind accounted for an estimated 42% of all added electricity capacity in the United States.[100] This makes it clear that a phase-out of new generating facilities fueled by dirty sources is feasible. This has been downplayed in global estimates for wind capacity expansion, as evidenced by misleadingly pessimistic predictions from the International Energy Agency. In 1998, for example, the IEA projected 47.4 GW of wind power capacity worldwide by 2020. This prediction was exceeded in December of 2004, a full 16 years ahead of the expected curve.[101] More recent estimates, too, have been far undervalued. The most accurately estimated capacity for 2020 to date, released in 2004, was surpassed three years later by a significant 68%.[102] Wind capacity continues to grow rapidly across the globe and shows no sign of losing significant momentum. The US and global governing bodies should do all that they can to facilitate the development of the industry and encourage confidence in the market.

2. Stimulating the Rural Economy

Wind farming has the potential to inject huge amounts of capital into struggling farming and ranching communities in rural areas across the country. According to the GAO, revenues from land leases and private ownership of wind turbines, though at present totaling less than 1% of net farm income in the ten leading wind producing states, have the potential to increase certain individual farmers' incomes by tens of thousands of dollars each year.[103] Land leases for wind facilities, usually with terms of twenty years or more, provide consistent and reliable revenue streams of $2,000 to $5,000 per turbine per year.[104] This is especially significant given that each turbine requires at most only a quarter-acre of land,[105] less than 3% of the total land occupied by the wind farm area as a whole.[106] Farmers and ranchers can continue to cultivate their properties around the turbines with minimal interference, and therefore do not sacrifice revenues in choosing to lease a small portion of their land for wind development. Wind turbines, then, serve to augment income in times of need and provides a dependable cash base that has the potential to prevent foreclosures and keep struggling rural families afloat.

Large wind power facilities, often constructed in the nation's poorest rural communities, provide invaluable tax revenues and employment opportunities. The GAO examines Pecos County, Texas to illustrate the benefits of wind farming. In 2002, "school districts… received about $5 million in property tax revenues from wind power projects. These projects also created about 30 to 35 full-time permanent jobs to operate and maintain the projects."[107] The fact that many of the windiest areas in the country are also some of the most impoverished suggests that large-scale wind power development will provide economic stimulus where it is needed most. While coal-fired electricity production harms those in close proximity to the site of generation, wind power has the opposite effect. This is a positive externality that should factor into a holistic analysis of wind electricity's cost relative to conventional sources.

With the enactment of the Farm Security and Rural Investment Act of 2002, the US Department of Agriculture was authorized to provide funding to farmers for alternative energy projects, including the development of rural wind farms. In fiscal year 2003, the USDA capitalized on this prerogative, offering grants totaling $7.5 million for 35 wind power projects nationwide.[108] Though industry growth in this first year appeared promising, USDA funding procedures have since proven ineffective, as reflected by the minimal impact the bill has had on US electricity supply as a whole. According to the Energy Information Administration, at year-end 2006, a full four years after the adoption of the Farm Bill, renewable sources (excluding hydroelectric dams) provided only 2.4% of total US electricity supply.[109] Though it is not the duty of the USDA to worry about electricity policy, significant efforts toward drastically expanding wind power capacity would benefit struggling farmers across the country a great deal while simultaneously providing stimulus to the national economy as a whole. This is a mutually beneficial arrangement for all parties involved and should be a high priority for government officials, industry professionals, and small town farmers alike. While direct economic benefits may be limited to utilities, turbine manufacturers and distributors, investors, and those with land holdings in windy areas, the emissions reductions associated with wind farm development have the potential to positively impact society as a whole.

3. Opportunities & Challenges

One major challenge that faces wind power (and solar) concerns their connection to the electricity grid. Wind and solar incidence tends to be most highly concentrated in regions that are fairly distant from major areas of consumption. Although there are transmission lines throughout the country, the level of capacity to potential sites is not high enough to support any mass scale distribution of new renewable energy sources. An early example of this infrastructural shortcoming can be observed in upstate New York, where some wind farms have been forced to shut down due to transmission bottlenecks.[110]

Concerns about the grid's capacity to handle future wind and solar developments must be considered in light of the fact that the antiquated electricity grid already is in desperate need of an overhaul. According to the DOE, construction of high-voltage transmission facilities from 2002-2012 is expected to increase line-mile supply by only 6%. This is troublesome, as projections indicate there will be a 20% increase in electricity demand and generation capacity during the same period. Though transmission lines do not necessarily require one-to-one correlation with installed capacity, the DOE points out that, as this developing disparity continues, the future grid will fail to "ensure reliability and sustain continued growth of competitive regional wholesale electricity markets."[111] This shortage will be further compounded by the fact that some portions of the grid, as discussed in the solar chapter above, are limited by technology and equipment that is, in some instances, more than 75 years old. Grid development in general has not kept up with generating capacity. Eventually, Americans will have to face the costs associated with a serious infrastructural overhaul. As electricity demand increases, the same problems that face wind, solar and other technologies that are more 'isolated' will affect conventional electricity generation and supply as well.

Another challenge for both wind and solar concerns intermittency. As many may have heard before, "the wind doesn't always blow and the sun doesn't always shine." It has already been mentioned in the nuclear chapter above that wise planning can mitigate some intermittency issues. Furthermore, the distributed nature of wind and solar technologies may actually make them *more reliable* than conventional generators. The average US fossil-fuel plant is unexpectedly out of service approximately 8% of the time.[112] Such outages usually occur in massive chunks and are extremely costly. The intermittency of distributed power generation, on the other hand, tends to occur more predictably and on a smaller scale. This is ultimately less stressful to the grid. If placed over large enough areas, wind and solar generation can be consistent and reliable, but only if future grid infrastructure is designed to link the most ideal areas for generation to urban and industrial centers of demand.

The important consideration here is the *direction* of grid development. Americans may maintain and develop grid infrastructure that is oriented towards current and potential coal and nuclear projects; or they may direct new development towards emerging technologies that, in addition to being cleaner and renewable, exhibit trends that suggest that they will soon be less expensive than their conventional counterparts. The wisest choice is obvious.

The interstate nature of grid challenges for renewable technology points to a problem that must necessarily be addressed on a national scale. President Barack Obama recognizes this, and has encouraged congress for some time to act "without delay" to pass legislation for the construction of Smart Grids, which use state-of the-art technology to improve efficiency and reliability of electricity supply while expanding renewable capacity.[113] Decision makers should take this to heart and ensure that such technology is implemented in a way that prioritizes long-term alternative energy development.

Federal influence on and financial input into future grid infrastructure geared towards renewable technologies can resolve the major challenges faced by the renewable energy sector. Overcoming these challenges will create thousands of job opportunities for Americans in places where they are needed most. This endeavor should therefore be viewed as an economic opportunity rather than simply as an obstacle.

4. Conclusions & Recommendations

In July of 2008, the Department of Energy's Office of Energy Efficiency and Renewable Energy released a comprehensive feasibility study regarding the prospects of producing 20% of US electricity from wind by 2030. This report, featuring input from the industry, government, and the nation's national laboratories, concluded that achieving the ambitious goal of 20% would be challenging, but not by any means impossible.[114] In order to prevent the serious consequences of anthropogenic climate change, the US must focus its energy and resources toward achieving this goal, if not one that is even more aggressive.

Federal and state governments alike must be careful but bold in orchestrating the overhaul of US electricity infrastructure needed to harness available wind resources more effectively and on a wider scale. The following policy recommendations are made with this necessary overhaul in mind:

- Consider allocating more funds from the 2008 Farm Bill focused on financing more rural wind farm development.
- Work to streamline the process by which land is zoned and permitted for wind turbine development to speed up installation of new capacity and eliminate the need for new fossil fuel and nuclear generators.
- Begin efforts now to modernize and expand grid infrastructure to allow for maximum utilization of available wind and solar resources.
- Consider state-level incentive programs to allow for the cooperative development of a cohesive and renewable-friendly national electricity grid.

It is imperative that policies at all levels of government support and encourage wind industry expansion. Climate change mitigation will require serious collaboration, compromise, and focus. This challenge has the potential to bring the nation together around the common cause of reducing costly externalities and preserving the earth for generations to come.

Looking Forward

While renewable technology is extremely promising, perhaps the most significant and cost-effective potential emissions reduction option in the immediate future comes in the form of increased energy efficiency and conservation efforts.

In addition, although coal, nuclear, solar and wind represent major options for electricity production, natural gas also merits consideration. Others, such as geothermal, wave, and co-generation, represent interesting options for the future, but as of today, R&D developments suggest that commercial viability is a rather distant possibility. Nevertheless, decision makers should keep their eyes open to possibilities and rapid developments within these sectors.

A final concern related to intermittent sources of renewable electricity is energy storage technology. Such systems may be more economically feasible than previously thought given current reliability problems with the antiquated and inadequate grid.

With these considerations in mind, the report draws a number of final conclusions and recommendations.

Since 1974, California has managed to maintain a relatively stable per capita annual electricity consumption rate of about 7,000 kWh, while the rest of the US has seen a 50% increase in consumption

1. Efficiency and Conservation

Promoting energy conservation should be at the forefront of any energy policy. Americans have become accustomed to a lifestyle in which ever-increasing energy consumption is an accepted reality. This society-wide psychological disposition must be confronted, as Americans are some of the most gluttonous consumers of electricity in the world. With just 5% of world population, US consumers use 25% of globally produced energy each year.[115] If habits do not change, increases in energy efficiency resulting from expanded renewable capacity, new building standards, and other low-power alternatives will be nullified by rapidly growing electricity demand. Decision makers should consider policy options that will increase personal awareness of consumption patterns among individuals. Increases in energy prices, ideally resulting from a reevaluation of production costs to incorporate health impacts, environmental degradation, and subsidy, may be the most effective method of raising energy consciousness in this free market society. Price alone, however, will not necessarily be a sufficient motivating tool. Public awareness campaigns and other tactics focused on conservation are needed if efficiency improvements are to make an impact on demand.

Combining conservation efforts with energy efficiency has the potential to greatly reduce total electricity use. Since 1974, California has managed to maintain a relatively stable per capita annual electricity consumption rate of about 7,000 kWh. In contrast, consumption in the rest of the United States has increased 50% in the same period. The average savings per family in California is about $800 per year. These savings are a direct result of state mandates, high (perhaps “true”) electricity prices, and effective incentives for power companies to reduce output.[116] If combined with appropriate efficiency and conservation efforts, an increase in electricity costs (even excluding the external costs cited above) could ultimately result in lower overall payments for the average consumer.

To further quantify some direct benefits of efficiency, we may consider the concept of ‘negawatts,’ or watts of energy that are *not* produced due to efficiency implementations. The converted end-user kWh cost for most efficiency improvements may range from -0.5 cents per kWh to 4 cents per kWh, much less than any form of electricity generation.[117] Given this cost information, it becomes absolutely clear that energy efficiency and conservation policy must be included in the carbon mitigation portfolio.

A good place to start with efficiency improvements is in the construction and operation of public and private buildings, which at present account for 76% of electricity used in the US each year. ‘The 2030 Challenge Stimulus Plan,’ a program championed by

Architecture 2030 founder Ed Mazria, demonstrates the potential economic and environmental benefits of reducing energy use in this sector. The plan calls for \$192 billion in public stimulus and incentive programs over the next two years for projects aimed at improving building efficiency in order to conserve energy. Though initially costly, this effort will revitalize the struggling US economy by generating 9.3 million jobs while laying the foundation for a market with a projected value of \$2.6 trillion by 2030. Incremental mortgage buy downs and accelerated depreciation options contingent upon significant carbon footprint reductions will spur this market, creating a tax revenue base in the process that will easily exceed the associated costs. Unlike the current buy down procedure under TARP, this program will ultimately result in a net public gain, from both an economic and social standpoint. The implementation of The 2030 Challenge Stimulus Plan has the potential to reduce CO_2 emissions and energy consumption by 504.47 million metric tons and 6.47 QBtu, respectively, over a five-year period.[118] This fiscally sound and environmentally benevolent strategy for economic recovery, energy use reduction, and renovation should be seriously considered as a policy option for lifting the country from recession.

Conservation and efficiency improvements in all sectors are the easiest and most cost effective ways to reduce consumption and mitigate emissions. Policymakers at every level of government, especially those in federal service, should aggressively pursue efforts toward significant demand reduction as part of any energy policy.

2. Natural Gas

Natural gas, responsible for around 19% of electricity produced in the United States each year (slightly less than nuclear), is another important energy source.[119] One feature of natural gas generation is that, like solar, it is usually supplied as a peak-load source of electricity. This stems from the fact that natural gas plants can be efficiently and reliably turned on and off as needed.

Natural gas plants emit about half the CO_2 of coal plants per unit of energy produced. This is an improvement, but not a solution. Externality analysis under the ExternE methodology points to a mean third-party cost of 0.16 cents per kWh, significantly less than coal, but still more than for renewables.[120] Though natural gas at present is a valuable source of peak-load electricity, it competes with solar, which, as described above, is poised for rapid market expansion.

The major drawback of natural gas is cost. Although capital input is not as significant for natural gas as it is for solar and wind,[121] fuel costs, representing up to 73% of total cost per generated kWh, are highly volatile.[122] Increases in demand and speculative pricing schemes for this fuel add uncertainty to the market.

A recent example of supply concerns related to natural gas resulted from international tension between Russia and Ukraine. After experiencing trade disagreements, Russia blocked supply to several Western European countries, causing costly outages in the heart of winter.[123] On a global scale, 'peak gas,' the point at which gas production from traditional methods begins to wane, is another point of concern, as some estimate supply to begin to decline as early as 2020.[124] The Energy Information Administration disagrees, however, estimating consistent supply levels well into 2030.[125] To accommodate increasing demand, the US may eventually rely on gas imports that will threaten energy security and add volatility to electricity pricing. Even more concerning is community and state resistance to the development of import infrastructure, particularly in the form of liquefied natural gas terminals. This too may have an upward impact on prices.[126]

To accommodate increasing demand, the US may eventually rely on natural gas imports that will threaten energy security and add volatility to electricity pricing

In short, although natural gas may serve as an important reduced-carbon source of energy, its environmental impacts are by no means insignificant. Furthermore, serious supply concerns remain for such generation. With these concerns and uncertainties in mind, investment in renewables to meet peak demand seems advantageous.

3. Storage

The intermittency problem associated with renewables mentioned earlier remains, to some extent, a problem, though there are a number of possible solutions. Grid infrastructure developed within the appropriate framework will ease some concerns regarding renewable electricity supply, but large-scale expansion may nonetheless require some form of storage.

There are many forms of electricity storage that have the potential to meet this challenge. Hydrogen generation may be a feasible option if fuel cell technology advances at a reasonable rate. ‘Flow batteries’ have also proven to be a scalable and distributed source of storage that may provide an economically viable stability to supply.[127] Wind turbines may also allow for underground storage in the form of pressurized air,[128] while some thermal solar plants already utilize heated molten salt to continue generation well into the night. Other promising options are on the horizon.

Although costs for such development may seem to be an immediate economic concern, further analysis indicates that storage infrastructure may ultimately *reduce* costs by increasing availability of supply.

The current grid system is by no means perfect. Estimates of costs for grid outages given current infrastructure conditions total upwards of $143 billion per year.[129] At this point, distributed renewables and accompanying storage facilities become relevant to the discussion. Appropriate storage infrastructure may allow for both the reduction of outage costs and the integration of clean renewables on a large-scale. Little research has been done in this area, but it remains an important consideration. Policy makers would do well to commission an analysis of technology options in this sector.

4. Final Conclusions

It has been shown that the cases for coal and nuclear are riddled with social, environmental and economic costs. Overruns, subsidies and lax regulation put unnecessary risks and responsibilities on the American people. This is not the optimal approach to energy policy in a country that places a high degree of faith in rational market sensibility. Solutions should be geared towards renewable technologies in light of economic considerations and carbon mitigation factors. In summary, decision makers should consider the following to begin to fundamentally shift US electricity policy toward a more reasonable market reality:

Estimates of costs for grid outages total upwards of $143 billion per year. At this point, distributed renewables and accompanying storage facilities become relevant to the discussion

- Prioritize conservation and energy efficiency in federal energy policy
- Comprehensively analyze subsidies in the electricity sector and phase-out incentives for more problematic technologies
- Analyze and consider external costs in the form of social and environmental harm by source when forming future energy policy
- Accelerate the phase-out of coal and nuclear facilities in a fiscally and socially responsible manner
- Develop new infrastructure that is compatible with renewable sources of electricity
- Invest public money in the renewable sector to eliminate existing market distortions created by years of neglect of external costs

Students gathered and compiled the information in this report to advocate serious change that will benefit young generations of Americans from all walks of life. The case presented is not tied to any traditional ideological divide between left and right. Rather, recommendations herein aim to preserve the world for future generations to enjoy while laying the foundation for a sustainable and thriving economy. To prevent catastrophic repercussions associated with climate change, electricity policy must change. It is in the hands of policymakers to ensure that this change happens now.

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