Frequently-Asked Questions (FAQs) About 100% Wind, Water, and Sunlight (WWS) All-Sector Energy Plans for the 50 United States

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Link for WWS energy plans and this document

http://www.stanford.edu/group/efmh/jacobson/Articles/I/WWS-50-USState-plans.html

Q: What is the purpose of these plans?

A: The purpose of these plans is to provide policy makers and the public with a technically- and economically-feasible pathway toward a sustainable, secure, and reliable energy infrastructure that eliminates health and environmental problems due to air, water, and soil pollution and global warming. The plans, if implemented, will result in long-term energy stability, energy price stability, human and environmental health, job growth, and energy security.

Q: Which electric power generation technologies will be used under the plans?

A: Wind turbines, concentrated solar power (CSP) plants, solar photovoltaic (PV) plants and rooftop systems, solar hot water heater systems, geothermal power plants, a few additional hydroelectric power plants, and a small amount of tidal and wave power. These technologies are referred to as wind, water, and sunlight (WWS) electric power technologies.

Q: Which vehicle technologies will be used under the plans?

A: Battery electric vehicles (BEVs), hydrogen fuel cell vehicles (HFCVs), and hybrid BEV-HFCVs. Hydrogen in all cases will be produced by electrolysis, where the electricity will originate from WWS electric power technologies. Long-distance trucks and buses will be hybrid BEV-HFCVs, pure HFCVs, or pure BEVs if battery swapping or additional supercharging stations become available.

Q: Which technologies will be used for air and water heating and cooling?

A: Electricity-powered air-source and ground-source heat pumps, geothermal heat pumps, and backup electric resistance heaters will replace natural gas and oil for home heating and air conditioning. Air-source heat pump water heaters powered by electricity and solar hot water preheaters will provide hot water for homes.

Q: Which technologies will be used for high-temperature industrial processes?
A: High-temperatures for industrial processes will be obtained by electricity and hydrogen combustion, where the hydrogen is obtained from electricity.

Q: What criteria were taken into account when determining the technologies?
A: The selection of these technologies took into account a combination of 11 criteria: carbon-dioxide equivalent emissions; air-pollution mortality and morbidity; resource abundance; footprint on the ground; spacing required; water consumption; effects on wildlife; thermal pollution; water chemical pollution/radioactive waste; energy supply disruption; and, normal operating reliability.

Q: How will the plan rely on energy efficiency?
A: Energy efficiency is an important component of our energy plans. The plans propose the use of the following energy-efficiency options: retrofitting and weatherizing homes with better insulation to reduce energy losses, improving the energy-out / energy-in efficiency of end uses with more efficient lighting and appliances (e.g., refrigerators, washing machines, dishwashers) and the use of heat-exchange and filtration systems, using public transit and telecommuting instead of driving, large-scale planning to reduce energy demand without compromising economic activity or comfort, and designing future city infrastructure to facilitate greater use of clean-energy transport, and designing new buildings to use solar energy better, among others. The quantities of new energy generators proposed in this plan assume minimal energy efficiency to be conservative. Thus, the more that energy efficiency measures are implemented, the fewer the new energy generators needed.

Q: Are there enough renewable energy resources available by state for these plans?
A: Each and every state has more wind, solar, geothermal, plus hydroelectric resources than needed to supply the state's all-purpose energy in 2050.

Q: What is the proposed timeline of this plan?
A: The plan anticipates that all new electric power generators will be WWS generators by 2020 and that existing conventional generator will be phased out over time, with 80-85% conversion by 2030 and 100% conversion by 2050.

Q: How many jobs will be created as a direct result of this plan?
A: This plan will generate, among all 50 United States, about 5.1 million jobs during construction and 2.6 million permanent annual jobs thereafter for the operation of new electric-power generating facilities alone. Many of the permanent jobs created will replace existing jobs in the fossil-fuel industry. We expect the number of permanent jobs created will exceed the number of lost jobs because nearly all energy for the United States will be produced within the country in all sectors (electricity, transportation, heating/cooling, industry). Currently, significant oil is shipped in from outside the U.S., so jobs are lost overseas. In addition, the solar energy sector, for example, employs a significant number of workers per unit energy generate compared with fossil energy sources.

Q: How are the numbers of jobs calculated in the plans?

A: The number of jobs needed to convert the electric power portion of the energy infrastructure to WWS is calculated using the Jobs and Economic Development Impact (JEDI) models developed at the Department of Energy (DOE)'s National Renewable Energy Laboratory (NREL). These models estimate the economic impacts of constructing and operating power plants, fuel production facilities, and other projects.

Q: How does the price of electricity projected in 2030 for fossil fuels compare with the projected price of electricity generated from renewable sources?

A: Levelized electricity costs (rather than price) in 2030 are estimated to be 4-8 ¢/kWh for most WWS technologies and 7-11 ¢/kWh for other WWS technologies (including local transmission), which compares with about 12-16 ¢/kWh for fossil-fuel generators in 2030 when externality costs are ignored and 20-25 ¢/kWh when health and climate costs are factored in. WWS provides that added benefit of hedging the United States against volatility and rises in fossil fuel prices over the long term. Long-distance transmission is estimated to be a median of 1 ¢/kWh for 1200-2000 km HVDC lines.

Q: How were the costs of WWS energy calculated?

A: The overnight capital costs used to evaluate the current cost of the electric power infrastructure to be installed was based on current industry numbers in $/kW installed.

	Cost in million $/MW
Onshore wind	1.40
Offshore wind	3.00
Wave device	3.00
Geothermal plant	1.70
Hydroelectric plant	2.00
Tidal turbine	3.00
Res. roof PV system	1.75
Com/gov roof PV system	1.50
Solar PV plant	1.50
CSP plant	2.50

The current and projected 2020-2030 U.S. levelized cost of energy (LCOE) were determined from referenced studies in the recent literature as described in the Washington State and California energy papers located at http://www.stanford.edu/group/efmh/jacobson/Articles/I/susenergy2030.html. The resulting values were

Energy Technology	2005-2012*	2020-2030*
Onshore wind	4[a] - 10.5[b]	≤4[a]
Offshore wind	11.3[c] -16.4[b]	7[b]-10.9[c]
Wave device	>11.0[a]	4-11[a]
Geothermal plant	9.9-54.2[b]	5.5 -8.8[g]
Hydroelectric plant	4.0-6.0[d]	4[a]
CSP plant	13.5-17.4[b]	7 -8[a]
Solar PV plant	10.1-11.4[b]	5.5[g]
Com/gov roof PV system	14.9-20.4[b]	7.1-7.4[i]

Res. roof PV system	19.3-29.4[e]	7.9-8.2[i]
Tidal turbine	>11.0[a]	5-7[a]
New conventional (no externalities)	**10.0-10.1[f]**	**12.2-15.7[h]**
New conventional (plus externalities)	**10.0-10.1[f] (+5.3[f])=15.3-15.4**	**12.2-15.7[h] (+5.7[f])=19.9-24.8**

Q: Why are 2020-2030 costs of fossil electricity expected to be so much larger than for WWS electricity?

A: The cost of fossil fuel electricity has been rising gradually over time because much of the cost is due to mining, transport, and refining of the fossil fuels, which occur continuously over the lifetime of the fossil-fuel electric power facility. As the cost of living increases, the cost of producing and moving the fossil fuels from the ground to the energy facility increases. WWS technologies, on the other hand, have zero fuel cost. As such, the price of electricity from them stays relatively constant. For example, from 2003-2013, the 10 U.S. states with the highest fraction of their electric power generation from wind saw only a 3 ¢/kWh increase in electricity prices versus 4 ¢/kWh in all other states, including 17 ¢/kWh in Hawaii. Although the capital cost of WWS electric power sources is often higher than that of fossil fuel sources, the zero fuel cost stabilizes prices of WWS generators, resulting in lower long-term costs of WWS generators compared with fossil fuel generators. This factor suggests that WWS technologies will ultimately replace conventional fuels on their own, although policies are needed to speed up the transition to obtain complete replacement by 2050.

Q: How many premature air-pollution deaths will be avoided due to this plan?

A: The plan is estimated to reduce premature air pollution-related deaths in the United States by a mean estimate of approximately 59,000 people per year.

Q: What is the estimated health cost savings to the U.S. due to these plans?

A: Complete implementation of the plans will result in a health-cost savings of approximately $530 billion per year in the U.S. due to reduced air pollution mortality and morbidity: fewer cases of chronic bronchitis, heart disease, asthma, hospitalization, emergency-room visits, lost school days, and lost work days. In addition, it will result in improved visibility and agricultural and forest productivity. These health and environmental cost savings, which take the form of lower medical costs, insurance costs, workman's compensation rates, and taxes, represent ~3% of the United States' gross domestic product in 2012 of $16.2 trillion.

Q: How were the air pollution mortalities calculated?

A: Average mortality risk from ozone (O_3) and particulate matter ($PM_{2.5}$) exposure were calculated for every county in the United States by combining data measured over three years from every monitoring station in every county in the U.S., together with the population exposed to the pollutants in each county and the relative risks of premature mortality determined from epidemiological data. Counties with no recording station were assigned the lowest health risk from any station within the boundaries of their state. The estimates provided here therefore underestimate the mortality risk.

Q: How were air pollution costs calculated?

A: The statistical cost of life is determined by economists based on what people are willing to pay to avoid health risks (Roman et al., 2012). USEPA (2006) and Levy et al. (2010) provided a central estimate for the statistical value of a human life at $7.7 million in 2007 dollars (based on 2000 GDP). Other costs due to air pollution include increased illness (morbidity from chronic bronchitis, heart disease, and asthma), hospitalizations, emergency-room visits, lost school days, lost workdays, visibility degradation, agricultural and forest damage, materials damage, and ecological damage. USEPA (2011) estimates that these non-mortality-related costs comprise an additional ~7% of the mortality-related costs. These are broken down into morbidity (3.8%), recreational plus residential visibility loss (2.8%), agricultural plus forest productivity loss (0.45%), and materials plus ecological loss (residual) costs. However, other studies in the economics literature indicate considerably higher non-mortality costs. McCubbin and Delucchi's (1999) comprehensive analysis of air pollution damages at every air quality monitor in the U.S found that the morbidity cost of air pollution (mainly chronic illness from exposure to particulate matter) might be as high as 25% to 30% of the mortality costs. Delucchi and McCubbin (2011) summarize studies that indicate that the cost of visibility and agriculture damages from motor-vehicle air pollution in the US is at least 15% of the cost of health damages (including morbidity damages) from motor-vehicle air pollution. Thus, the total cost of air pollution, including morbidity and non-health damages, is at least ~$8.2 million/death, and probably over $10 million/death.

Q: How were the climate costs calculated?

A: Ackerman et al. (2008) estimated global-warming damage costs (in 2006 U.S. dollars) to the U.S. alone of $271 billion/yr in 2025, $506 billion/yr in 2050, $961 billion/yr in 2075, and $1.9 trillion/yr in 2100. Anthoff et al. (2011) found that damages to the world are at least an order of magnitude higher than are damages to the U.S. alone. The climate costs caused by each state were estimated in proportion to the global share of the state's energy related greenhouse gas (GHG) emissions.

Q. What are collateral benefits to education and research of the plans?

A: The development of a large-scale energy infrastructure will motivate additional research and development into technologies and methods of improving efficiency, which will serve as an additional benefit to higher education and research institutes.

Q: How much land is required for the energy infrastructure proposed in the plans?

A: The additional footprint on land for the electric power devices proposed over the U.S. as a whole is equivalent to about 0.66% of the U.S. land area, mostly for CSP and PV. This compares with the current footprint of cropland in the U.S. of 19%. An additional on-land spacing area of about 1.82% of the U.S. is required for the plans for on-shore wind, but this area can be used for multiple purposes, such as open space, agricultural land, farmland, or grazing land, for example.

Q: How were footprint and spacing areas for WWS electricity generation found?

A: The footprint area is representative of space that has to be dedicated to the sole purpose of electric power production. It accounts for the surface of wind turbine towers and their cement casing that touch the ground and appear above the ground, the area required for ground mounted solar photovoltaic (PV) plants, the area required for concentrated solar power (CSP) plants, and for the area required for hydropower. Rooftop solar does not add to the final footprint as it is built on existing roofs. The useful space between wind turbines is accounted for in the spacing area over land. This spacing area can be used for farming, grazing, agricultural, or industrial purposes or can be left as open space.

Q: Why don't the plans include power generation from nuclear energy plants?

A: Nuclear energy is not included in the solution because it results in 9-25 times more carbon and air pollution than does wind energy per unit energy produced, partly due to the fossil energy used to mine and refine uranium continuously during the plant's life, partly due to the construction of the plant, and partly due to the fact that the time between planning and operation of a new nuclear facility is 10-19 years, whereas that of the proposed technologies (wind, water, and sunlight) is much less, generally 2-5 years for wind and solar, resulting in opportunity-cost emissions from the background fossil-fuel energy sector during the period that nuclear is waiting to come online. In addition, nuclear poses catastrophic risks due to the historic worldwide relationship between nuclear energy facilities and nuclear weapons proliferation and due to nuclear reactor accidents. Further, in the U.S., radioactive waste currently accumulates at nuclear energy facilities, and no plan exists to store that waste permanently.

Q: Why doesn't the plan include liquid biofuels?

A: Biofuels crops require energy to grow, fertilize (for some crops), irrigate, cultivate, transport to energy production plants, and liquid biofuels require additional energy to transport to their end use locations. Because biofuels are combusted, they release similar conventional air pollutants as fossil fuels. We do not propose to use liquid biofuels for transportation since combustion is 4-5 times less efficient than electric power for transportation. As such the effective cost of a liquid biofuel is 4-5 times that of the electric power to move an electric car the same distance. This results in lower fuel costs for an electric vehicle (~$0.80/gallon equivalent) than a biofuel vehicle (~$4/gallon). For example, if a person uses an electric car for 15 years, driving 15,000 miles per year, that person will save ~$20,000 in fuel costs during this period relative to a biofuel or gasoline car. If the price of electricity and fuel both double, the driver will save $40,000 during the same period.

In addition, the land required to power a fleet of flex-fuel vehicles on corn or cellulosic ethanol is about 30 times the spacing area and a million times the footprint on the ground required for wind turbines to power an equivalent fleet of electric cars. Ethanol combustion, regardless of the source, also increases slightly the air pollution mortality relative to gasoline due to the aldehyde and unburned ethanol emissions from ethanol fuel combustion and the air pollution from the upstream production of ethanol and biodiesel fuel increase health-affecting air pollutants more than do gasoline or diesel. Finally, carbon emissions from cellulosic ethanol for flex-fuel vehicles are about 125 times those from wind energy powering electric vehicles without considering world price changes due to using land for fuel instead of food.

Q: Why doesn't the plan include natural gas, particularly from hydrofracking?
A: Natural gas is a fossil fuel and is not included because it results in 60-80 times more carbon and air pollution than does wind energy per unit energy input, results in much greater land degradation and water pollution, particularly through hydrofracking, and is not a long-term sustainable solution. The methane emissions from natural gas are of significant concern because of methane's powerful global warming impact. The Arctic sea ice is disappearing quickly and will likely be gone in 30 years, and the only potential method of saving it is to eliminate emissions of short-life-time global warming agents, including particulate black carbon and methane. Instead of reducing methane, natural gas mining and production increases it, posing a greater danger to the Arctic sea ice greater than most other pollutants. In addition, electricity generated from fossil fuels such as natural gas is subject to fuel price volatility.

Q: How can the plans ensure reliable electric power?
A: To ensure that the renewable energy supply will match demand and to smooth out the variability of these renewable resources, several strategies will be deployed, including: (1) combining wind, water and solar (WWS) resources as a bundled set of resources rather than separate resources and using hydroelectric power plus stored concentrated solar power, to balance much of the remaining load; (2) interconnecting geographically-dispersed variable WWS resources (e.g., solar, wind, wave) to smooth out the variability of these resources; (3) using demand-response management to shift times of demand to better match the availability of WWS power, (4) over-sizing WWS peak generation capacity to minimize the times when available WWS power is less than demand and provide power to produce district heat for cities and hydrogen for transportation when WWS power exceeds demand, (5) storing energy at the site of generation or use, (6) storing energy in electric-vehicle batteries, and (7) integrating weather forecasts into system operation.

Q: What policy mechanisms can be implemented to promote this plan?
A: The following policy mechanisms are options which can be implemented or revised in each state: 1) Renewable Portfolio Standards (RPS) (also called Renewable Electricity Standards, RES); 2) feed-in tariffs (FITs) and output subsidies; 3) investment incentives (direct or indirect payments by governments to energy producers to build energy infrastructure and for research), including loan guarantees; 4) municipal financing for residential energy-efficiency retrofits and solar installations, and/or purchase incentives and rebates for electric vehicles; 5) a revenue-neutral pollution tax (a tax on polluting energy sources, with the revenue transferred directly to non-polluting energy sources); 6) a straight pollution tax (e.g., a carbon tax); 7) a non-economic policy program reducing demand by improving the efficiency of end use energy or substituting low-energy activities and technologies for high-energy ones; 8) a command-and-control policy option of mandated emission limits for technologies; 9) cap-and-trade; and, 10) community renewable energy programs.