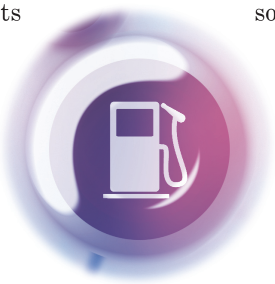
A Closer Look at the T. Boone Pickens Energy Plan

by Dr. Vernon P. Roan Jr., P.E., Florida Alpha '58, and Dr. Robert E. Uhrig, P.E., Iowa Alpha '48

Recent presentations by T. Boone Pickens have described the essence of his plan to generate electricity with wind energy for the indirect purpose of replacing oil used for transportation. Since wind energy is a domestic energy source, this could avoid the transfer of hundreds of billions of dollars per year from the United States. The authors believe that this plan has many favorable aspects, but are concerned that there are a number of pertinent issues that have not yet been adequately addressed. A review of some of these issues is presented here.

Huge and Growing Problem

The plan that Mr. Pickens has presented to the American public would reduce dependence on imported petroleum by a relatively large amount in a relatively short period of time. There is little doubt that American dependence on imported petroleum is a huge and growing problem. The economics of current petroleum imports virtually guarantee a very large trade deficit for the foreseeable future and the possibility of supply disruptions that could threaten national security.



Clearly, any plan of action that could decrease American dependence on imported petroleum should receive serious consideration. However, it is important that any plan be examined closely for feasibility and possible unintended consequences.

The T. Boone Pickens Energy Plan

The projected time scale and potential magnitude of the plan is over a ten-year period to reduce petroleum imports by 38 percent. The primary elements of the *Pickens plan* are:

1. Generate massive amounts of electrical power using new wind turbines.

2. Use the new wind-generated electrical power to remove from service virtually all of the generating units (mostly turbine and combined-cycle units) that consume natural gas (NG).

3. Use the natural gas freed from electricity generating requirements to fuel a large number of transportation vehicles that would otherwise consume petroleum-based fuels.

The importation of oil, including that from countries unfriendly to the U.S., is to be replaced by the use of natural gas that is available in the U.S. The primary motivation for using natural gas is that most of it can be obtained in the U.S. (we are currently importing about one-fifth of what we consume), and, hence, hundreds of billions of dollars per year could remain in the country. This is to be accomplished by diverting the natural gas used to generate electricity into providing fuel for transportation vehicles (trucks and automobiles).

If natural gas is used directly in transportation vehicles, it would require that the natural gas be used as compressed natural gas (CNG), typically stored at about 250 bar [~3,600 pounds per square inch (psi)] or as liquefied natural gas (LNG) stored at -162°C (-259°F).

Authors' Concerns

The intent of the authors is neither to speculate on possible motivations for the *Pickens plan* nor to offer suggestions for improving the plan. The intent is simply to review some of the more important issues relating to the major elements of the plan as presented. These issues could identify physical constraints or time-and-scale limitations that could affect the benefits of the plan.

A look at the approximate numbers associated with the plan's elements provides a feel for the magnitude of the efforts and costs involved. To replace 38 percent of yearly imported petroleum would require displacing more than 5-million barrels of oil daily with natural gas equivalent, which amounts to about 20 billion standard cubic feet (SCF) of natural gas per day or about 7-trillion SCF per year. This amounts to a little more than one-fourth of the approximately 25-trillion SCF of natural gas consumed annually in the U.S. and essentially 100 percent of the natural gas used to generate electricity.

Some of our specific concerns include:

1. The long-term adequacy of the supply of natural gas in the U.S., which is a critical issue that becomes increasingly important as the population grows. Current supplies of natural gas increasingly rely on imported (almost 21 percent of our supply is imported, mostly from Canada) and *coal-bed methane*, which is more expensive than natural gas that typically is pumped or accompanies the pumping of oil out of the ground. In spite of the increasing number of, and deeper, gas wells, the domestic production is slightly decreasing while the demand is increasing.

2. The number and specific types of vehicles that must operate on natural gas to consume 7-trillion SCF of natural gas per year. Modification of vehicles to use CNG can be

expensive. There are about five-million vehicles capable of using CNG in the world, but only about 150,000 of them are in the U.S. Even these tend to be in fleets of buses or smaller delivery vehicles (courier services, mail, municipal, and school buses, etc.). We find little information in the literature about conversion of large trucks, especially tractor-trailers.

Eliminating 38 percent of 15,000,000 barrels per day of imported petroleum would require a consumption reduction of more than 5,000,000 barrels per day. This corresponds to oil that would be refined to provide fuel for more than 100,000,000 light-duty vehicles. This means that the required corresponding new or aftermarket light-duty conversions for a 10-year plan would be more than 10,000,000 vehicles per year. Does manufacturing and installation capacity exist for this many new and/or retrofitted vehicles? What would be the source of the additional funding of perhaps \$100 to \$200 billion per year?

3. Establishing sufficient CNG filling stations in the areas of operation. According to DoE/EERE Fact #548, the number of service stations dispensing gasoline is declining, but there were 164,300 in 2007. In another presentation on on-road diesel, DoE estimates that 20-30 percent of the stations can supply fuel for advanced diesel vehicles. That would correspond to approximately 30,000 to 50,000 stations dispensing diesel fuel. However, DoE data (February 2009) shows that there are only 778 stations that refuel with CNG and only 37 that refuel with LNG.

How many stations would be required to reasonably accommodate tens of millions of CNG or LNG vehicles? Probably at least tens of thousands. How would this be accomplished, especially considering existing current codes and standards that could prevent many locations from even dispensing high-pressure gas? Where would the many billions of dollars come from to design, build, and operate the gas dispensing facilities? What happens to the self-service concept for refueling? Could this be done safely by the average consumer?

Classes of Wind Power Density at Heights of 10m & 50m[a]

	10m (33 ft.)		50m (164 ft.)	
Wind Power Class*	Wind Power Density (W/m^2)	Speed[b] m/s (mph)	Wind Power Density (W/m^2)	Speed[b] m/s (mph)
1	≤100	≤4.4 (9.8)	≤200	≤5.6 (12.5)
2	100-150	≤5.1 (11.5)	200-300	≤6.4 (14.3)
3	150-200	≤5.6 (12.5)	300-400	≤7.0 (15.7)
4	200-250	≤6.0 (13.4)	400-500	≤7.5 (16.8)
5	250-300	≤6.4 (14.3)	500-600	≤8.0 (17.9)
6	300-400	≤7.0 (15.7)	600-800	≤8.8 (19.7)
7	400-1,000	≤9.4 (21.1)	800-2,000	≤11.9 (26.6)

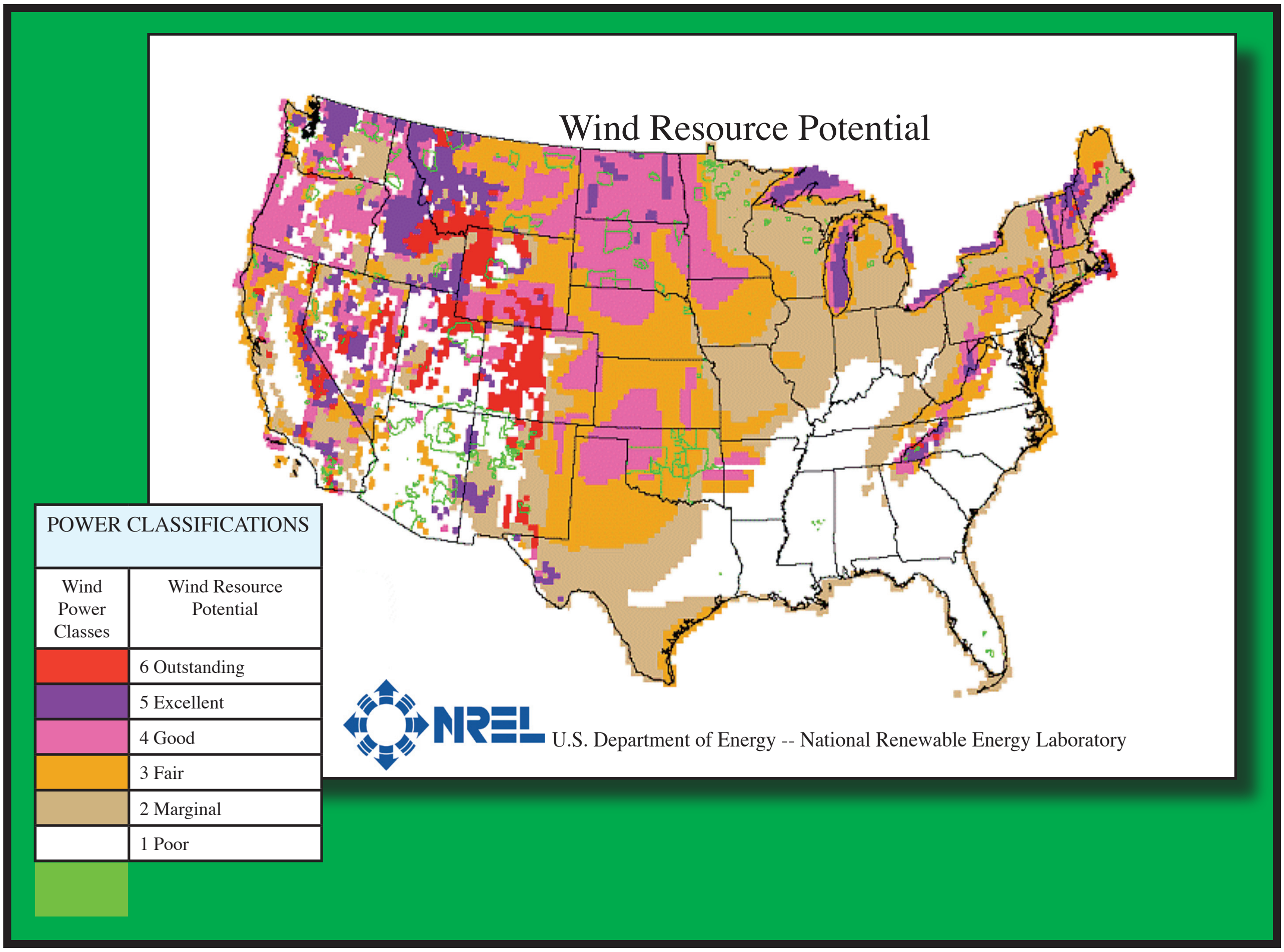
[a] Vertical extrapolation of wind speed based on the 1/7 power law.

[b] Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, speed increases 3%/1000 m (5%/5,000 ft.) elevation.

[*] Note: Each wind power class should span two power densities. For example, Wind Power Class = 3 represents the Wind Power Density range between 150 W/m^2 and 200 W/m^2. The offset cells in the first column attempt to illustrate this concept. Source: NREL—Dynamic Maps, GIS Data, and Analysis Tools. (2006 data released: April 2008)

4. The number and size of wind turbines required to generate sufficient electricity to displace all the natural gas-fired power plants. In 2006, there were approximately 5,500 electric-generating power plants fired by natural gas. These are mostly gas-turbine *peaking* units and combined-cycle (very efficient) units. Together, they have a nameplate power-producing capacity of almost 450,000 megawatts. Assuming wind turbines with an average nameplate power of 3 megawatts (typical of the larger modern installations) and a load factor of 0.5 (a very optimistic assumption), about 300,000 wind turbines would be required to replace the gas-fired units. This translates into new installations of about 30,000 units per year with nameplate combined-power ratings of about 90,000 megawatts each year. By comparison, about 5,000 megawatts was installed in 2007 at a cost of about \$9 billion. Thus, manufacturing and installation of wind turbines would have to be increased by a factor of almost 20 at a cost (assuming similar cost factors) of more than \$150 billion per year. Is such a manufacturing increase feasible? What would be the source of the funding?

5. Vehicle onboard storage presents cost and range problems. The energy content of CNG at 250 bar (~3,600 psi) is about 34,000 BTU per gallon (lower heating value). This compares to the heating value of gasoline (which varies with additives and ethanol content) of about 115,000 BTU/gallon. Because the energy density of CNG at 250 bar (~ 3,600 psi) is only about one-third that of gasoline, a large



tank (40 to 60 gallons) would be required for most cars to provide a gasoline-equivalent range. Such a tank would not fit into the existing space for gasoline tanks in modern light vehicles, so the CNG tank might have to be located in the trunk (for sedans), in the interior storage area (for SUVs and some pickup trucks), or in the bed (for some pickup trucks). Would consumers be willing to give up most of their trunk or storage areas, or would they be willing to accept a much shorter range between refills—or would they balk at both options? An alternative could be to convert natural gas to a liquid fuel. However, even though the technology to do so is well known, there would be a significant net energy loss, there would be large numbers of non-existing conversion facilities required to produce it, and the resulting liquid fuel would contain far more carbon and thus produce more CO_2 than natural gas when burned.

6. Another issue to be addressed is the location of the wind turbines. The EIA/DoE map above shows that the best sites (Categories 4, 5, and 6—see legend) are located predominately in three general regions of the nation. These regions include a north-south strip in the Midwest (ND, SD, IA, NE, KS, OK, and TX), in mountainous areas where wind-turbine installation could be difficult, and along some of the shorelines where there is likely to be considerable resistance. The plan seems to emphasize the Midwest strip. Unfortunately, there are only a few nearby large centers of population—Chicago, Minneapolis-St. Paul, Denver, St. Louis, Dallas-Ft.Worth, and Omaha. The large centers of population are the New York-Philadelphia-Washington, D.C.-Cleveland area and the Los Angeles-San Francisco area, and both of these centers are a long way from the Midwest.

If we assume that the vehicles involved in the conversion to natural gas would be diesel trucks instead of gasoline cars and light-duty trucks, then the number of vehicles required would be greatly reduced. These vehicles, especially the long-distance tractor-trailer rigs, typically are driven many more miles per year and also get much lower fuel mileage than cars. However, there are only about two million such rigs, and they would consume only about half of the target of 5,000,000 barrels per day. Therefore, it is likely that more than 10 million total conversions involving a mix of diesel trucks would be required, with costs and potential problem areas generally greater per truck than with cars. In addition, even beyond those issues, there are limitations on the amounts of gasoline and diesel fuel that can be refined from a barrel of oil. Thus, it isn't completely arbitrary what mix of converted vehicles would be required to account for a reduction of 5,000,000 barrels per day of crude oil.

Another major issue is the assumption that the power generated by the wind turbines would be used to retire gas-fired power plants. There is already much public perception (and growing proof) that greenhouse gas released by the coal-fired power plants is a major problem. Is it likely that clean-burning, gas-fired plants would be retired, without protests, while older and less efficient power plants that produce far more CO_2 were kept on line?

Finally, it must be considered that the *plan* could drive the price of natural gas up significantly. Because millions of homes and a large segment of industry use natural gas, could this not lead to a major problem?

CONCLUSION

There are a number of desirable aspects of the Pickens Energy Plan that could provide many benefits to the United States and its citizens. However, clearly there are many issues to be considered, and this article is attempting to address only some of the more important ones. We believe that debating and successfully resolving the issues listed above, as well as serious investigations to determine other issues, can significantly increase the probability of implementing the *Pickens plan* or any alternative energy plan.

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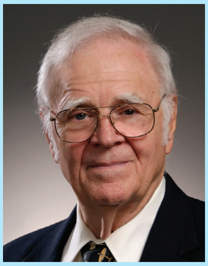

A registered professional engineer, he earned his B.S. in aeronautical engineering in1958, an M.S. in engineering at the University of Florida in1959, and his Ph.D. in engineering at the University of Illinois in1966.

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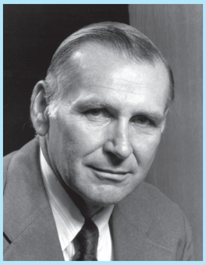

Dr. Uhrig was a vice president at Florida Power & Light Company (1973-86), deputy assistant director for research for the Department of Defense (1967-68), dean of engineering at the University of Florida (1968-73), and was appointed dean emeritus in 1989.

He served on committees for the Nuclear Regulatory Commission, the NSF, and the National Academy of Science/National Research Council. He is the author of 250 technical articles and the book Random Noise Techniques in Nuclear Reactor Systems and co-author of a book entitled Fuzzy and Neural Approaches in Engineering. Recipient of the 2005 ASME medal, he is a member of ΦΚΦ and ΤΒΠ, a fellow of the American Nuclear Society, AAAS, and the ASME, and may be reached at ruhrig@utk.edu.