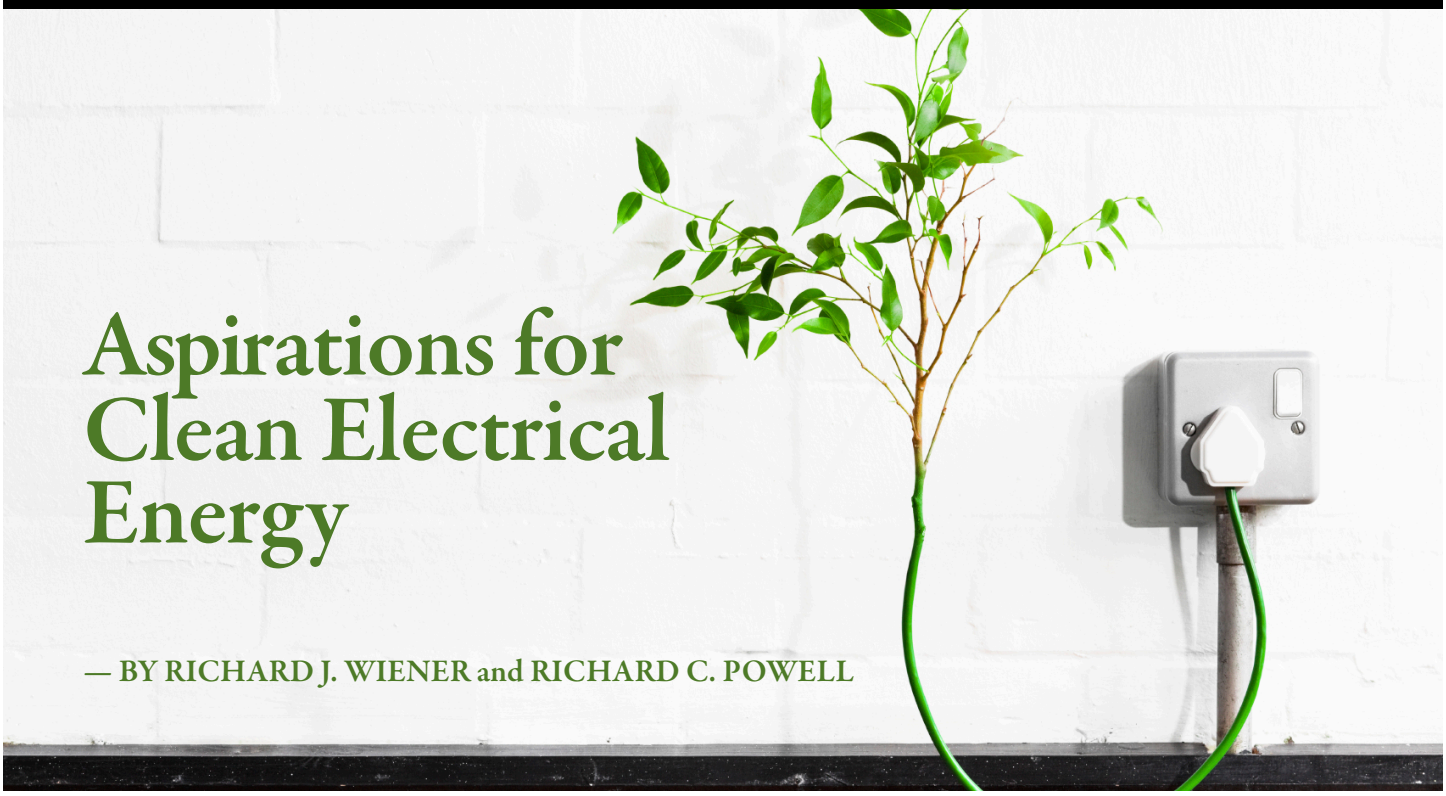

Aspirations for Clean Electrical Energy

— BY RICHARD J. WIENER and RICHARD C. POWELL

Seventy-five percent of the electricity generating capacity in the United States depends on the combustion of fossil fuels. However, there is growing recognition that a large scale transition to clean energy is desirable. This recognition is based on a multitude of concerns, perhaps foremost that dependence on fossil fuels for electricity is causing severe environmental and health hazards including large emissions of toxic air pollutants and greenhouse gases. What will this transition to non-fossil fuel energy look like? How quickly can it come about? Will it be driven primarily by top-down official regulatory agencies, by bottom-up grass roots efforts, free market incentives, or a combination of these effects?

By now the majority of states in the country have officially established renewable energy standards that require their utility companies to generate a specific fraction of their electricity production by clean energy sources by some specific future date. In general these official requirements are in the range of 20 percent clean energy by around 2020. The portfolios for meeting this demand almost always include solar and wind power with other options including hydroelectric, geothermal, nuclear, and biomass generation. The variation from one state plan to another is determined by potential for each type of generation source in each geographical area and local environmental issues affecting the use of these technologies. For example, states such as Nevada and California have a high potential for geothermal electrical generation while Arizona has a very low geothermal potential. As another example, states with sparse water resources such as Arizona are less likely to meet renewable energy standards by adopting non-fossil fuels electrical generation technologies that require significant amounts of cooling water such as nuclear plants, whereas water usage is less of an issue in the Pacific Northwest. As a result of these considerations, it is not possible to have one plan that is appropriate for every state, but rather many different plans tailored to regional needs.

In many regions there are grass roots efforts to push for the adoption of clean energy far beyond official renewable energy standards. Groups such as the National Wildlife Federation (NWF) have developed plans for several states.[1] The NWF plan for New Mexico calls for 65 percent clean electricity by 2050. An environmental group in Utah obtained funding from several foundations to form a committee of experts that developed five possible scenarios for the state.[2] The most aggressive of these scenarios calls for 100 percent clean electricity by 2050. Energy policy experts at universities have published plans setting the goal for California at 100 percent clean electricity by 2020 and for the entire world[3-5] by 2030. In Massachusetts a group of citizens have initiated a petition to the governor and legislature to require 100 percent clean electricity by 2020. We have developed a plan for Arizona[6] that calls for the state to generate 100 percent of its electricity through clean technologies by 2040. President Obama, perhaps influenced by grass roots advocacy, has set the goal for the United States at 80 percent clean electricity by 2035, and the Department of Defense has announced its electricity use will be 25 percent clean energy by 2025. The various groups advocating these aggressive goals cite the need to become free of volatile price fluctuations of fossil fuels, acquire greater energy independence, create local employment, reduce water

usage, reduce emissions of greenhouse gases and toxic pollutants, and establish a revenue source by exporting clean electricity. All of these objectives improve the quality of life and potential for regional economic development. These state plans provide roadmaps with plausible scenarios for phasing out fossil fuels and achieving clean energy generation of electricity. But these plans also illustrate the scale of the challenge of replacing fossil fuels with clean energy in a matter of decades.

The generation portfolios for the clean electricity plans vary significantly for the reasons discussed above. The total quantity of electrical energy projected for each plan depends on the estimated growth in demand, estimated effect of efficiency programs, and the seriousness of the intent to export electrical energy to other regions. States such as Utah, Arizona and California have experienced an increase in electrical power demand over the past decade, but the severe economic downturn, due to the housing bubble bursting, suggests this trend will weaken at least in the near term. Also states like Arizona have recently adopted very aggressive conservation measures in an attempt to stem the continual increase in demand for electricity. And if the cost of electricity rises substantially over the next several decades, elasticity in demand will likely dampen growth. On the other hand, population growth and a transition to plug-in hybrid and electric vehicles will undoubtedly increase demand. Due to such contravening potential effects, there is significant uncertainty about electric power demand several decades from now. The plans for each region have to be flexible enough to accommodate this uncertainty.

The plan for Arizona that we have proposed suggests that the current amount of electrical power generated through hydroelectric and nuclear plants in the state remain constant through 2040, while the current coal and gas fired power plants are phased out. Solar and wind generation along with compressed air energy storage will be phased in to replace the fossil fuel plants and to meet the future growth in demand. The proposed photovoltaic energy is a mix of distributed roof top generation and grid power plants.

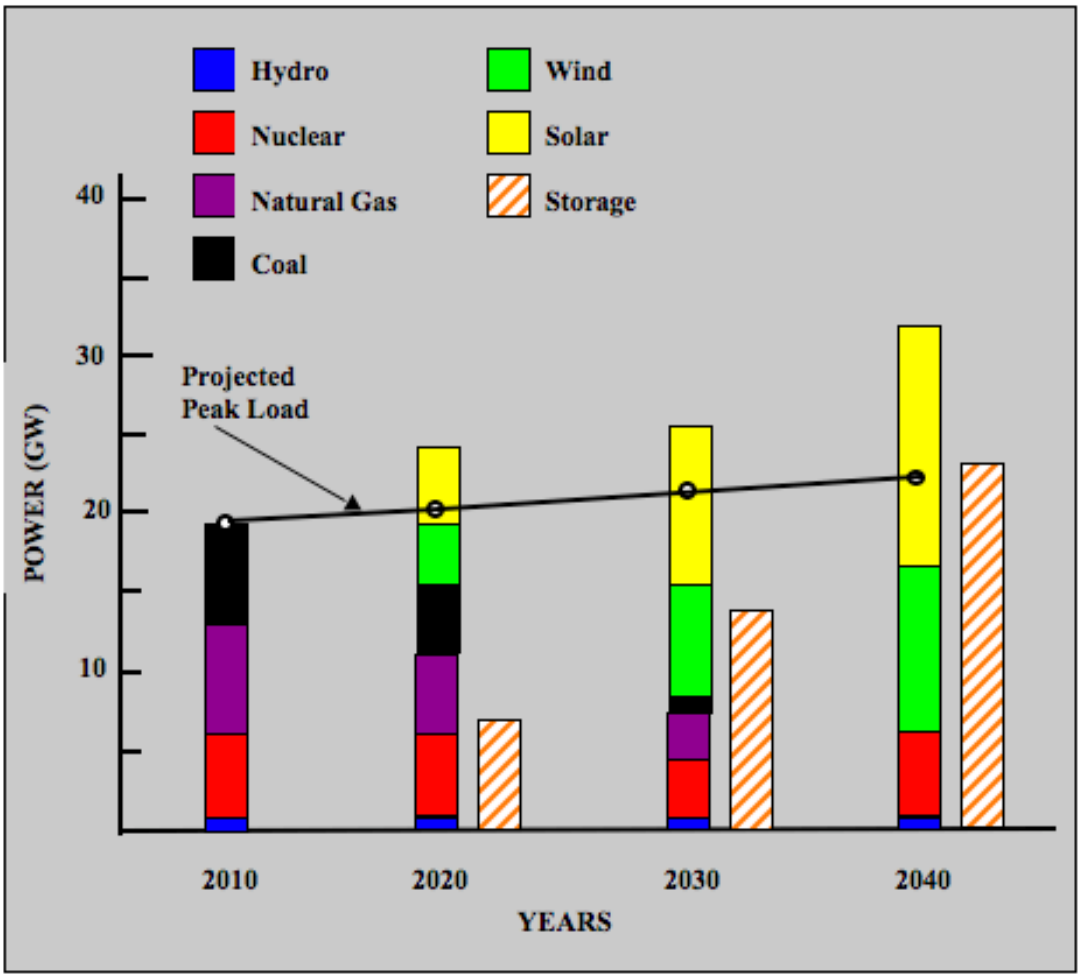

Figure 1. Phased implementation of the Arizona Clean Energy Vision.

demand for electricity in Arizona is assumed to grow at a modest rate of 0.5 percent per year over the next thirty years. This estimate for the rate of growth in demand in Arizona is based on an analysis by University of Arizona economist Stan Reynolds.[7] If this projected growth in demand proves accurate, Arizona will need approximately 10 Gigawatts (GW) of wind power, 15 GW of solar power, and 20 GW of energy storage to be built in the next thirty years to achieve 100 percent clean generation of electricity and have additional capacity for exporting clean energy by 2040.

Although the amounts of needed clean energy generating and storage capacity are substantial in this example, it is certainly conceivable that such a transition could occur. However, there are several key actions required if any of these clean electricity plans are to succeed. The first is addressing the issue of intermittency. All of the plans require a significant amount of solar and wind energy, both of which are intermittent on short term (seconds or minutes) and long term (hours or days) time scales. Currently, the demand response required of utility companies cannot handle this type of intermittency in more than about 20 percent of their generation portfolio. Having a grid penetration of 80 to 100 percent can only be achieved if a significant amount of energy storage capability is present to mitigate the intermittency. For short-term intermittency, supercapacitors appear to be a promising technology, but additional research and development is needed to bring these devices to the level of commercial products. For long-term intermittency, both pumped hydro and compressed air energy storage are proven technologies. The choice for a specific region will depend on issues such as the availability of water and environmental concerns over siting. The current round trip efficiency of compressed air storage technology must be improved through the use of heat exchangers and more efficient compressors. Thus, for both short-term and long-term energy storage there is a critical need for more research and development.

Another important action item for implementing clean electricity plans is upgrading the current electrical grid. The command and control software must be updated to accommodate multiple generation sources with intermittency and two-way flow of electricity. Much of the hardware is old and needs to be replaced and expanded to meet future demand regardless of the type of generating technology. The amount of new grid lines associated with implementing new wind and solar generating stations will depend on the location of the stations. The amount of land available in Arizona, for example, that has been identified as appropriate for solar energy generation is many times more than enough to supply electrical demand far into the future. But deciding which part of this land to use is critical. There are existing solar generation areas near Springerville and Gila Bend, both of which have major grid lines near to them. Expansion of these facilities would require relatively little grid upgrade. However, some advocates of clean energy in Arizona have argued it would be better to have many smaller solar generation stations located on old mine tailings, since such land is already severely damaged and no longer ecologically sensitive. This latter option would require a significant number of miles of new grid lines. Obviously many environmental and social concerns will enter into the decision making process. One major issue in Arizona is that much of the income of some Native American tribes comes from coal mines and power plants. Replacing coal energy by solar and wind energy must be done in such a way that tribal economies are not damaged.

Perhaps the largest issue of all in making the transition from fossil fuel electricity to clean electricity is cost. The installed cost of photovoltaic solar energy is still significantly higher than that of coal and natural gas. To meet the goal of $1/W installed cost of solar electricity (i.e. approximate parity with fossil fuels) set by Secretary of Energy Steven Chu will require targeted research to improve the efficiency of photovoltaic cells and lower the manufacturing costs of both the cells and the balance of system components as well as the installation costs. Even when grid parity for solar energy is achieved, creative financing will be required to provide the incentive for utility companies and private power providers to invest in new clean electrical generation plants. There is a need for a detailed economic analysis of each of the clean electricity plans to determine their financial feasibility as a function of cost curves for clean energy and storage technologies.

Implementing any of these aggressive clean electricity plans will require a shared vision of all the stakeholders as well as strong leadership of the decision makers in a region. As noted above, making these plans happen will require targeted research and development in several key areas and critical decisions about details in the plan such as the siting of new power plants. But articulating aspirations for clean energy in detailed regional plans is a critical first step on the path to a sustainable future. ■

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