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1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138
1200 South Hayes Street, Arlington, VA 22202-5050
201 North Craig Street, Suite 202, Pittsburgh, PA 15213-1516
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Summary

This report presents the initial (Phase I) results of a two-phase project undertaken to characterize and estimate the benefits of applying advanced communications and information technologies, through the GridWise™ initiative, to bring the aging U.S. electricity grid into the information age.

GridWise is a vision, a concept, and a national initiative developed by the U.S. Department of Energy (DOE), the Pacific Northwest National Laboratory (PNNL), and participants from the electricity industry. GridWise seeks to link electricity suppliers and end-users with high-speed networks that provide real-time information about system capacities, demand, prices, and status. Its proponents anticipate that the integration of communications and information with the electricity grid will facilitate competitive, efficient markets for power, enable each participant to actively manage its own production and consumption decisions, help the system balance supply and demand under both normal and stressful conditions, and in general provide diagnostic information and tools to better manage both system operations and end-user applications.

The essence of GridWise is the revealing of value to all parties through information and communications, so that the least-cost resources are used to meet new demand for power and its underlying infrastructure. Markets may be the simplest and most transparent way to reveal value, but regulatory approaches using incentives and resource bidding appear workable as well. Whether in a regulated utility environment or in a deregulated market-based system, advanced information and communications technologies are the keys to revealing value and enabling stakeholders to act on the opportunities presented to them. While this analysis relies on a competitive market model to characterize and estimate benefits from implementing GridWise, we recognize that such benefits may also be realized in a regulated system or in one with both competitive and regulated components.

Smoothing out the daily peaks and valleys of electricity production and consumption can benefit both electricity suppliers and end-users. With GridWise, end-users will see time-varying prices that reflect high supply costs when power consumption peaks and lower costs at other times. Users can then adjust their peak and off-peak demands, either manually or by programming their appliances and other electrical equipment to respond to price signals. This
“demand response” will result in less power consumption during high-cost peak periods and the shift of some peak usage to lower-cost off-peak times. Changes in power usage due to demand response will generally be greater for commercial and industrial facilities than for residential end-users. Overall, end-users will gain from lower expenditures for power, while suppliers will benefit from reduced operating costs and better utilization of their generation, transmission, and distribution assets.

Enabling end-users to interact directly with the grid can also help the electricity system respond to equipment failures, weather-related emergencies, and other stressful conditions. At present, each of the ten North American Reliability Council (NERC) regions must maintain enough excess generating capacity to supply system demand if a large generating unit or transmission line fails. In the GridWise concept, much of that reserve could be provided by smaller generating units located at or near end-user sites or by end-user loads themselves. The GridWise vision of collaborative networks, ubiquitous information flows, distributed intelligence, and automated control systems promises important additional benefits in terms of improved power quality, reliability, and security, as well as energy efficiency.

The Phase I analysis develops a microeconomic framework for making quantitative estimates of demand response and other benefits from the widespread implementation and adoption of GridWise. To establish a baseline without GridWise, we use the projections through 2025 of electricity system capacities, power consumption, and prices contained in the most recent Annual Energy Outlook (AEO) published by the U.S. Energy Information Administration. We then phase in GridWise over 20 years and compare the results with those from the AEO baseline.

To explore the sensitivity of benefits to the input data and assumptions, we develop a series of scenarios representing different, but plausible, development paths for GridWise. Benefits for each scenario are calculated as the present value over 20 years of the cash flow differences from the AEO baseline projections.

Figure S.1 compares the benefits calculated for five scenarios:

- A “nominal” scenario with midrange values chosen for important input variables such as GridWise market penetration among end-users and within the transmission and distribution (T&D) grid; demand response parameters; electricity market competitiveness; and GridWise impact on generating reserve margins, power quality and reliability (PQR), and energy efficiency in buildings.
A highly competitive and responsive markets scenario with higher values for GridWise market penetration among end-users, demand response, impact on generating reserve margins, and electricity market competitiveness.

A less competitive and responsive markets scenario with correspondingly lower values for GridWise market penetration among end-users, demand response, impact on generating reserve margins, and electricity market competitiveness.

A high-PQR-impact scenario with higher pre-GridWise costs of power outages and disturbances for end-users and greater GridWise efficacy in reducing these costs.

A low-PQR-impact scenario with less GridWise efficacy in reducing outages and disturbances.

The systemwide benefits from demand response accrue partly to industry suppliers (the bottom segment of each bar) and partly to end-users (the next segment of each bar). The split depends largely on the extent of market competitiveness and responsiveness. In the nominal scenario, end-users receive 40 percent of the demand response benefits, passed on primarily as lower off-peak prices, which result in lower total expenditures for power. Suppliers receive the rest, benefiting from deferred and reduced costs that substantially outweigh the impact of lower end-user spending. Including benefits from improved PQR
and energy efficiency brings the present value total of benefits to suppliers and end-users to $81 billion.

When electricity markets are both highly competitive and responsive, end-users receive an even larger share (60 percent); but the total benefits from demand response are greater, so the industry suppliers also receive large benefits. Total benefits, including improved PQR and energy efficiency, rise to $132 billion. In the less competitive and responsive market scenario, suppliers get most of the demand response benefits (75 percent), but there is considerably less to divide. Total benefits, including improved PQR and energy efficiency, are only $32 billion, $100 billion less than those for the highly competitive and responsive scenario. The last two scenarios in Figure S.1, in which GridWise has high and low impact on power quality and reliability, yield total benefits of $115 billion and $70 billion, respectively.

These results clearly show that the estimated gross benefits from GridWise can be quite large, exceeding $100 billion in two of the five scenarios. However, the variance among estimates is also very large, depending, of course, on the input data and assumptions. At this early stage of GridWise development, many of the input variables and projections are highly uncertain. Consequently, we believe that delineating the range of benefits based on plausible input variables is more useful than trying to converge on a single “best estimate.”

Our Phase I analysis does not include quantitative estimates of other categories of possible GridWise benefits, notably,

- Lower costs of capital for generation, transmission, and distribution investments.
- Integration of smaller-scale, distributed generation and related assets with the grid.
- Reduced emissions and other environmental externalities.
- Intangible benefits.
- End-user productivity gains.

Based on our preliminary analysis, benefits in the first three categories appear to have relatively small present values compared with those shown in Figure S.1. The latter two categories could conceivably yield much larger benefits, but they depend on assumptions that at this point seem very difficult to validate. In Phase II of this project, we will evaluate these benefit categories more fully and will develop estimates of the costs to implement GridWise.