

21st Century Grid Modernization: *Enabling an “Intelligent” Energy Future*

All reasonable paths toward an invigorated U.S. energy economy rely upon a comprehensive modernization of the U.S. electricity grid, creating a 21st century intelligent grid that is the spine of a new energy paradigm. A vision for this new grid infrastructure is a “smart” power system that utilizes innovations in sensing, computation and communications to establish visibility and two way communication across the entire system from big generation to transmission to distribution systems and end-use. The real time price of energy production and delivery is transparent to all participants and reflects all true costs of power. Demand, which has traditionally been passive in grid operations, is now a full partner in grid operations, responding to real-time price/incentive signals to manage peaks and continually optimize voltage, providing support to the grid (ancillary services) to aid reliability and renewable energy integration. This smart demand capability also enables better emergency response, allowing the grid to keep critical services on without the use of rolling blackouts. At the transmission level, the system is monitored by a continental network of more than 1000 phasor measurement units that measure the system performance 60 times every second and provide this data to regional/local operators to avoid blackouts, optimally load critical assets, maximize the efficiency of the entire system, and enable the grid to detect and automatically adapt to threats in real-time.

EED has demonstrated its leadership in this area, pushing DOE to develop a vision and plan before the current call to arms emerged. We have been influencing this space for the past five years and expect to play a key role in bringing about this essential national outcome over the next decade. As ‘first in’ to this market niche, we are already partnered with leading vendors including IBM, Itron and mid-market/ tier one domestic municipal and investor owned utilities. Our goal is to help create the vision and roadmap for an electric grid that will deliver the new energy economy being outlined by the new Obama Administration. EED will develop and integrate many of the science and technology elements essential to delivering the grid’s new and expanded functions, and will continue to design and lead large scale demonstrations similar to the Peninsula Project Collaboration and the highly regarded GridWise Alliance. PNNL’s Energy Infrastructure Operations Center will serve as a strategic national asset in establishing the vision and performance expectation for the new grid, and will support and enable the DOE, utilities, state agencies and municipalities in realizing that vision for years to come.

We expect that an aggressive effort to bring the new grid on line in time to meet other ambitious energy and economic goals will require ~\$50 million in federal funding each year for the next decade. A significant and initial portion of the overall effort could be accomplished in concert with an economic stimulus package to accelerate the development of required infrastructure, training and operations centers that will lay down the “rails” for the new grid. Expanded, regional public-private demonstrations will comprise the heart of the program. EED expects to increase programmatic funding in this area by \$10-15 million/year to fund an expanded EIOC capability, support specific areas of technology development (e.g., storage, security and control systems) and enable design and leadership of large scale smart grid demonstrations.

Background and Context

The U.S. power grid started as a single system in New York City more than a century ago and has gradually evolved into an integrated system that is central to America’s prosperity and lifestyle. Today, however, this system is under increasing pressure to perform missions it was not designed to handle. Increasing demand and lagging investment have eroded reserve margins and increased

our exposure to outages. Public support for renewable energy is gaining momentum and a national program to accelerate introduction of plug-in hybrid and other electric vehicles is also emerging, both of which will add further complexity and challenge to grid planning and operations. And the “game changer” of monetizing carbon, likely to occur in the next 2-4 years, will profoundly change system economics and create new drivers for transmission siting and construction. This carbon policy will drive end-use efficiency to new levels, mitigating some of the pressure for new capacity but adding complexity to grid operations with a new wave of end use technologies that have profoundly different electrical properties.

To manage this new and diverse energy load and power the new energy economy, a transformed electricity grid must:

- reliably carry a higher and more diverse energy load, on-boarding and integrating renewables and extending support to new transportation systems;
- effectively store energy to manage intermittent supply and peak demand;
- provide two-way communications, effectively dispatching and managing demand to encourage efficiency and enable reliability;
- deploy real-time controls to further increase reliability and security;
- serve as an accurate data monitor and energy currency exchange agent for supply, demand and carbon credits; and
- operate seamlessly and transparently for the benefit of the nation, adapting to and delivering the full advantage of regional resources without the current patchwork of regional and local regulatory constraints.

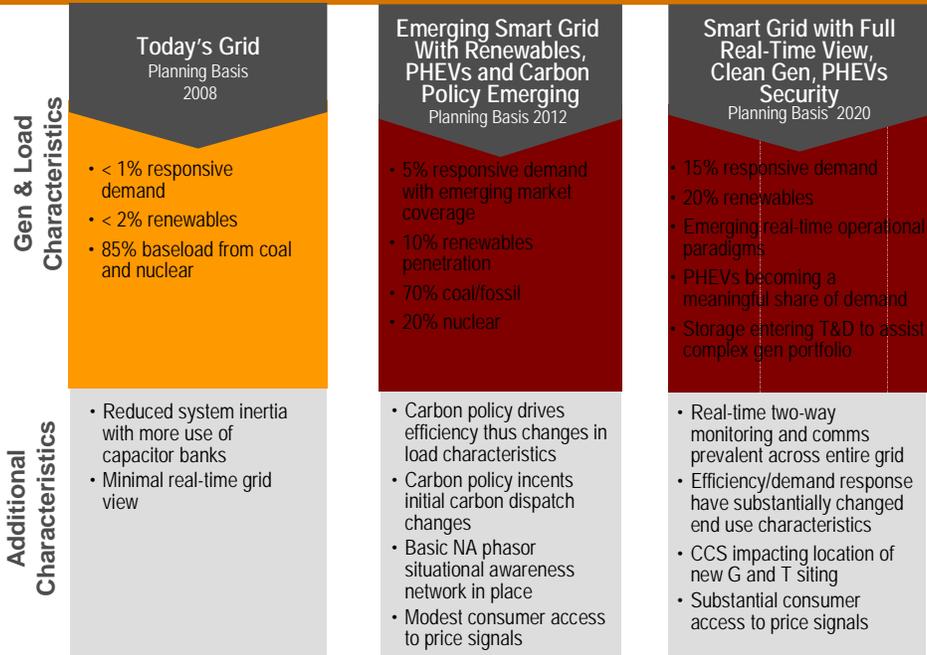
This 21st Century Grid will deliver expanded service reliably and efficiently, maximizing consumer choices in response to the full market value of energy and minimizing the national reserve margin, while freeing up national resources for other high priorities. It would facilitate a new paradigm of power generation that includes more than 25% of electricity generated by intermittent renewable sources without impacting reliability, provides 15% price responsive demand to defer investment and clean up emissions, and embraces a new generation of clean base load generation that is water and carbon neutral (e.g., nuclear, coal with CCS, etc.). The smart grid infrastructure of two-way communications, combined with monitoring and control at each premise will enable the country to meet 40% of demand growth through energy efficiency rather than building new capacity, will enable quantification and verification of the avoided carbon for use in carbon trading markets, and will enable the optimal integration of electrification of transportation. The result will be a transformed power system that gives the U.S. a strategic platform to meet and successfully solve the climate-energy challenge in a way that enhances U.S. vitality and global leadership for future generations.

The Path Ahead

Rahm Emanuel, incoming White House chief of staff, laid out the new administration's priorities in a speech to American CEOs, November 19, 2008 highlighting this area as one element of President-elect Obama's agenda, specifically "green infrastructure" which he said would include “upgraded electricity transmission lines and electrical meters that allow consumers to save money by using electricity at off-peak hours.”¹ This “first order of business” must be considered as on part of a comprehensive blueprint for the new smart grid, described in Figure 1 and outlined below.

¹ Jonathan, Weisman, “Emanuel Sets a Challenge,” *Wall Street Journal*, November 19, 2008.

Emerging Context for National Leadership on Electric Infrastructure Transformation



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Figure 1: Transformation of the U.S. Electric Grid

- **Achieve real-time digital view and two-way communication across the entire grid to provide the foundation for transforming our power system to meet the challenges of our carbon-constrained energy future.** The nation must achieve the outcome of transforming the sensing and communications across the entire power system (G to T to D to customer) to handle the substantially transformed system of the future, and to give us the flexibility to adapt over the long haul to our response to a carbon constrained world. This requires a build-out of a phasor network across the North American interconnections to deliver time synchronized, high resolution (30 to 60 samples per second capability). It also requires two-way communications and sensing (open architecture, multiple platforms) across distribution systems and into customer premises to enable full transparency from G to T to D to customer. This foundation of communications, monitoring and control, deployed within an interoperable and open protocol, will provide the basis for decades of innovation and accomplishment at the scale and pace necessary to win the energy-carbon challenge facing the U.S.
- **Make demand a full resource and tool in grid operations by incenting the infrastructure investment (two way communications, smart gateway and smart end-uses) and getting real time price signals to consumers.** A grid infrastructure must be installed that captures the resource of demand response for energy and economic efficiency. This requires the

transparent, two-way communications infrastructure and the regulatory incentives to pass incentive signals thru to the customers.

- **Deploy a national transmission system to optimize nation's 50-year investment in strategic issues of clean renewables, clean baseload (carbon and water neutral), and energy security via transportation electrification and real-time grid protection.** Transmission capacity must be expanded in a coordinated and accelerated (top down) fashion, ensuring the necessary flexibility and controllability to handle national need for renewables and clean base load over next 50 years. In the near-term, this includes expanding renewable generation to load centers but also overlays other issues that will affect optimal placement of transmission assets that have long life cycles, substantial cost and broad responsibility for reliable, adequate and secure grid operations.
- **Demonstrate and strategically deploy real-time grid control paradigms based upon the ability to see and control the grid as never before.** Real-time control for reliability and security must be incorporated into grid infrastructure investments to ensure that the grid can manage the dramatically different generation portfolios and demand characteristics of our future grid. A continental phasor network driving high speed operational tools, integrated with real-time view and operation of the demand side will transform the resilience, efficiency and flexibility of the grid.
- **Invest for the future.** Finally, the investments we make now must be designed to capture future roles and value propositions over the next 20 to 50 years. This includes establishing the foundation and flexibility to deliver substantial energy efficiency and carbon offsets as a scale and rate to meet the nation's carbon agenda; accommodating the electrification of substantial fractions of the transportation sector; and permitting significant expansion of renewables and/or nuclear energy over time.

The immediate and most obvious consequence of the transformation of the grid is a transformation in energy supply (greater capacity, diversity, reliability, efficiency, productivity and stability). Perhaps less obvious, but equally important and perhaps more game-changing, will be a transformation of the energy market itself by fundamentally altering the demand function to incorporate control and choice in response to variable cost, mix, rate and need of energy. Market signals and control responses will be immediate, accurate and directly accessible to consumers and suppliers via the internet, cable, wireless or other communication devices; appliances and buildings will be designed to adjust their demand for energy in response to its availability at any moment; consumers will be empowered to choose rates and mix of energy based on national, regional and local factors as well as personal need and preference; and major new market opportunities will be available for utilities and other service providers.