Appendix A2:
A Systems View of the Modern Grid

MOTIVATES AND INCLUDES THE CONSUMER

Conducted by the National Energy Technology Laboratory
for the U.S. Department of Energy
Office of Electricity Delivery and Energy Reliability
January 2007

Office of Electricity
Delivery and Energy
Reliability

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EXECUTIVE SUMMARY

The systems view of the modern grid features seven principal characteristics. (See Figure 1.) One of those characteristics is to provide the consumer with choices that benefit both consumers and the grid itself. We describe this as 'motivating and including the consumer'.

Figure 1: The Modern Grid Systems View provides an "ecosystem" perspective that considers all aspects and all stakeholders.

In the modern grid, consumers will be an integral part of the electric power system. They will help balance supply and demand and ensure reliability by modifying the way they use and purchase electricity. These modifications will come as a result of consumers having choices that will motivate different purchasing patterns and behavior. These choices will involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives.

From the modern grid's perspective, consumer demand, or *electric load*, is simply another manageable resource, similar to power generation, grid capacity and energy storage.

From the consumer's perspective, electric consumption is an economic *choice* that recognizes both the variable cost of electricity and its value to the consumer under a range of times, places, and circumstances.

Consumers with choices in how they purchase and use energy will be able to:

- Use price signals and other economic incentives (i.e. demand response or DR) to decide if and when to purchase electricity, and

whether to produce or store it using a distributed energy resource (DER).

- Purchase "intelligent load" end-use devices that consume power wisely and that become integral parts of the grid to help optimize its operations and reliability.

Permitting consumers to face the underlying variability in electricity costs can improve economic efficiency, increase reliability and reduce the environmental impacts of electricity production. (*Hirst, E. and B. Kirby, Retail-load participation in competitive wholesale electricity markets, 2001)*

Each of these choices has already been demonstrated to provide numerous benefits to multiple parties. The technologies that enable each, such as advanced metering, smart thermostats and appliances, distributed generation, and energy storage, have been demonstrated to give utilities, system operators, retail marketers, electricity consumers and policy makers new tools for achieving their mutual and separate objectives. Much like the earliest personal computers and cellular phones, these technologies are poised for widespread adoption and deployment, as well as continual improvement.

The benefits of enabling the consumer to take a greater role are tangible and significant. For example, clipping the spikes of peak demand reduces the need to build new facilities, improves the utilization of existing plants and improves the environment by allowing the retirement or reduced use of inefficient generation.

Peak management activities also support a more efficient marketplace by acting as a dampening factor on wholesale electricity prices, which all consumers ultimately pay. In doing so, they help limit the amount of market power that electricity producers and sellers can exercise.

Environmental benefits also accrue because emissions, worse during peak demands, are substantially avoided.

As a result of these benefits being available, and customers taking actions to obtain them, the modern grid will be a more holistic and dynamic system where customers and their dynamic actions will be an integral part.

This document covers key elements of one of the seven principal characteristics of the modern grid — how to motivate and include the consumer. Although it can be read on its own, it supports and supplements "A Systems View of the Modern Grid," an overview prepared by the Modern Grid Initiative (MGI) team.

CURRENT AND FUTURE STATES

We begin by contrasting the current situation for consumers and their electricity purchases, with what it could be like in the future state with a modern grid.

CURRENT STATE

In today's environment, the vast majority of consumers are fully insulated from the volatility of wholesale electricity markets and the true underlying moment-to-moment cost to produce and deliver the electricity they consume. They purchase electricity under fixed, time-invariant prices that are set months or years ahead. The costs of generating that electricity, however, vary substantially from hour to hour, often by a factor of ten within a single day. (*Hirst and Kirby*)

Retail consumers who modify their usage in response to price volatility help lower the size of price spikes. This demand-induced reduction in prices is a powerful way to discipline the market power that some generators would otherwise have when demand is high and supplies tight. And these price-spike reductions benefit all retail consumers, not just those who modify their consumption in response to changing prices. (*Hirst, E. and B. Kirby, Retail-load participation in competitive wholesale electricity markets, 2001*)

Today there are new opportunities emerging that provide the consumer with better information on the actual cost of electricity. They also present a monetary incentive for consumers to modify their usage in response to that information.

These opportunities primarily fall under the new business and policy area known as demand response (DR). Examples of DR are time-based or dynamic pricing options where the price of the electricity purchased by a consumer varies by time-of-day – sometimes even hourly or more frequently. Other examples are programs offered by utilities or independent system operators (ISOs) where customers are paid to curtail or cut back their usage when electric system conditions would benefit.

Demand response offerings have been and can be made by utilities, systems operators or third parties such as retail marketers or companies that specialize in demand response technologies and services. These offerings can be made in either restructured markets or those that are still a traditional, vertically integrated model. Evidence shows that customers both large and small can be counted on to participate in demand response programs and market offerings.

Another area of opportunity is the use of distributed energy resources (DER). This refers to the use of generation systems that are on the customer side of the meter and which can be operated at times of the customer's choosing as an alternative to taking electricity off the grid. It also refers to the emerging storage technologies. (DER is covered extensively in Appendix A5, entitled "Accommodates All Generation and Storage Options," which is available from the Modern Grid Initiative at www.TheModernGrid.org.)

It should be noted that frequently a distributed energy resource is the technology that is used by a customer to participate in a demand response program.

The demonstrations of DR and DER to date illustrate the substantial benefits to reliability and economic stability attainable by motivating and including the consumer. Today, a number of technologies that support DR and DER are available, and many more are under development. The relevant information technologies and digital communications have become both more powerful and less expensive; they are ripe for deployment.

FUTURE STATE

The future will see a robust and widespread link between energy consumers and the modern grid's operators. Creating this linkage will allow consumers to make informed consumption choices, which in turn will benefit both the consumer and utilities.

As technology improves and new policies allow or even encourage increased deployment, the number of customers actively participating will increase and costs will drop. DR and DER programs and market-based offerings will become even more attractive to consumers.

Achieving this customer participation means making it easy and understandable. And essential to this will be providing a user interface that successfully motivates and supports customer action. These interfaces can take a variety of forms, depending on the sophistication and desires of the consumer. They could range from a

Ultimately, competitive electricity markets will feature two kinds of demand-response programs. First, some consumers will choose to face electricity prices that vary from hour to hour. Typically, these prices will be established in the day-ahead markets run by regional transmission organizations, such as those now operating in California, New York and the mid-Atlantic region. Second, some consumers will select fixed prices, as they have in the past, but voluntarily cut demand during periods of very high prices. In this second option, the consumer and the electricity supplier will share the savings associated with such load reductions. (*Hirst, E. and B. Kirby, Retail-load participation in competitive wholesale electricity markets, 2001*)

Figure 2: Consumers may be able to make their electricity choices via a simple point-and-Click Web interface, as in this example from a DOE GridWise demonstration project. Source: This graphic was produced at the Pacific Northwest National Laboratory under Contract DE-AC05-76RL0 1830 with the U.S. Department of Energy, and the GRIDWISE™ trademark is owned by Battelle Memorial Institute.

series of simple indicator/warning lights to detailed computer-generated displays of energy and pricing information. (See Figure 2.) Today's communications and electronic technologies create options that were just not viable in the past.

One example of a future architecture is shown in Figure 3, below. In this example, which visualizes the broad implementation of real time pricing, the mechanism to provide consumers with greater choice involves the insertion of a gateway unit between the energy company and the consumer's appliances. This gateway provides load control based on the consumer's pre-programmed price preferences. In a sense, the gateway acts here as the consumer's agent. New technologies such as computer agents to support consumer decisions and broadband over power lines (BPL) to communicate pricing and other information will enable more effective interaction between the energy company and the consumer.

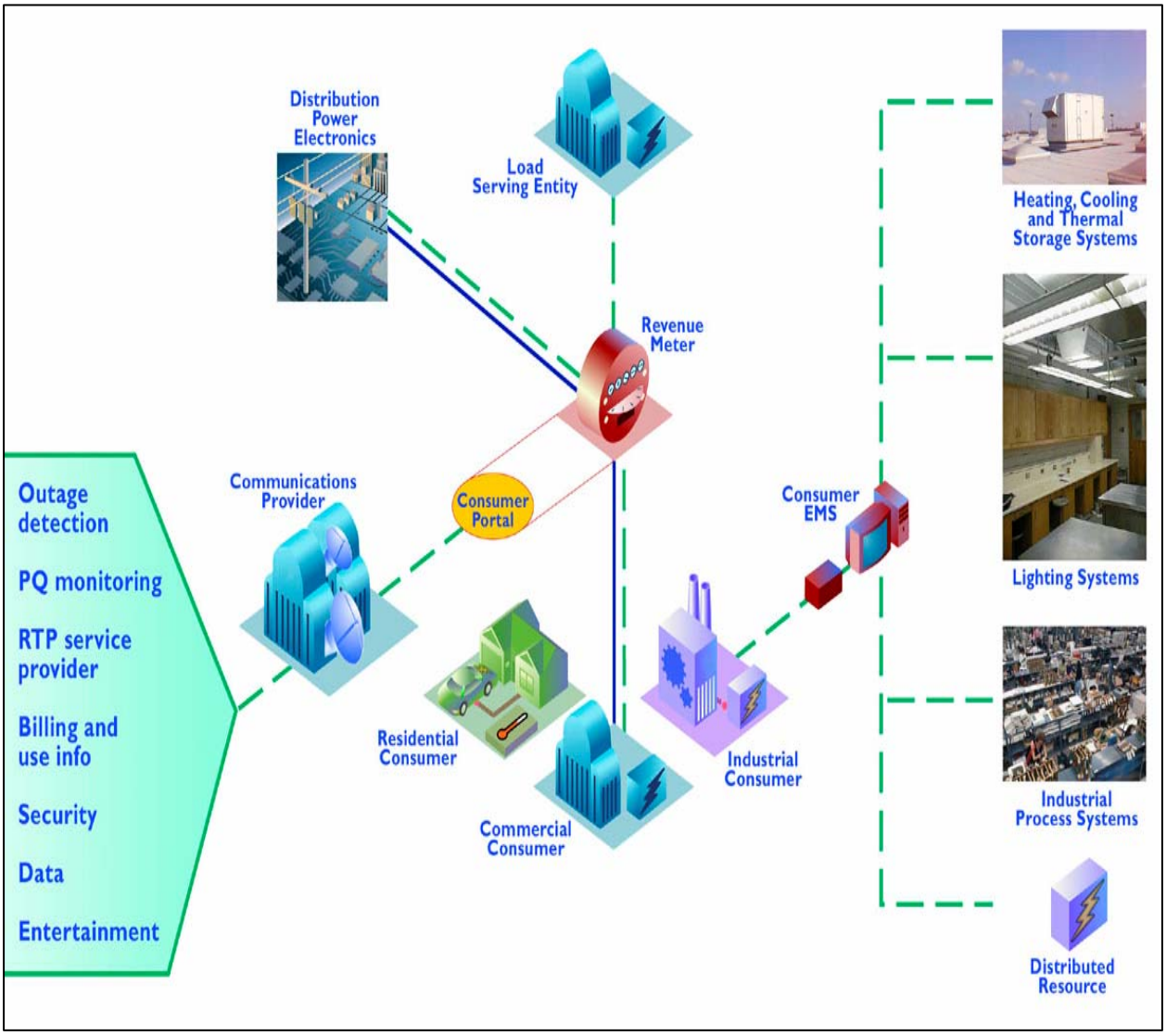


Figure 3. A consumer electricity portal, as envisioned by the Intelligrid research initiative, controls load based on the consumer's pre-programmed price preferences. Image courtesy of EPRI.

Motivated by economic incentives, consumers will adopt newly-available smart appliances. Such appliances will monitor electrical conditions such as voltage and frequency, and automatically turn on or off to support the stability of the grid. Some will also automatically respond to price signals. Distributed resources, another enabling technology, will further strengthen and expand consumers' support of grid operations. Today's digital revolution will seed the needed advances in metering, communications, and decision support. Innovation will be stimulated by competition and economics of scale.

REQUIREMENTS

Having described the current state and envisioned the future state, what are the requirements for achieving that future? This section describes the features and components of the modern grid that are required to offer informed choices to the consumer on how they use power.

FEATURES

Above all, the modern grid must address the consumer's primary objectives. Whether that is simply lowering the electrical bill at home or enhancing the productivity of manufacturing with cheaper, higher quality or more reliable energy, the overarching requirement is the same: choices and tools that are easy to understand and operate – even to the extent of being automatic.

Electricity customers, with the exception of some large businesses, do not want to become buyers and sellers of electricity – their main pursuit is economical and reliable electricity that can yield for them the true values they seek. An energy management program that operates in the background, quietly providing the quality, reliability and economics sought by the consumer is an example of solutions that can meet these customer desires and needs.

The modern grid must therefore strive to incorporate the consumer into grid operations in an automatic and cost-effective way. The system must have features that:

- Perform consistently within the rules, regulations and agreements between the utility and the consumer.
- Provide power and/or reduce load when needed or desired
- Deliver cost savings over time.

Consumer programs such as DR and DER must be cost effective to be successful. Lowering the costs of the required components — such as meters, communications and central support — is achievable only in mass quantity production. With sufficient consumer interest, the market itself would then support the required production scale needed to make these systems pay for themselves.

KEY COMPONENTS

There are a number of key components of the modern grid that are required to enable greater consumer choice in energy consumption and to link the consumer into the electricity practices of the grid:

- Consumer applications (such as DR systems) that are reliable, easy to use and tamper-resistant.
- Software applications for the consumer that respond to pricing signals from the utility — this agent software automatically

manages the consumer's usage based on price and within boundaries established by the consumer in concert with the utility.

- Smart communicating meters that measure both consumer usage and grid conditions to help the utility provide desired service at minimum cost.
- The communications infrastructure and control systems to support two-way information flow and load management.
- Processes, tariffs and incentive programs that serve both the utility and consumer.

Using these systems to the full benefit of consumers and the grid requires:

- Semi-autonomous processes and programs that enable both consumers and utilities to share the benefits of grid efficiencies.
- New pricing regimens, enabling consumer choice and planning as well as acceptable utility returns.
- Grid-friendly appliances that consumers can be encouraged to deploy.
- Multiple, affordable choices for consumer-usable DER.

BARRIERS

In the context of motivating and including the consumer, we have described the current state, explored the future state and identified the features and functions required to transport us from one to the other. This section discusses the barriers that must be overcome.

The technologies that enable DR and DER are now and will be for some time in a constant state of technological evolution. Research and development work remains to be done. For example, further development is required on:

- Cost-effective, secure, and reliable metering, communications, and information technologies.
- Systems and processes that more fully recognize and incorporate the active consumer role in grid management
- Extensive development in the design of user interfaces and the tariffs associated with them.

Although the potential benefits of dynamic pricing are large, so too are the barriers to widespread adoption. State legislatures and regulatory commissions have inadvertently blocked consumer access to wholesale markets in their efforts to protect retail consumers, especially residential consumers, from the vagaries of competition. State regulators need to rethink their decisions on standard-offer rates that are set so low that new suppliers are unable to compete and consumers have no incentive to look elsewhere for a better deal. Although regulators should not force consumers to face dynamic pricing, neither should they make it difficult for them to do so. Ultimately, consumers will have to pay for prices that are set too low today. (*Hirst, E. and B. Kirby, Retail-load participation in competitive wholesale electricity markets, 2001)*

Much non-technological work also remains to be done.

- Consumer education will be necessary to promote the broad acceptance of voluntary programs.
- The design of innovative rate structures that benefit both the consumer and the power system's managers require more attention and testing.
- Many different stakeholders must agree upon a clear, auditable method to manage the various programs of rates and tariffs as consumer options multiply.
- Federal and state regulatory bodies need to set a clear direction, including reaching agreement on promoting DR programs. In the case of retail electricity pricing, state regulators have the authority to determine whether customers are provided with time-based pricing options or not.

Barriers in the way of accomplishing this work include:

- **Cultural views of electricity services** — The transition from a passive protected user to a proactive informed consumer should apply to electricity, just as it does to other products
- **Long-established regulations** — Current state legislatures and regulatory commissions' efforts exist largely to protect consumers from the risks of competition.
- **Lack of consumer education on electricity services** — The consumer must come to understand that the price of electricity should reflect its current cost of production and delivery so that more economic usage decisions can be taken. The vital role of electricity makes it important to recognize that everyone benefits from its optimal use.

- **Slow process of technology deployment** — Advances in metering, communications, information processing and distributed resources are being deployed, but only gradually.

BENEFITS

Once we fill the gaps and overcome the barriers, the economic ripple effect of giving consumers informed choices will benefit all sectors of society. In fact, it is already happening, as this section reveals.

DEMAND RESPONSE

Demand Response has enjoyed considerable progress in overcoming the barriers of regulation and consumer education.

Diverse interest groups that include prominent regional and national stakeholders have formed the Demand Response Coordinating Committee.

Through the committee, the US is taking the lead on the International Energy Association's first DR project. Such issues as valuations, technology, coordination, barriers, and funding are on the agenda.

Recently, the chair of the Federal Energy Regulatory Commission described DR as "the silver bullet of market design." The US Congress has included strong DR provisions in the Energy Policy Act of 2005. This signals national recognition of DR's value in reshaping the industry.

The DOE Office of Electricity Delivery and Energy Reliability views DR as an essential element of the modern grid. At the same time, the Environmental Protection Agency believes DR can be a valuable driver of energy efficiency. This is because pricing signals will likely lead to more investment in efficient end-use devices. The integration of DR and energy efficiency is likely to provide additional synergies.

DR projects that included consumers have already produced very positive results. One program in Illinois was the first to clearly demonstrate just how effective DR can be. Independent evaluators found:

- Participants respond to peak period prices — Overall demand reduced by up to 20 percent with small changes in behavior.
- Participants saved money — Approximately 15 percent for the first two years of the program.
- Participants of all incomes benefited — Low-income households especially respond pro-actively to high prices.
- The meters were not expensive.
- Participants developed better understanding and attitudes about energy usage.

Independent System Operators (ISO) are increasing their focus on DR, both as a tool to mitigate emergencies and as a means to realize

substantial economies. NY ISO has measured benefit ratios exceeding 5:1 with their emergency DR program.

PJM Interconnection, the world's largest electric grid operator, has stated that 20,000 MW of its load is served only 1 percent of the time. The huge value of shifting this load to lower-use periods is clear to PJM operators.

ISO New England has shown that DR programs can be very responsive, reaching committed reduction levels in less than 30 minutes

ISO New England and other cases prove that DR will be an important facet of another characteristic of the modern grid—enabling markets. In fact, each of the seven characteristics of a modern grid can be affected in one way or another by the broad deployment of systems and processes that include the consumer.

DISTRIBUTED ENERGY RESOURCES

Consumers may represent the largest market for DER well into the next decade as they use it to save money and improve reliability.

Deployment of DER will benefit the entire value chain of consumers — commercial, industrial and residential. Simple connections to the grid will accelerate consumer usage of small generation and storage devices and pave the way for larger ones.

Allowing the consumer to store and generate electricity in a coordinated way can support the grid by:

- Lowering the risk of load imbalances.
- Providing quality power for digital devices, regardless of local area fluctuations.
- Providing a wide range of economic and environmental benefits

RECOMMENDATIONS

With an understanding of the barriers to be overcome and the benefits that are attainable, this section summarizes the recommendations of the Modern Grid Initiative.

The transition to motivate and include the consumer will be gradual, with pockets of progress occurring first in those regions where regulators are most supportive. Over time, and with the emergence of increasingly effective programs and technology, consumer involvement will become the norm. Each step along the path will produce its own set of benefits.

Our recommended steps include:

- **Regulatory encouragement at federal and state levels.** Society would benefit greatly from clear directives that treat DR/DER programs as equal, or even preferred, solutions to the fundamental power system requirement of continuously balancing generation and load. Utilities would be far more likely to employ these tools if it was clear that their investment would not be questioned some time in the future. Regulatory clarity is also needed regarding the question of voluntary versus mandatory DR programs across the wide range of customer types.

- **Broader education regarding the opportunities to deploy DR and DER and the overall benefits they produce.** Education programs can reveal the many beneficiaries of well conceived programs that motivate and involve the consumer. The value of transitioning from passive protected users to proactive informed consumers must be conveyed clearly. In addition to higher quality, lower cost, greater customer choice and more reliable energy, there are substantial environmental benefits to be had — as well as national security and energy market stabilization gains. Such education, and the increased regulator and consumer receptivity it creates, can also encourage intermediaries (aggregators) to make wider use of these programs.

- **Continued improvement in the cost and performance of supporting technologies.** Considerable work is needed to develop and demonstrate the most effective, secure and reliable metering, communications and IT solutions. Available modern advances in digital communications can be applied to these utility applications — establishing reliable, secure low cost channels to each consumer. Today's digital electronics can enable accurate, sophisticated, low cost meters (actually consumer gateways that can incorporate decision-support agents) that allow intelligent interaction between consumers and grid operators. In addition, new smart appliances and enhanced distributed energy resources must be developed to help support the consumer's

proactive interaction with the grid. Integration of such devices requires substantial engineering to insure compatibility with existing electric infrastructure.

- **Development of programs, tariffs and computer agents that satisfy both utility and consumer needs.** This includes the development of systems that enable timely *and effortless* interaction between the consumer and the power grid operator. Innovative rate structures that provide economic benefits to both the consumer and the utility are integral to these systems. New software programs are also needed to connect the new applications to the many utility legacy programs that will still be required for reliable and efficient overall operation of the grid.

SUMMARY

In the modern grid, consumers become an integral active part of the overall electric power system. Consumer actions taken in their own self-interest will help balance electrical demand (loads) with electrical supply.

Motivating consumers to play that part means giving them the opportunity to make informed choices, profitably. Consumers with choices in their energy usage will be able to:

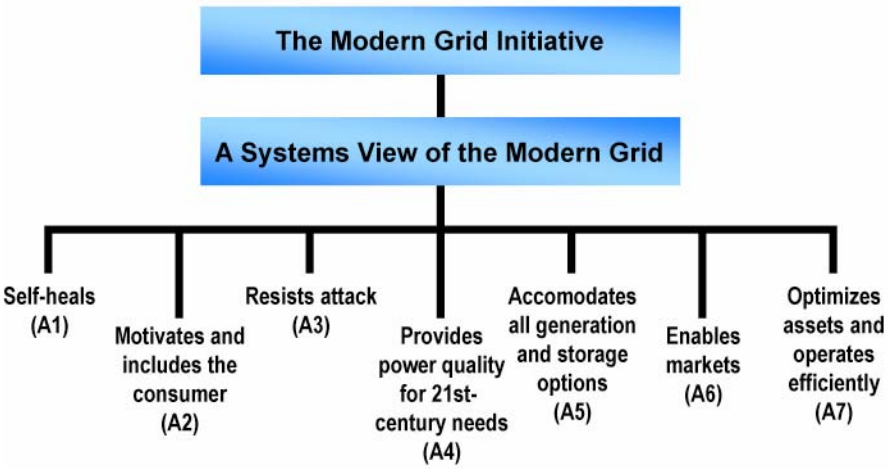
- Rely on price signals to decide when and if to purchase, store, or generate power.
- Employ smart devices that know the consumer's preferences about energy usage, and which respond automatically. Smart devices can also improve the stability of the power system.
- Relieve the grid's loads by reducing peak demand when necessary.

Demand response programs are examples of proven consumer receptivity to being included as a part of the power system. And DR has demonstrated measurable benefits to suppliers of electrical power.

Distributed Energy Resources are poised now for the same inevitable widespread deployment seen with personal computers and cell phones in years past. DER can also be an important component of consumer involvement, one that can complement large central generation and reduce the burden on the grid, while offering environmental, reliability and economic improvements.

For more information

This document is part of a collection of documents prepared by The Modern Grid Initiative team. For a high-level overview of the modern grid, see "A Systems View of the Modern Grid." For additional background on the motivating factors for the modern grid, see "The Modern Grid Initiative." MGI has also prepared seven papers that support and supplement these overviews by detailing more specifics on each of the principal characteristics of the modern grid. This paper describes the second principal characteristic: "Motivates and Includes the Consumer."



Documents are available for free download from the Modern Grid Web site.

The Modern Grid Initiative

Website: www.netl.doe.gov/moderngrid

Email: moderngrid@netl.doe.gov

(304) 599-4273 x101

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