Evaluation of the T. Boone Pickens Plan for United States Energy Independence

Energy & Energy Policy Final Paper
December 10th, 2008

Mary Geiger
Jeff Picel
Andrew Walcher
Jian Yang

Introduction: The T. Boone Pickens Plan

On July 8, 2008, T. Boone Pickens proposed a National energy plan aimed at reducing United States (U.S.) dependence on foreign oil imports. According to the United States Energy Information Agency (EIA), the U.S. net imports about 58% of its petroleum from a variety of foreign sources. However, the steady depletion of oil reserves in Mexico and other regions friendly towards the U.S. may necessitate increased imports from the Middle East and other less stable regions over the next decade. Dependence on foreign oil from these regions poses a significant liability to U.S. economic interests. The Pickens Plan aims to address this liability by creating greater energy independence within the U.S..

The plan calls for the construction of thousands of wind turbines in the American Great Plains, which would allow for the transfer of natural gas from electricity production to the transportation sector, specifically to heavy vehicles like trucks and buses. Pickens claims that his plan could potentially reduce oil imports by “at least 30% within 10 years.”[1] Using a combination of natural gas and wind power has the additional benefit of creating jobs in the alternative energy industry while combating global warming by limiting greenhouse emissions. Furthermore, he claims that all of plan's goals can be met with existing technology.

The purpose of this paper is to assess the feasibility of the Pickens plan and explore that potential of solar power to be a significant source of clean energy for the U.S. economy. This analysis examines three main topics: the feasibility of using wind energy to produce 20% of U.S. electricity needs by 2020, the prospect of using natural gas to power transportation in the U.S., and an analysis of solar power as a possible alternative or supplement for wind power in the Pickens Plan. The final section of this paper includes possible changes to the Pickens Plan, areas for future study, and several policy recommendations.

The T. Boone Pickens Plan

Successful implementation of the Pickens Plan requires two major shifts in current U.S. energy consumption: the replacement of natural gas by wind power as a significant source of electricity generation and the use of natural gas for transportation purposes instead of imported oil. In 2006, 20% of total electrical power production came from natural gas and only about 1% of total power came from wind. The Pickens Plan aims to increase the fraction of power from wind to 20% over the next ten years (or by 2020)[2] by encouraging private industry to construct thousands of windmills ranging from Texas to North Dakota. The plan estimates that the proposed project would require about $1 trillion to construct the windmills and another $200 billion to connect the windmills to the power grid. A major benefit of replacing natural gas with wind power is a significant reduction in carbon emissions from power production.

Moreover, Pickens claims that the cost of the project may be partially offset by the creation of jobs in the wind power industry especially in construction. Pickens indicated that when a large wind power facility was built outside Sweetwater, Texas, the population grew to 12,000[3] due to the new high-skill jobs that were created. According to Pickens, currently about a fourth of the jobs in Sweetwater are now related to the wind power industry. He believes that the economic resuscitation of Sweetwater can be replicated in America's wind corridor where he plans to build wind power plants. Under the 20% Wind Scenario outlined by the U.S. DOE, the domestic wind industry has the potential to create

3.3 million cumulative full-time equivalent jobs in direct, indirect, and other affected industries between 2007-2030[4].

Increased use of wind power for electricity generation would also free-up natural gas for use in the transportation sector, which enables the second part of the plan: the transfer of natural gas from electric power production to the transportation sector. The Pickens Plan emphasizes converting trucks and buses to natural gas (NG) because NG engines are more effective for operating large vehicles than alternative battery-powered technologies. Trucks and buses already use specialized refueling stations and some of this fleet is controlled by public institutions such as city, state, and federal governments, allowing for a swifter transition.

The Pickens Plan presents three main motivations for a potential switch to natural gas. First, natural gas is the cleanest of all hydrocarbons used for transportation fuel, releasing 29% fewer emissions than gasoline. This will yield further emission reductions than those already gained by replacing NG with wind in power production. Second, natural gas is cheaper than gasoline or diesel for the same amount of energy output. A gallon equivalent of natural gas costs about $1.50 less than a gallon of gasoline. Finally, the vast majority of current U.S. consumption of natural gas can be supplied by North American sources that are friendly towards the United States.[5] The Pickens Plan claims that switching trucks, buses, and other vehicles to natural gas will yield a reduction of at least 33% in foreign oil imports.[6] The technology for NG vehicles such as the Honda Civic GX already exists and there are currently 7 million NG vehicles operating worldwide.

Section I: Wind Power

The United States' energy demands are continually increasing. According to the U.S. EIA, U.S. electricity demand is estimated to grow by 39% from 2005 to 2030.[7] This includes the implementation of energy efficiency and demand reduction programs. Domestically produced wind power is a critical part of the Pickens Plan. The plan cites a U.S. DOE report that estimates as much as 20% of America's electricity can be produced from domestic wind sources by 2030, however the Pickens Plan has a much more aggressive goal of achieving 20% wind power by 2020. Although possible, a 2020 target is not realistic given the challenges outlined in the DOE analysis. Therefore, this paper will assess the feasibility of achieving 20% wind power by 2030 based on the DOE's study.

Wind power currently accounts for only about 1% of U.S. electricity demand (48 billion kWh per year or about 4.5 million households' energy demand). To increase wind power generation by 20 times its current level would cost $1 trillion plus an additional investment of $200 billion to build the capacity to transmit that energy to cities and towns[8]. To properly evaluate this plan one must understand the constraints, assumptions, and other factors that will influence the outcome of such an effort.

Technology

Windmills have been in use for centuries, but modern wind-driven electricity generators have only been used since the late 1970's. The efficiency and design of wind energy technology have improved dramatically since then. New, taller turbines take advantage of higher wind speeds at higher elevation. A single 1.5 MW wind turbine can displace up to 2,700 metric tons of CO_2 per year compared with the current U.S. average utility fuel mix.[9]

If the U.S. is able to generate 20% of its electricity from wind, natural gas consumption could be reduced by 11%, which is equivalent to 60% of expected LNG imports in 2030.[10]

Concerns regarding the technical feasibility of using wind to generate large amounts of electricity include: the availability and remote location of many wind resources, wind variability, the transmission and integration of wind energy into the existing power grid, wind turbine reliability, and the installation and structural integrity of increasingly large blades and towers. There are enough land-based and offshore 100-m altitude wind sites in the United States to generate electricity for the whole country; the area from Texas to North Dakota in particular is very rich in wind energy resources.[11] Although there are ample wind resources within the U.S., many of the sites are far removed from major electricity demanding areas. Increased wind energy generation will require capital investment in both trunk-line and backbone high-voltage transmission lines to deliver energy from production areas to load centers.[12] The amount of new lines required varies with choice of sites and the location of the load centers being served, but the 20% Wind Scenario assumes 30 million MW-miles of additional transmission lines will be required to support wind energy delivery at a transmission loss rate of 0.236 kW/MW-miles and an average cost of $1,600/MW-mile, or a total of $48 billion.[13] The intermittent nature of wind will introduce additional variability and uncertainty into a power grid that already handles a large amount of output and load variability. Reliance on wind energy will require large back-up electricity generation capacity to smooth the inherent variability of wind generation, however, assuming that wind generation and load levels are independent, the "resultant variability [and need for back up capacity] is the square root of the sum of the squares" of these two independent variables. As a result, the larger the total system, the smaller the fraction of reserves needed to balance the load net of wind.[14] Since the net system load must be balanced, not the individual load or generation sources, integrating wind energy into the grid is technically feasible for most of the major grids in the U.S..

Economic Analysis

Profitability is the most significant hurdle to the rapid adoption of wind energy generation. The cost-benefit analysis of wind farms is extremely sensitive to the price of energy, interest rates, the availability of capital and financing, construction costs, transmission installation costs, operations and maintenance costs, government incentives and subsidies, and the cost of material, components and human capital. Tables A.1-A.6 in the Appendix summarize the most critical financial assumptions and cost estimates of the DOE 20% wind scenario report.

The cost of installing additional transmission lines required for the distribution of wind energy is one of the most noted factors in the wind energy debate. Investment in transmission infrastructure was on a general decline from 1980 to 2000. Since 2000, investment has risen from $3.0 billion per year to $6.9 billion per year in 2006 and is expected to rise to $8.4 billion in 2009.[15] To meet rising electricity demand, new energy generation facilities and new transmission lines must be built with or without 20% of U.S. electricity being produced by wind. Under the No New Wind Scenario in the DOE report, about $2,366 billion of investment is required whereas $2,409 billion is required for the 20% Wind Scenario.[16] The present value of the difference between the direct costs of these two scenarios is $43 billion (in 2006 US$).[1] It should also be noted that there is a considerable cost difference between land-based and offshore wind generation. The

1 See Table A.3 in appendix for list of assumptions including fuel, construction, operations, and maintenance

current installed capital cost of offshore wind generation is about $2,400 to $5,000 per kW[17] with a variable cost of about $18 per MWh, while land-based wind energy capital and variable costs are about $1,650 per kW and $5.50 per MWh, respectively[18]. Although offshore applications may be attractive to some, the capital cost required for offshore installations make them less competitive than land-based sites.[2] The 20% Wind Scenario assumes that out of the 293 GW of wind energy that could be produced by 2030, only about 50 GW of that would be produced offshore, "mostly along the northeastern and southeastern seaboards."[19]

Both the 20% Wind and No Wind scenarios account for "all currently enacted federal and state emission standards, renewable portfolio standards (RPS) and tax credits" at the time the report was published (2007).[20] The 20% Wind Scenario analysis assumed the federal renewable energy production tax credit would be allowed to expire at the end of 2008 and that no additional PTC would be implemented.[21] However, the Energy Improvement and Extension Act of 2008, passed by Congress on October 3, 2008, renewed these tax credits through the end of 2009.[22] Although the applicable renewable energy tax credit is worth $19/MWh[23], since it is only extended for one year it will not significantly affect the long-term cost analysis. Future production tax credits or other incentives will likely affect wind energy investment since they provide financial incentives to produce and use renewable energy technology. It should be noted that historic increases in wind energy investment are strongly correlated with the renewal of renewable energy production tax credits.[24] The DOE analysis incorporates state energy incentive and renewable portfolio standards in place as of 2007. The state level incentives have a

2 The 20% Wind Energy by 2030 report assumes a 12.5% reduction in future capital costs due to technology developments and a maturing market

minimal impact on the final analysis. To incorporate various policies, including renewable portfolio standards, a social discount rate of 7% in accordance with the OMB instead of the utility's 8.5% real weighted cost of capital discount rate was used in the DOE analysis.[25]

Aggregated across all domestic electricity consumption, the direct incremental cost of the 20% wind scenario will increase electricity rates by an average of $0.6/MWh over the 2007–2050 analysis period. This is equivalent to "raising average residential monthly electricity bills by just $0.5/month over that same time period". [26] Of course, the incremental costs of the additional wind energy will not be borne by all Americans; most of it will be paid for by those consuming energy from the affected grids. Regions or utilities that choose to install wind generation facilities will pay an average incremental levelized cost for installation and operation (cost per unit of energy) of $8.6/MWh for wind energy compared to the conventional mix of electricity sources.[27] Although this incremental cost can be offset with the current production tax credit of $19/MWh, some utilities may not invest in wind because of specific concerns regarding grid reliability, the availability of reliable wind turbines, the availability of technically knowledgeable maintenance resources, less expensive local energy resources, local special interest groups, other local and state incentives, public opposition to preferred farm sites and other potential challenges.

Social and Political Considerations

Even though a goal of 20% wind energy by 2030 is technically feasible and economically viable given the right set of incentives, there are a number of social and political hurdles. There has been much debate and public concern over the unsightliness and noise of wind farms, the danger rotating blades pose to animals, radar interference, the disruption the construction and operation of wind farms will cause in some communities, the danger of constructing and operating a tower in deep water, and the disruption of water flow (on and off land). These are valid concerns, however one could find faults of similar magnitude with almost every form of electricity generation. Studies have shown noise and bird deaths caused by wind generators are negligible compared to other sources.[28] A recently developed type of radar that can distinguish between aircraft and moving wind turbine blades has been shown to alleviate some of the security concerns associated with wind farms.[29] Unfortunately, concerns over the unsightliness of wind farms, the community disruption of constructing and operating a wind farm, and the potential negative economic impact of reduced reliance on domestically produced coal and natural gas (ie. the loss coal mining or natural gas related jobs) are less easy to address. These concerns, in addition to the financial cost of adopting wind energy, are the biggest challenges to successfully implementing the 20% wind by 2030 plan.

Section II: Natural Gas for Transportation

Since 2002, total U.S. consumption of natural gas has remained relatively flat. While overall growth annual has been fairly small (0.4%), certain segments have grown at much higher rates. Natural gas used for electricity generation in the U.S. has grown at about 4% annually over this period and now accounts for 17% of electricity produced. During this time, the price has risen by 15% annually.[30, 3]

The following data from the U.S. EIA will be the basis for the analysis of the Pickens Plan's assertion regarding natural gas use in electricity generation.

3 See Exhibits B.1 and B.2 for greater trend details

Year	Electricity Generation		Transportation	
	Natural Gas Consumption	Price	Natural Gas Consumption	Price
	(Quadrillion BTUs)	(Trillions)	(Quadrillion BTUs)	(Trillions)
2007	7.1	$7.3	0.7	$14.3
2020	6.1	$6.3	0.8	$12.9

(1) Price is dollars per quadrillion BTUs (units are in trillions)

Source: US Energy Information Agency

These projections contradict some of the details Pickens has stated about his plan. Mainly, natural gas use in electricity generation is projected to decline, starting in 2015 due to a large price shock, while natural gas use in transportation is expected to grow just slightly. The figures Pickens quotes in his plan assume that both of these quantities increase. On the other hand, electricity consumption is expected to grow by 34% from 2007 to 2020, with much of this growth coming from coal generated power. Based on EIA projections of the future energy mix, natural gas will account for approximately 13% of the total electricity generated in 2020. If wind energy is to replace this, then it should account for 13% rather than 20% of the total electricity generated as Pickens has stated.[31, 4]

From an energy security standpoint, it does appear that the U.S. is well positioned to address its own natural gas needs for the immediate future. At the projected annual rate of consumption in 2020, current U.S. natural gas reserves would last 121 years. However, it is important to note that the U.S. only has 3% of the world's natural gas reserves.[30] Therefore, while substituting oil for natural gas consumption would move the U.S. closer to energy independence, natural gas should at best be seen as an energy source that facilitates this transition and not the final solution. If it simply substitutes one liquid fossil fuel for another, the U.S. will end up in the same situation as it is in today.

4 Please reference Exhibit B.3 for additional information on potential forecasting issues

Total Energy Offset and Carbon Footprint Savings

If the Pickens plan is implemented, to what extent will it offset the U.S.'s dependence on foreign oil? Based on the EIA's natural gas projections, approximately 49 billion gallons of gasoline would be replaced. This is equal to 22% of oil used for transportation in 2007 and 37% of U.S. current oil imports. However, based on projected energy consumption in 2020, these figures fall to 20% of oil used in transportation and 22% of total imported oil.[31, 32]

A gallon equivalent of natural gas emits 29% less carbon than a gallon of gasoline. Therefore in the presence of a carbon tax, natural gas will yield an economic benefit over gasoline. The following chart shows the reduction in carbon and economic benefits that could be expected from such an offset for both the 2007 and projected 2020 levels of natural gas used in electricity generation.

Year	Total Carbon Savings (1)	Total Carbon Savings	Natual Gas Savings (2)	Total Annual Savings	Perpetuity Value (3)
	(million tons)	*(billions)*	*(billions)*	*(billions)*	*(billions)*
2007	166.4	$4.7	$85.8	$90.5	$1,850.5
2020	143.4	$4.1	$73.9	$78.0	$1,595.3

(1) Based on amount of natural gas used in electricity generation for each year

(2) Savings from price difference between natual gas and oil ($1.50 per gallon)

(3) Present value of annual savings continued indefintely into future (7% discount rate, 2% growth rate)

Assuming a carbon tax of $28.49 per ton of CO_2 (based on European Union Allowances prices)[33], the total economic savings from reduced carbon taxes are $4 - $5 billion for CNG vehicle owners. However, if a gallon equivalent of natural gas continues to effectively cost $1.50 less than a gallon of conventional gasoline ($1.00 per gallon price difference + $0.50 per gallon tax credit)[34, 35, 36], total savings realized from this cost difference ($74 - $86 billion) will dwarf those obtained through emission reductions. Thus, these cost savings are primarily contingent upon this price relationship holding long-term.

Additionally, natural gas provides other benefits, such as lower sulfur dioxide, nitrogen oxide, total particulate matter (TPM), and mercury emissions, which if incorporated into this analysis would further increase the social benefit of this plan.[37]

<u>Natural Gas Transportation</u>

In order to assess the feasibility of the Pickens Plan to shift natural gas from electricity generation into transportation, a cost/benefit analysis was conducted on the two main types of natural gas vehicles currently in use in the U.S.. While Pickens has stated that natural gas would best be used in heavy duty trucks, there has been much discussion in the press recently about utilizing compressed natural gas (CNG) cars as well. This section analyzes the economic viability of both types of vehicles.

<u>Compressed Natural Gas (CNG) Cars</u>

The only natural gas car sold in the U.S. is the Honda Civic GX. Compared to a Civic sedan, the GX sells for a premium of $9,685.[38] Less than half of this premium is offset by a $4,000 Qualified Alternative Fuel Motor Vehicle tax credit, while the rest is made up over time through a $1.00 cost savings between a gallon equivalent of natural gas and convention gas.[38, 39] Additionally, owners of CNG vehicles are eligible for a $0.50 per gallon equivalent tax credit and may realize additional benefits through local state incentives (state incentives have been omitted in this analysis).[36]

Assuming a scenario where a CNG car owner fills up the gas tank once per week, and another where he/she fills up twice per week, the payback period is as follows:

Packback Period Type	Fill Up Once per Week		Fill Up Twice per Week	
	Without a Carbon Tax	**With a Carbon Tax (2)**	**Without a Carbon Tax**	**With a Carbon Tax (2)**
	(Years)	*(Years)*	*(Years)*	*(Years)*
Undiscounted	7.3	6.9	3.6	3.5
Discounted (1)	10.5	9.8	4.4	4.1

(1) 7% discount rate applied to future benefits

(2) 29% reduction in carbon emissions. Carbon tax of $28.49 - European CCX 10/22/08 close price

(3) Based on performance specifications of Honda Civic GX

This table provides two important insights. First, under the scenario which more closely resembles the annual fuel consumption of an average American (fill up once per week), the true discounted payback period is between 9.5 – 10.5 years.[40] Using the average term of a car lease (5 years) as a proxy for the average ownership term of an automobile, in order to fully recoup this premium, CNG car owners would have to own this vehicle for almost twice as long as they would a typical car. Only owners who use twice the annual fuel of an average American would recoup their investment in less than 5 years. Second, even if a carbon tax is instituted, the cost savings realized by CNG car owners from such a policy would be fairly minor. In order for significant savings to be obtained, these cars would either have to emit much less carbon, or the carbon tax would have to be much higher than the value used in this analysis ($28.49 per ton of CO_2).

The other main step in analyzing the viability of CNG cars to effectively support the goals of the Pickens Plan is to calculate the number of these vehicles that could be powered by the 6.1 quadrillion BTUs (49B gasoline gallon equivalents) of natural gas that would be shifted into the transportation sector. Assuming Americans maintain their average transportation fuel consumption, this could power 95 million Civic GXs.

However, it is extremely unlikely that Honda could produce enough of these vehicles to saturate the market by 2020 as it currently produces just 2,000 per year.[41] In order to have 95 million active GXs in the U.S. market by 2020, production would have to grow at a rate of 135% per year. Furthermore, average annual production between now and 2020 would have to be 7.5 million cars (about 45% of average annual new car sales in the U.S. from 2003 – 2008).[5] Even if it is assumed that people fuel up their CNG car twice per week (necessitating half the number of cars) the annual growth rate only reduces to 121%. Thus, there are strong growth requirements over the near term regardless of the assumptions used in this analysis. Moreover, while Ford, Mercedes, and Opel do produce CNG cars for the European market, their combined global annual production is only 300,000 vehicles.[42] The main takeaway from all of this is that it appears there will be a major timing misalignment between when the natural gas currently used in electricity generation is made available for transportation and when a large enough number of CNG cars capable of fully utilizing this fuel would be available.

Other significant concerns with CNG vehicles include that of the limited number of Civic GXs annually produced by Honda, these are only sold in California and New York. Another major issue is that the Civic GX has about half the range of a typical automobile (225 – 250 miles vs. 500 miles per tank). Also, there are very few CNG fueling stations available in the U.S.. Of the 175,000 gas stations in the U.S., only 1,000 have CNG pumps (.6% market penetration).[42] Thus, the Civic GX has to be mainly used for city driving and is not very practical for long trips across the country.

The Civic GX can be refueled at home, however the process can take up to 16 hrs if the tank is near empty.[38] The owner has to remember to plug car in at night to refuel, which will be a lifestyle change for most Americans. Also, the CNG tank is larger than a

---

5 See exhibit B.4 for simulated market growth

conventional gas tank and reduces trunk space.[42] Finally, CNG is still a fossil fuel and can have a carbon footprint similar to coal if it needs to be liquefied in order to be transported.[43]

CNG Heavy Trucks and Buses

Pickens has advocated for the natural gas freed up under his plan to be used towards heavy trucks and buses and to let fuel efficiency in passenger cars and light trucks be addressed through hybrid technology.[44] This section analyzes two types of such vehicles, CNG buses and garbage trucks.

A CNG bus typically costs $25,000 to $50,000 more than a comparable diesel bus (for purposes of this analysis, a similar premium is assumed for garbage trucks).[45] Under the 2005 Highway and Energy bill, a tax credit of $32,000 is available for heavy duty CNG vehicles over 26,000 lbs.[46] Therefore much of this premium is immediately offset. However, unlike CNG cars, these vehicles typically require their owners to build dedicated fueling stations. The cost for a station capable of handling up to 200 vehicles is $2.7M, however a tax credit of up to $30,000 or 30% of the station's cost (whichever is lower), can be applied toward this.[45, 47]

The main difference between CNG buses and garbage trucks is the amount of fuel consumed per year. CNG buses on average consume around 30,000 gallons per year, while garbage trucks consume 8,928 gallons.[48] Based on this data, the average payback for each type of vehicle is as follows:

Natural Gas Vehicle Type	Packback Period Type	$25,000 Premium Without a Carbon Tax	$25,000 Premium With a Carbon Tax [3]	$50,000 Premium Without a Carbon Tax	$50,000 Premium With a Carbon Tax [3]
		(Years)	*(Years)*	*(Years)*	*(Years)*
Bus	Undiscounted	0.1	0.1	0.7	0.7
	Discounted [2]	0.2	0.1	0.7	0.7
Truck [1]	Undiscounted	0.5	0.5	2.4	2.2
	Discounted [2]	0.5	0.5	2.7	2.5

(1) Reflects performance specifications of natural gas garbage trucks

(2) 7% discount rate applied to future benefits

(3) 29% reduction in carbon emissions. Carbon tax of $28.49 - European CCX 10/22/08 close price

Compared to CNG cars, these heavy duty vehicles have much shorter payback periods. This is primarily due to their higher annual fuel consumption, which allows for the faster accumulation of savings through both emission reductions and the $1.50 per gallon cost differential between natural gas and conventional gas. While the savings due to reduced carbon emission are greater for these types of vehicles, they still have a minor effect on the length of the payback period. Based on this information, heavy duty vehicles (particularly CNG buses) appear to be a better investment under the Pickens plan than CNG cars.

It should be noted that a 2002 study by the National Renewable Energy Lab found that "CNG buses emitted 53% fewer nitrogen oxides, 85% lower TPM, and 89% lower carbon monoxide than a conventional diesel bus."[49] Since a more conservative 29% savings in carbon emissions was used in the analysis above, an even greater carbon footprint reduction could be assumed. This would further reduce the CNG bus' payback period under the presence of a carbon tax.

Similar to CNG cars, the number of producers of heavy duty CNG trucks and buses is very limited. There are currently only two producers of natural gas engines used in these vehicles, Cummins Westport Inc. and John Deere.[50] In 2000, there were approximately 3,500 CNG buses operating in the U.S. (8% market share), and CNG buses accounted for

18% of new bus orders.[45] While these are a better investment than CNG cars for using the natural gas freed up under the Pickens Plan, it would take 1.6 million CNG buses to consume this fuel. This is 20 times the number of buses in the U.S. and approximately 470 times the number of U.S. natural gas buses in the year 2000.[51]

The market for CNG garbage trucks is also limited. There were 966 of these in operation in 2004, and the population is projected to grow to 2,221 in 2010. However the total garbage truck market is just 179,000 vehicles.[48] Even if this entire population was converted to CNG, it would only consume 3% of the natural gas freed up under the Pickens Plan. However, these trucks account for just 2% of all heavy duty trucks in the U.S..[51] Thus, there are potentially many other types of heavy duty vehicles that may also be superior investments to CNG cars for utilizing the freed up energy.

The general conclusion from this analysis is that heavy duty trucks and buses are a more attractive vehicle segment to convert to natural gas due to their shorter payback periods. However, because the population for each type of heavy duty vehicle is much smaller than for passenger cars and light trucks, more than one type will need to be switched over to CNG if the freed up natural gas is to be used effectively in transportation. CNG cars may become a more attractive transportation option once heavy trucks, and other vehicles yielding greater economic and environmental benefits from a CNG conversion, have been changed over to run on natural gas. This section identifies two types of heavy duty trucks that appear to be good candidates for conversion, however this is an area that should be further explored in future studies to confirm the most suitable types for future investment and expansion of production.

Section III: Supplemental Energy Source: Solar

Pickens' Plan has the dual purpose of increasing U.S. energy security and reducing U.S. carbon emissions. As part of the evaluation, this report assesses the potential for solar energy to supplement wind energy as a source of domestic electricity generation.

Current Technologies

There are a host of technologies being developed in the solar energy sector. The most popular is Photovoltaic (PV) technology, which works by converting solar energy into electricity from sunlight. "A PV cell consists of two or more thin layers of semi-conducting material, most commonly silicon. When the silicon is exposed to light, electrical charges are generated and this can be conducted away by metal contacts as direct current (DC)."[52] PV equipment has very low maintenance cost due to few moving parts and generates no greenhouse gases. Other solar technologies include solar heating and solar towers. Currently, there are four main types of PV technologies: Monocrystalline Silicon Cells, Multicrystalline Silicon Cells, Thick-film Silicon, and Amorphous Silicon. These range from highly efficient (approximately 15%) and expensive to the less efficient (6%) but cheaper to manufacture.[53] New technologies under development will potentially be less expensive and more efficient (approximately 30% efficient) than most of today's commercially available solar cells. The latest generation of solar heating technology, consists of collectors (which are mirrors or parabolic dishes) that can track and gather enough sunlight to transform water to steam. This steam is then used to move electricity generating turbines. Solar towers consist of large-scale towers of mirrors that focus sunlight and convert it into heat. Large solar heating towers may become commercially viable in the next few years.[54]

Feasibility Analysis

While solar power promises to be another source of clean renewable energy, is it feasible for this energy source to be a major factor in achieving U.S. energy security? Currently, the U.S. uses 19 trillion kWh of electricity. This report investigates several aspects of solar to see if it can be used to offset part of this usage. First, how much energy can the U.S. realistically obtain using current or near current solar technologies? Second, how much will this cost based on current prices and demand? Finally, what policies must be in place to allow solar to be commercially viable?

The analysis begins by calculating the amount of available sunlight. According to the U.S. National Renewable Energy Lab, the West and Southwest of the United States are exposed to the most sunlight on average[6] and therefore it is expected that the majority of solar power generation in the U.S. will take place in this area. The amount of convertible solar energy available in the U.S. will be extrapolated from the amount of sunlight available in this area. The analysis takes the combined surface areas of Texas, New Mexico, Arizona, California, Nevada, Colorado, and Utah and calculates the total amount of sunlight this area receives based on annual sunlight exposure. A 5% surface area utilization rate and an average efficiency conversion rate of 15% from sunlight to electricity are assumed. According to these calculations and even with the most optimistic projections, only 3,565 gigawatt hours (without transmission loss which is generally about 7%) or about 0.02% of current United States electricity consumption can be satisfied by solar energy conversion with current technologies across this area.[7] In addition, even if

6 See Appendix C.1

7 See Appendix C.2 and C.3 for calculations

this plan was extended to the whole of the United States, solar energy using current technologies would not provide a substantial supplement to current energy needs.

Current PV and solar technologies can generate electricity at a price range of $0.15 to $0.50 per kWh (kilowatt hour). At this price, the minimal cost to generate the full 3,565 gigawatt hours calculated would result in a price tag of $534 million. Based on current prices, it would only cost $357 million to generate the same amount of energy with coal (including carbon sequestration costs) and $178 million utilizing natural gas.[55] Therefore, without any government grants or incentive policies (even with carbon sequestration requirements), solar energy is not economically feasible.

The last part of this analysis will investigate possible policies that will allow solar to compete with carbon emitting energy sources in the marketplace. The Energy Improvement and Extension Act of 2008 extended a 30% tax credit to solar energy revenues that lowers the total cost of solar energy from $534 million to $374 million.[56] At this price, solar is more expensive that coal or natural gas but comes within range of coal based electricity. An additional subsidy of 5% to 10% would lower the cost of solar to approximately equal that of coal.

Section IV: Conclusion, Future Considerations, and Recommendations

This paper's analysis of the Pickens Plan yields the following conclusions. First, while wind power does represent a possible replacement for some natural gas electricity production and 20% of U.S. electricity can realistically be generated using wind, major challenges must be overcome to achieve this goal. Second, using natural gas as the main fuel source for transportation represents significant manufacturing, infrastructure, and economic challenges. While the benefits of transferring natural gas use from electricity generation to the transportation sector are negative for passenger vehicles; positive economic and environmental returns can be realized by using CNG to replace the gasoline or diesel used in heavy vehicles. Finally, current technical and economic constraints do not make solar power a viable replacement for a significant amount conventionally generated electricity.

Future Considerations

One area not fully analyzed in this paper is whether it is an optimal strategy to move natural gas from the electricity to transportation sector. While natural gas emits 29% less carbon than oil, it creates 44% fewer carbon emissions than coal.[37] Therefore, a greater carbon footprint reduction (and economic savings) could be achieved by keeping natural gas in the electricity sector and using wind power to offset the electricity produced by coal. Furthermore, the intermittent nature of wind and solar energy requires significant back up generation capacity. Since natural gas is the best energy source for short lead time, intermittent power generation (as shown by its use in peaker plants), it would seem that its continued use it the electrical sector would be a prerequisite for expanding the capacity of wind and solar power.

However, if natural gas is not moved into the transportation sector the Pickens Plan will not achieve one of its core goals of decreasing the U.S.'s dependence on foreign oil. Instead it will be offsetting an abundant U.S. resource (coal) with another relatively abundant one (natural gas). This decision is dependent upon three key issues. First, how quickly can automotive hybrid technology improve so that heavy trucks can achieve a cost savings equal to the fuel price and carbon emission reductions achieved by heavy trucks powered by CNG? Second, if series (plug-in) hybrids turn out to be the optimal hybrid technology, then is it environmentally and economically better to use this natural gas to generate electricity to power these vehicles, or should it still be used to power CNG vehicles? Third, and perhaps most important, what is the price of foreign energy independence? Is it the cost of the Iraq war, a present value estimate of the cost of future conflicts in the Middle East, or something else entirely larger?

These questions should be explored in future studies. While they are difficult areas of analysis, the impact of the findings in these areas will extend beyond the Pickens Plan and have significant implications for future U.S. energy policy.

Policy Insights

Several policy insights can be derived from this analysis of the Pickens plan. Financial incentives or an increase in coal and/or natural gas prices are necessary to encourage the active adoption of wind or solar energy as the preferable sources of electricity generation. The turmoil in the financial markets and tight credit markets also makes the immediate adoption of wind energy less likely. Pickens recently announced that the construction of a large wind farm in Texas would be delayed, "due to the unexpected fall in the price of fossil fuels and the sudden difficulty of borrowing money"[57].

The introduction of more aggressive renewable portfolio standards, a carbon tax, a federally mandated carbon market, reduced carbon emission limits, reduced water consumption limits, renewable energy government purchase agreements, and renewable energy subsidies have all been discussed as ways to increase the cost of conventional electricity generation relative to the cost of wind and solar energy, making investment in these types of energy generation facilities more attractive to public utilities. The potential effectiveness of any of these policies varies greatly with market conditions and implementation details. Most politicians advocate a cap and trade system to hasten the adoption of low-carbon emitting electricity generation. This policy will raise the price of conventional electricity generation, reduce general demand, and drive the adoption of renewable generation.[58]

Cap-and-trade programs force producers to choose between purchasing credits/allowances or reducing carbon emissions (whichever method is least expensive). The European Union's Emissions Trading Scheme (EU ETS), which was implemented at the beginning of 2005, shows this approach can be successful in achieving this goal.[59] Although determining the appropriate cap levels (and subsequent reductions), allocating emission allowances, monitoring emissions, monitoring the trading market and other implementation details are critical to the overall success of such a system, a federally mandated cap-and-trade program has the potential to efficiently reduce carbon emissions in the U.S.. This may be one of the most efficient methods for driving change, but it is also politically challenging since it will increase energy prices. Without significant public support, any policy that results in an increase in energy prices will be extremely difficult to pass into law.

If a cap-and-trade program is implemented in such a way as to affect the price of retail transportation fuel, it would also encourage the replacement of gasoline with natural gas in the transportation sector. Even though a carbon tax savings will probably not be the major source of cost savings in the switch from gasoline to CNG in the transportation sector, it will increase the benefits of such a transition. However, a price on carbon ties a population's environmental impact to their financial well being, giving them a stronger incentive to change their lifestyle in a manner that further supports the goals of the Pickens Plan (cleaner power and energy independence).

Appendix

A.1 Assumptions used for scenario analysis[60]

Scenario Assumptions	
Renewable Energy Technologies (other than wind)	• Contributions to U.S. electricity supply from renewable energy (other than wind) are held constant at 2006 levels through 2030
Land-Based Wind Technology Cost	• $1,730/kW in 2005 and 2010, decreasing 10% by 2030 • Regional costs vary with population density, with an additional 20% in New England
Shallow Offshore Wind Technology Cost	• $2,520/kW in 2005, decreasing 12.5% by 2030
Wind Technology Performance	• Capacity factor improvements about 15% on average over all wind classes between 2005 and 2030
Existing Transmission	• 10% of existing transmission capacity available to wind plants at point of interconnection
New Transmission	• Transmission will be expanded • $1,600/megawatt-mile (MW-mile) • 50% of cost covered by wind project • Regional cost variations prescribed as follows: 40% higher in New England and New York, 30% higher in Pennsylvania-New Jersey-Maryland (PJM) East interconnection, 20% higher in PJM West, 20% higher in California
Wheeling Charges	• No wheeling charges between balancing areas
Conventional Generation Technology Cost and Performance	• Natural gas plant cost ($780/kW in 2005) and performance flat through 2030 • Coal plant capital cost ($2,120/kW in 2005) increases about 5% through 2015 and then remains flat through 2030 • Coal plant performance improvement of about 5% between 2005 and 2030 • Nuclear plant capital cost ($3,260/kW in 2005) decreases 28% between 2005 and 2030 • Nuclear plant performance stays flat through 2030
Fuel Prices	• Natural gas prices follow AEO high fuel price forecast • Coal prices follow AEO reference fuel price forecast • Uranium fuel price is constant

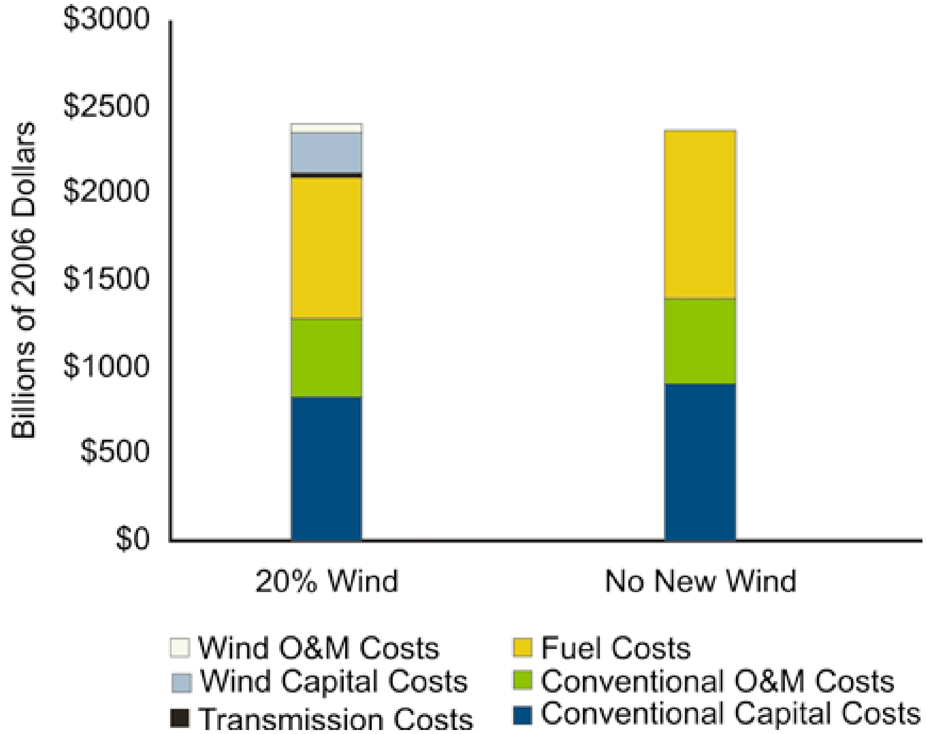
A.2 Distribution of wind capacity on existing and new transmission lines[61]

Transmission Type	2030 Wind Capacity	2030 MW-Miles	Average Distance Traveled for Each MW
Existing Transmission Lines	71 GW	20 million MW-miles	278 miles
New Capacity Lines within a WinDS region	67 GW	N/A	N/A (estimated at 50 miles)
New Capacity Lines that Cross One or More WinDS Region Boundaries	166 GW	30 million MW-miles	180 Miles

A.3 Direct electricity sector costs for 20% Wind Scenario and No New Wind Scenario (US$2006)[62]

	Present Value Direct Costs for 20% Wind Scenario* (billion US$2006)	Present Value Direct Costs for No New Wind after 2006* (billion US$2006)
Wind Technology O&M Costs	$51	$3
Wind Technology Capital Costs	$236	$0
Transmission Costs	$23	$2
Fuel Costs	$813	$968
Conventional Generation O&M Costs	$464	$488
Conventional Generation Capital Costs	$822	$905

A.4 Direct electricity sector costs for 20% Wind Scenario and no-new-Wind Scenario[63]



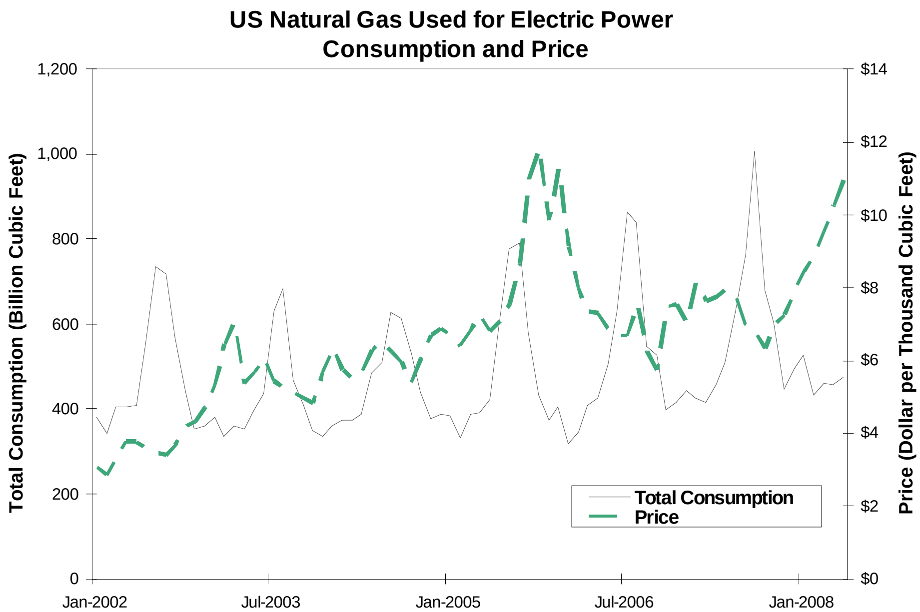
A.5 Incremental direct cost of achieving 20% wind, excluding certain benefits (US$2006)[64]

Present Value Direct Costs (billion US $2006) **a**	**Average Incremental LC of Wind** ($/MWh-Wind)**b**	**Average Incremental Levelized Rate Impact** ($/MWh-Total)	**Impact on Average Household Customer** ($/month)**c**
43 billion	$8.6/MWh	$0.6/MWh	$0.5/month

A.6 Baseline financial assumptions[65]

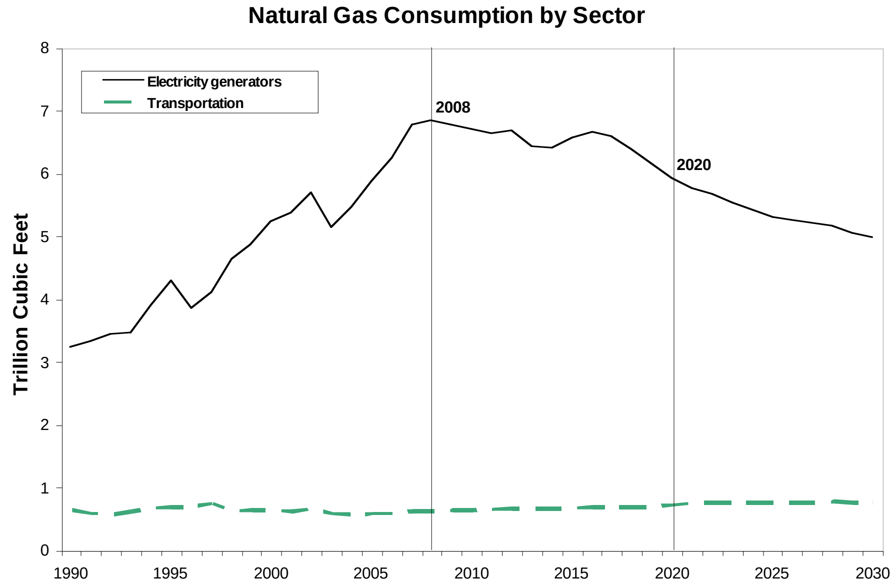
Name	Value	Notes and Source
Inflation Rate	3%	Based on recent historical inflation rates
Real Discount Rate	8.5%	Equivalent to weighted cost of capital. Based on EIA assumptions (EIA 2006)
Marginal Income Tax Rate	40%	Combined federal/state corporate income tax rates
Evaluation Period	20 Years	Base Case Assumption
Depreciation Schedule Conventional Wind	15 Year 5 Year	MACRS (Modified Accelerated Cost Recovery Schedule) MACRS (Modified Accelerated Cost Recovery Schedule)
Nominal Interest Rate during Construction	10%	Base Case Assumption
Dollar Year	2004	All costs are expressed in year 2004 dollars.

B.1. – Natural Gas Trends



Source: US Energy Information Agency – Annual Energy Outlook 2008

B.2. – Natural Gas Trends



Source: US. Energy Information Agency – Annual Energy Outlook 2008

B.3. – Forecast data Issues

It is difficult to say whether Pickens or the EIA will be more accurate in their projections. The EIA is not allowed to utilize non-official government sources in determining its forecasts (which poses significant problems when trying to predict the actions of China and Iran) and has been negatively impacted by budget cuts over the past few years.[66] Also, its projections have come under recent criticism from Congress for failing to predict the massive oil price shocks during the summer of 2008.[67]

Pickens has over 50 years of experience in the oil and gas industry and manages a hedge fund (BP Capital) which has traded energy futures for over 11 years.[68] Success with these financial instruments is predicated on a fund's ability to develop better assumptions and forecasts than the market. However, Pickens has substantial natural gas holdings through his company Mesa Petroleum (the largest U.S. producer of oil and gas) and therefore has a vested interest to see this market grow.[69]

It appears though the figures Pickens has cited for his plan's impact, and particularly for U.S. energy independence, were calculated using current energy consumption levels. Whether this was done because he believes conditions in 2020 will be similar to today, or because these yield higher impact numbers that are more useful in gaining support among the public, is unclear.

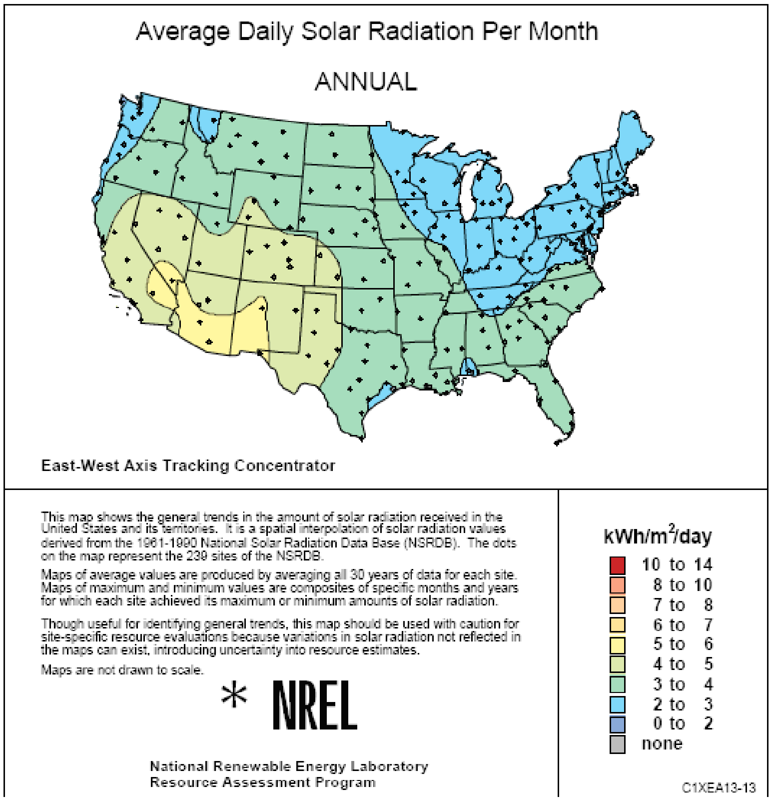
B.4. – Simulated CNG Car Production

CNG Annual Car Production to Achieve 2020 Market Saturation

Year	CNG Cars Produced	CNG Cars Decommisioned	CNG Cars In Use
2008	2,000	0	2,000
2009	4,696	0	4,696
2010	11,024	0	11,024
2011	25,883	0	25,883
2012	60,767	0	60,767
2013	142,669	2,000	140,669
2014	334,958	4,696	330,262
2015	786,411	11,024	775,387
2016	1,846,332	25,883	1,820,449
2017	4,334,806	60,767	4,274,039
2018	10,177,231	142,669	10,034,562
2019	23,894,040	334,958	23,559,082
2020	56,098,280	786,411	55,311,869

Note: Shaded cells indicate amounts are greater than average annual U.S. new car sales from 2002 - 2007

C.1



C.2

Feasibility		
Sunlight	4.75351E+11	kWh
Surface Area Dedicated	5%	%
Efficiency	15%	%
Total Sunlight Converted	3,565,129,004	kWh
Transmission Loss	249,559,030	kWh
Total Sunlight Available	3,315,569,974	kWh
Costs		
Generation Costs	$534,769,351	
Transmission Costs	$0	
Storage Costs	$0	
Other Costs	$0	
Total Cost	$534,769,351	
Subsidy	0	
Tax Credit	30%	
Other	0	
Net Cost	$374,338,545	
Current Electricity Use	19,178,082,191,781	kWh
Solar	$374,338,545	
Coal	$356,512,900	
Oil		
Gas	$178,256,450	
Solar/Total energy	0.02%	

C.3

State	Area (miles)	Area (meters2)	Average Light kWh/day	Average Light kWh	Total Sunlight
Texas	268581	6.95622E+11	4	0.166666667	1.15937E+11
Arizona	113998	2.95253E+11	5	0.208333333	61511135838
California	163696	4.23971E+11	4	0.166666667	70661779275
New Mexico	121589	3.14914E+11	5	0.208333333	65607093944
Nevada	110561	2.86352E+11	5	0.208333333	59656596514
Colorado	104094	2.69602E+11	5	0.208333333	56167127265
Utah	84899	2.19887E+11	5	0.208333333	45809873169
Total					4.75351E+11

source: http://www.statemaster.com/graph/geo_are_lan-geography-total-area

Endnotes

---

1 Pickens Plan, 2008, http://www.pickensplan.com/theplan

2 Pickens Plan, 2008, http://www.pickensplan.com/theplan

3Pickens Plan, 2008, http://www.pickensplan.com/theplan

4 U.S. DOE Report, 20% Wind Energy by 2030, p. 206

5 In August 2008, the U.S. received 89% of total imports via pipeline from Canada and Mexico according to DOE EIA. http://tonto.eia.doe.gov/dnav/ng/ng_move_impc_s1_m.htm

6 Pickens Plan, 2008, http://www.pickensplan.com/theplan

7 U.S. Energy Information Administration's Annual Energy Outlook 2007

8 Pickens Plan, 2008, http://www.pickensplan.com/theplan

9 AWEA 2007

10 Pickens Plan, 2008, http://www.pickensplan.com/theplan

11 U.S. DOE Report, 20% Wind Energy by 2030, p. 24

12 U.S. DOE Report, 20% Wind Energy by 2030, p. 95

13 U.S. DOE Report, 20% Wind Energy by 2030, p. 188

14 U.S. DOE Report, 20% Wind Energy by 2030, p. 79

15 U.S. DOE Report, 20% Wind Energy by 2030, p.94

16 U.S. DOE Report, 20% Wind Energy by 2030, p.162

17 U.S. DOE Report, 20% Wind Energy by 2030, p. 49

18 U.S. DOE Report, 20% Wind Energy by 2030, p. 203

19 U.S. DOE Report, 20% Wind Energy by 2030, p. 9

20 U.S. DOE Report, 20% Wind Energy by 2030, p. 191

21 U.S. DOE Report, 20% Wind Energy by 2030, p. 145

22 http://www1.eere.energy.gov/windandhydro/news_detail.html?news_id=12032

23 U.S. DOE Report, 20% Wind Energy by 2030, p.192

24 U.S. DOE Report, 20% Wind Energy by 2030, p.134

25 U.S. DOE Report, 20% Wind Energy by 2030, p.194

26 U.S. DOE Report, 20% Wind Energy by 2030, p.163

27 U.S. DOE Report, 20% Wind Energy by 2030, p.163

28 U.S. DOE Report, 20% Wind Energy by 2030, pp.112-117

29 http://www.newscientist.com/article/mg20026796.600-radar-can-finally-tell-a-wind-turbine-from-a-plane--.html

30 U.S. Energy Information Agency. Natural Gas Statistical Database. http://www.eia.doe.gov/oil_gas/natural_gas/info_glance/natural_gas.html

31 U.S. Energy Information Agency. "EIA Annual Energy Outlook 2008". June. 2008 http://www.eia.doe.gov/oiaf/aeo/index.html

32 Calculated figures based on data from EIA Annual Energy Outlook 2008 - http://www.eia.doe.gov/oiaf/aeo/index.html

33 Based on price of carbon on European Carbon Climate Exchange as of 10/22/2008. http://www.europeanclimateexchange.com/default_flash.asp

34 Gasoline Price Infomation: Energy Information Agency Database of Average Gas Prices. October 22, 2008 http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_home_page.html

35 Natural Gas Price Information: CNGPrices.com - http://www.cngprices.com/

36 Natural Gas Tax Credit Information: Natural Gas Vehicles for America Website. http://www.ngvc.org/incentives/federalTax.html

37 Energy Information Agency – Natural Gas Issues and Trends 1998. www.naturalgas.org/environment/naturalgas.asp

38 Honda Civic GX website - http://automobiles.honda.com/civic-gx/

39 McClure, Darin R. "Our Honda Civic GX". October 31, 2007. http://hondacivicgx.blogspot.com/2008/02/qualified-alternative-fuel-motor.html

40 U.S. Energy Information Agency. "Petroleum Basic Statistics". September 2008. http://www.eia.doe.gov/basics/quickoil.html

41 O'Dell, John. "Toyota Jumps on Natural Gas Bandwagon With CNG Hybrid at LA Auto Show". Green Car Advisor. September 24, 2008. http://blogs.edmunds.com/greencaradvisor/2008/09/toyota-jumps-on-natural-gas-bandwagon-with-cng-hybrid-for-la-auto-show.html

42 Mitchell, Jacquelin. "The World's Cleanest Cars?" www.Forbes.com. July 30, 2008

43 Odion-Esene, Brai. "Expert: Despite Boone Pickens, NatGas Expensive Oil Alternative", Market News International. July 10, 2008

44 Pickens, T. Boone. Interview with John Stewart on the Daily Show. November 12, 2008

45 World Bank. Clean Air Initiative in Latin American Cities. March 10, 2008. http://www.cleanairnet.org/infopool/1411/article-33906.html

46 Cummins Westport Inc. Website - http://www.cumminswestport.com/products/incentives.php

47 Blue Bird Inc. Website - http://www.blue-bird.com/product.aspx?category=cng&item=All%20American%20Rear%20Engine

48 Underwood, Joanna D. President, INFORM, "Presentation for U.S. Conference of Mayors", www.informinc.org, March 23, 2005

49 Melendez, Margo. "Heavy-Duty Vehicle Emission Testing". National Renewable Energy Lab. June 2003. http://www.nrel.gov/docs/fy03osti/33280.pdf

50 U.S. Department of Energy. "Alternative Fuels and Advanced Vehicles Data Center". September 19, 2008. http://www.afdc.energy.gov/afdc/fuels/natural_gas.html

51 U.S. Bureau of Transportation Statistics. "Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances". http://www.bts.gov/publications/national_transportation_statistics/html/table_01_11.html

52 The Electricity Forum. "Solar Electricity Explained". http://www.electricityforum.com/solar-electricity.html

53 Solar Energy Technologies http://greennature.com/article63.html

54 Solar Energy Technologies http://greennature.com/article2604.html

55 Professor Tolley's Week 2 Class Presentation – „Economic Perspectives on Energy„. Slide 8

56 Environmental News Service http://www.ens-newswire.com/ens/oct2008/2008-10-03-02.asp

57 Clean technology in the downturn, Gathering clouds, Nov 6th 2008, The Economist print edition

58 Fighting for the planet, Nov 19th 2008, The Economist (The World in 2009), Edward McBride

59 Ellerman, A. Denny and Buchner, Barbara K., The European Union Emissions Trading Scheme: Origins, Allocation, and Early Results, http://reep.oxfordjournals.org/cgi/content/full/1/1/66#SEC10

60 U.S. Department of Energy Report, 20% Wind Energy by 2030, p. 124

61 U.S. Department of Energy Report, 20% Wind Energy by 2030, p. 161

62 U.S. Department of Energy Report, 20% Wind Energy by 2030, p. 162

63 U.S. Department of Energy Report, 20% Wind Energy by 2030, p. 162

64 U.S. Department of Energy Report, 20% Wind Energy by 2030, p. 163

65 U.S. Department of Energy Report, 20% Wind Energy by 2030, p. 169

66 Dephills, Lydia. "DOE; Energy Information Chief – 'the calmest person' in a tempest –moves on" Greenwire, August 20, 2008

67 Loveless, Bill. "For EIA, changes in energy markets make gathering data harder: Caruso", Inside Energy, September 1, 2008

68 BP Capital website - https://www.bpcap.net/

69 Flynn, Keli. “The Handbook of Texas Online”. http://www.tshaonline.org/handbook/online/articles/MM/dom4.html