

**The Green Wave of Electrification:
A Systems Solution to the Energy Challenges Facing the U.S.**
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At a time when the United States is faced with the dual challenges of an addiction to oil and the threat of climate change, our historical leadership in energy and environmental innovation is declining. Other countries in Europe and Asia are now rapidly catching up, if not leading the world, in cutting edge technologies such as energy efficiency, alternative energy, electric transmission, and energy storage. This erosion of leadership threatens jobs, the American economy, national security, and the environment. To address these threats and to keep the United States competitive in the global marketplace of the 21st century, we believe that we must undertake a comprehensive effort in five key areas.

Increase energy efficiency

The first task must be to greatly increase the efficiency of energy use across the economy from transportation to electric power generation and delivery to our buildings and industry. Historically, innovative new technologies enabled by electricity and electronics have substantially increased energy efficiency. We are seeing a new wave of innovation in transportation. A significant increase in vehicle efficiency can be achieved by the widespread adoption of electric drive technology in today's hybrid vehicles, just as we saw a major increase in efficiency in industry a century ago, when electric drives replaced various mechanical drives. Yet many barriers and disincentives exist. A focused national effort to apply best practices and higher efficiency standards is essential.

Electrify transportation and develop alternative fuels

Oil provides 96.5% of the energy used in transportation. This dependence exposes the economy to price volatility and supply interruptions. Liquid fuels derived from coal or oil shale could alleviate the dependence on foreign oil, but that would result in substantially greater release of greenhouse gasses. The use of carbon capture technologies on hundreds of millions of cars and trucks is not practical. Neither is it practical, today, to use solar power, nuclear power, or other low greenhouse gas emission technologies, in large numbers of vehicles. Bio-fuels can be used in transportation, and may reduce the net release of greenhouse gasses, but this renewable resource will not soon displace a large fraction of petroleum usage. The most realistic scenario for freeing transportation from petroleum is to maximize the use of electricity as an energy source, shifting to hybrid electric drives that are substantially more efficient than the internal combustion engine, and designing those vehicles so that they draw much of their electricity from the grid. Such vehicles are known as plug-in hybrid electric vehicles (PHEVs). Bio-fuels can then provide a much more substantial fraction of the remaining fuel required.

Green electric power supply

Transforming transportation to systems that utilize electricity and bio-fuels will fully address the threat of climate change only if the supply of electric energy is also made greener. This can be accomplished by greatly expanding the use of renewable and nuclear power generation and the deployment of carbon capture and storage technologies where fossil fuels must continue to be used. Carbon capture and storage appears technologically feasible, yet it will be a decade or two before it can be deployed economically and at large scale. Consequently, the near term focus must be on the rapid deployment of renewable and nuclear generation, while carbon capture and storage research,

development, and demonstration are pursued vigorously. Renewable generation will also benefit from programs to continue to improve the technology. Additional work on managing spent nuclear fuel and radioactive wastes is also needed.

Build a stronger and smarter electric grid

The expanded reliance on renewable electric generation creates an additional challenge. The leading forms of renewable generation are generally far from population concentrations where demand for electricity is the greatest. If renewable generation is to provide 25% or 50% of our energy needs, then a substantial increase in the extent and capacity of our electric delivery infrastructure, a stronger grid, needs to be built. To make this expansion of the nation's electric grid affordable and to manage the energy flows effectively, the infrastructure needs more than increased capacity. It needs to be made smarter with more intelligent control and communications technology. We need both a stronger and smarter grid.

Develop massive electricity storage systems

The second complication of renewable generation is that the two most promising technologies, wind and solar generation, are intermittent and variable. Such technologies could provide a much greater portion of electric generation if massive electric storage technologies can be developed. Several possibilities exist. Energy can be stored in hydroelectric reservoirs or compressed air for subsequent release through a turbine, but these technologies are generally limited to certain geographic areas. A major initiative to develop the ability to affordably store massive amounts of electric energy is thus needed. Massive electricity storage on the grid would complement the battery storage in the plug-in hybrid vehicles.

Together a stronger, smarter grid with massive energy storage systems connected to it and distributed storage in the form of the batteries in plug-in hybrids may be sufficient to reduce the need for back-up power generation from fossil fuels. We will only find out if we move to follow this vision of a new energy system.

Take action now

With each passing year, U.S. dependence on imported oil is increasing and the threat to the economy and national security is growing. To address these challenges, the United States needs to aggressively pursue a comprehensive strategy to increase energy efficiency, transform transportation, strengthen and modernize the electric grid and develop and deploy renewable energy technologies. A comprehensive and concerted research and development effort will be absolutely crucial to this endeavor.