Modern Grid v1.0

Powering Our 21st-Century Economy

The Modern Grid Initiative

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Office of Electricity Delivery and Energy Reliability
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INTRODUCTION

Throughout the 20th century, the U.S. electric power delivery infrastructure served our nation well, providing adequate, affordable energy to homes, businesses, and factories. This once state-of-the-art system brought a level of prosperity to the United States unmatched by any other nation in the world.

As we move into the 21st century, however, our world is changing. Terrorist threats, new business rules, and electrical networks that are gaining in size but losing in operating margins have combined to reveal and exacerbate what are now vulnerabilities in our nation's electricity infrastructure.

America's challenge is to transform the current structure into a modern grid that generates and distributes electricity more effectively, economically, and securely and meets the demands of a changing society. Within the U.S. Department of Energy (DOE), the Office of Electricity Delivery and Energy Reliability (OE) is taking up that challenge.

In July 2003 and January 2004, DOE sponsored two stakeholder meetings that produced "Grid 2030" and the "National Electric Delivery Technologies Roadmap." These documents crystallized the Department's vision of a modernized national electric system and, combined with industry guidance, led to the creation of GridWise and GridWorks—two programs established in fiscal year 2005 to improve the reliability of the electric infrastructure through the research and development of key grid systems and components.

With the release of the proposed fiscal year 2007 budget, DOE has further refined its efforts by collapsing GridWise, GridWorks, and other related programs into its Visualization and Controls program. In addition, OE is funding an initiative at the National Energy Technology Laboratory (NETL) to further develop the ideas first laid out in "Grid 2030" and "National Electric Delivery Technologies Roadmap."

The Modern Grid Initiative will develop a shared national vision of a modern grid's principal characteristics and key technologies by analyzing performance and technology gaps, developing a national concept of the grid, encouraging industry consensus, and coordinating regional technology integration projects. It complements OE's mission, as well as industry efforts led by Intelligrid, the Galvin Electricity Initiative, the GridWise Architecture Council, and others focused on raising national awareness about the need to radically improve grid performance, reliability, and security.

This document describes the Modern Grid Initiative—its scope, stakeholder roles and responsibilities, project plan, and timeline. It begins to explain why America needs to modernize its grid, as well as some of the associated challenges and opportunities. It also offers readers an opportunity to engage in the process of refining these concepts into a national plan for modernizing the grid.

Over the next several months, NETL will develop a series of documents that provide further details about the concepts and planned actions of the initiative. These will include a technical description of the proposed national vision of the modern grid, a plan for conducting regional demonstrations of integrated technologies and processes, and brochures, white papers, and presentations.

Together, these documents will provide a foundation for integrating stakeholder input and creating a common vision for the grid. They will evolve as additional stakeholder input is received and lessons are learned. A broad range of stakeholders will be actively involved in the process through regional meetings, national meetings, working groups, and an interactive website.

WHY IS A MODERN GRID SO IMPORTANT?

A 21st-century U.S. economy cannot be built on a 20th-century electric grid. This is why the decisions made today are so vital. Will our nation follow a business-as-usual pathway or step up to the challenge of modernizing the grid? Either way, utilities and transmission owners will invest billions of dollars in the power-delivery infrastructure over the coming decades to meet projected load growth. With this massive investment comes a once-in-a-century opportunity to invest wisely—to not merely shore up America's infrastructure but to revolutionize its capabilities.

Under a business-as-usual scenario, the Energy Information Administration projects that more than $200 billion will be spent between now and 2020 to maintain and expand our electricity transmission and distribution infrastructures. Without a modern grid perspective, this money will be spent based on 20th century technology. That would be like expanding the nation's telecommunications system without taking advantage of today's digital and wireless technologies.

With a coordinated, comprehensive modernization framework, the nation can invest more wisely and, over time, save billions of dollars. A modernized system will also mean value-added services and benefits for consumers. Over the next two decades, consumers can look forward to:

- Near-zero wide-area blackouts
- Rare localized interruptions and rapid recovery when interruptions do occur
- High-quality power for sensitive electronics and complex computer applications
- Options for consumers to manage their electricity use and costs
- The plug-and-play integration of control systems, power electronics, and distributed resources
- Improved resilience to terrorist attack and natural disasters

- More efficient system operations

The nature of our electrical load is changing. In the 1980s, electrical load from sensitive electronic equipment, such as chips (computerized systems, appliances, and equipment) and automated manufacturing, was limited. In the 1990s, chip share grew to roughly 10%. Today, load from chip technologies and automated manufacturing is 40%, and the load is expected to increase to more than 60% by 2015.

These changes require significantly higher power quality and reliability. With a safer, more reliable, more affordable power delivery system, the U.S. economy will have room to grow and thrive.

CHALLENGES AND OPPORTUNITIES

There are many reasons a modern grid is not emerging more quickly. Fundamentally, no single business owns or operates the grid. With so many players in the grid system, finding a common interest in or vision for change is difficult.

In addition, individual players have no incentive to risk major change. Businesses are willing to make small improvements to parts of the system, but they lack the long-term financial incentives to make changes that will improve power transmission and distribution for decades.

Finally, the benefits are so broad and far reaching that only government can account for the cumulative value. A government-industry partnership is needed to recognize and account for the broad public and private benefits of modernizing the nation's electricity grid.

Achieving the vision of the modern grid will be difficult. Many challenges exist today and more will arise before the vision is realized. Some of the challenges the nation faces now include:

- **Stakeholder involvement**—Numerous stakeholders have an interest in creating a vision for the modern grid, but they differ in their ideas of what the vision is and how it should be achieved. Modernizing the grid will be a long and arduous journey; without stakeholder consensus, it will be nearly impossible.
- **Regulatory impacts**—The nation's uncertain regulatory climate has helped dampen grid modernization. Causes include incomplete industry restructuring, federal and state regulatory agencies' unfamiliarity with needed technologies and processes, varying phases of state-to-state deregulation, inconsistent setting of rates and investment recovery by state public utility commissions, and frequently unclear and inconsistent interfaces between these commissions and the Federal Energy Regulatory Commission.

- **Human resources and training**—With utility downsizing, retirement without replacement, and low student enrollment in power engineering training programs, America is fast losing the advanced power system and information technology skills needed to support a more modern grid.
- **Other issues**
  - Physical and cyber security threats will become progressively more sophisticated
  - Many regions in the United States see generation shortages on the ten-year horizon, yet plans to expand generation and transmission facilities are limited
  - Long lead times make transmission additions difficult
  - Some areas depend on natural gas for up to 70% of their power generation while the supply, availability, and cost of natural gas over the long term is uncertain

These challenges are daunting, but they can be overcome. In fact, they provide an opportunity to:

- Continuously engage stakeholders through modern grid summits, working groups, and communication vehicles and interactions with Modern Grid Initiative team members
- Create a common understanding and a shared purpose regarding the most urgent modernization needs and each participant's ability to contribute to the solutions
- Identify needed technologies and spur their development
- Quickly engage the best minds in government, industry, academia, national laboratories, and research and development (R&D) organizations
- Promote the electric power industry as a desirable career path
- Rectify the regulatory environment through a balanced mix of legislation, policy, standards, and incentives
- Address the true costs of reliability and power quality and create integrated physical-economic models that accurately predict the system impacts of various technologies and processes
- Encourage investments that are consistent with the common modern grid vision
- Articulate a vision for the next generation of researchers, professionals, and policy makers

Through the Modern Grid Initiative, OE and NETL intend to work objectively with all stakeholders—federal, state, and local government, utilities, vendors, policy and regulation agencies, advocacy groups, consumers, and others—to find acceptable solutions to the issues faced.

THE MODERN GRID INITIATIVE

In fiscal year 2005, OE asked NETL to explore the possibility of creating a coordinated national program to facilitate the modernization of the U.S. electric transmission and distribution system. OE's intent was to engage all stakeholders in developing a shared vision of a modern grid and help achieve that vision by conducting regional demonstrations of integrated technologies and processes.

At NETL, these efforts have evolved into the Modern Grid Initiative, which is focusing DOE's related efforts into a long-term program.

The intent of the Modern Grid Initiative is to accelerate the nation's move to a modern electric grid by creating a flagship industry-DOE partnership that invests significant funds in the demonstration projects. These demonstrations will establish the value of developing an integrated suite of technologies and processes that move the grid toward modernization. They will address key barriers and establish scalability, broad applicability, and a clear path to full deployment for solutions that offer compelling benefits. Each project will involve a full spectrum of national and regional stakeholders and multiple funding parties.

Following each project, results and lessons learned will be shared among regional participants, with a continuing stakeholder activity to synthesize these results into a format that can be broadly discussed and disseminated. The size, structure, and goals of the regional demonstrations will vary to maximize impact to the participants and the regions in which the projects are located.

It is envisioned that the demonstration program will consist of 10–15 projects carried out over 5 years and will ultimately produce a set of modern grid design specifications for the nation. It will also support the creation of standards and guidelines for the utilities, consumers, vendors, regulators, researchers, and trade associations that constitute the electric grid industry.

Roles and Responsibilities

A successful effort will require coordination among OE, NETL, and grid stakeholders. Specific personnel assignments, roles, and responsibilities will be determined as the initiative moves forward, but broad roles have been identified:

DOE OE

- Provide project sponsorship, guidance, and direction
- Integrate and coordinate with related DOE and federal government programs
- Represent DOE in working with stakeholders
- Provide project funding

DOE NETL

- Coordinate modern grid conceptualization
- Facilitate stakeholder outreach
- Define and manage demonstration projects
- Facilitate technology integration
- Provide technical expertise

Stakeholders

- Review grid documentation and provide content and technical expertise
- Participate in demonstration projects
- Provide project funding
- Participate in Modern Grid Initiative working groups

Federal, state, and local government will play a significant part in championing the broad societal benefits of a modern grid. As a neutral third party, government is uniquely positioned to convene the nation's top talent—in academia, industry, national laboratories, and research organizations—to define a shared vision, develop innovative solutions, and speed the adoption of new technologies and processes. It is also government's role to ensure that appropriate stakeholders are involved as the fully modern grid emerges.

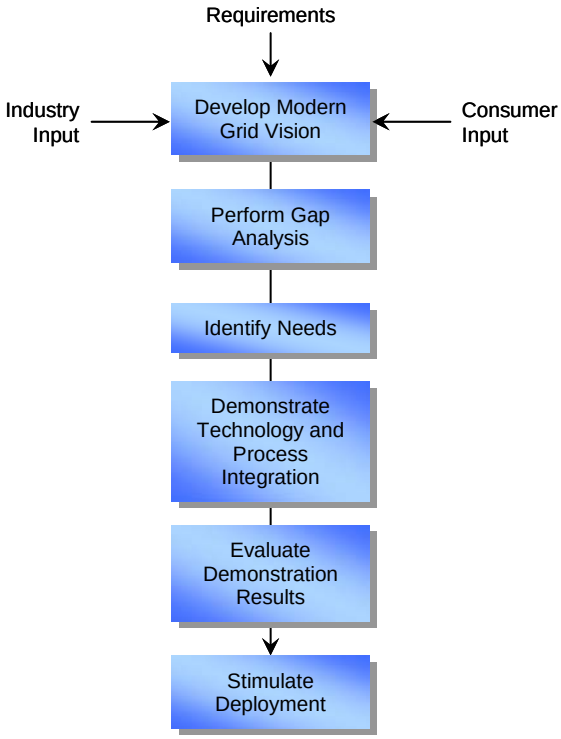
DOE must enhance its position in developing national programs that provide focused, systematic methods of examining the multi-faceted nature of the grid. Government-sponsored programs can then provide mechanisms for federal and state regulators to include new technologies and processes in electricity rates so utilities and grid operators are more willing to invest in transforming the grid.

The Modern Grid Initiative will provide this national leadership and the visibility needed for modern grid development. Working with every stakeholder, the Modern Grid Initiative will accelerate our nation's achievement of the modern grid vision.

Project Plan

The Modern Grid Initiative project plan will provide the necessary framework to accelerate the nation's progress toward achieving the modern grid vision. Stakeholders will be involved throughout. The following figure and text describe how the Modern Grid Initiative plans to move forward.

- **Develop Modern Grid Vision**—Create the vision and define it through the grid's principal characteristics and key technology areas.
- **Perform Gap Analysis**—Determine the technology and research gaps preventing realization of the modern grid.
- **Identify Needs**—Identify technologies and processes needing assistance in widespread deployment and areas of research that require increased focus.
- **Demonstrate Technology and Process Integration**—Demonstrate integrated technologies and processes that have the potential to achieve modern grid principal characteristics and key technology areas.
- **Evaluate Demonstration Results**—Extrapolate demonstration results and benefits from the local or regional level to the national level.



Modern Grid Initiative Project Plan

- **Stimulate Deployment**—Turn lessons learned during demonstration into modern grid business cases and provide position papers to stimulate action.

Develop Modern Grid Vision

The power delivery system has the potential to make the kinds of leaps in capabilities and cost efficiencies seen in telecommunications during the past decade. The implementation of modern information technologies, along with other technologies and processes now emerging from the laboratory, will be central to achieving similar advances in power delivery capabilities and efficiencies.

Investing in the context of a coordinated plan can be less costly and more beneficial than business-as-usual approaches. Various stakeholders have developed and implemented new technologies and devices over the past few years, but these activities have been conducted with limited scope. Widespread adoption and integration is seriously lagging.

New technologies allow us to rethink grid design and operations. For example, a modernized grid will detect and address emerging problems before they impact service. Protective relaying will be the last line of defense, not the only defense as it often is today. The modern grid will know much more about emerging broad system problems and will respond to both local and system-wide inputs.

This "self-healing" characteristic is one of seven principal modern grid characteristics identified, defined, and proposed, based on broad industry consensus. Once agreed upon by stakeholders, these characteristics will become the focal point for developing new strategies for grid research, technology development, regulation, integration, operation, maintenance, and asset management. The seven principal characteristics are outlined as follows:

- **Self-healing**—The grid monitors itself and automatically detects, analyzes, responds to, and restores grid components or network sections to maintain reliability, security, affordability, power quality, and an efficient state.
- **Empowers and incorporates the consumer**—Individual, business, and industry consumers become integral, active parts of the electric power system. Participating in electricity markets will benefit both the individual consumer and overall system reliability.
- **Tolerates security attack**—It is critical for the modern grid to address security from the outset, making security a requirement and ensuring an integrated and balanced approach across the system.
- **Provides power quality needed by 21st-century users**—Sensitive loads represent an increasing portion of the total power system load. The power quality delivered by the modern grid must be improved to meet the requirements of these sensitive loads. In addition, improvements in the design of the loads will make them more tolerant of distorted power.
- **Accommodates a wide variety of generation options**—The modern grid will accommodate a portfolio of diverse generation types, necessitating a greatly simplified interconnection process analogous to plug-and-play in today's computer environment, particularly at the distributed energy resources level.
- **Fully enables electricity markets**—The modern grid will integrate electricity markets into the fabric of the electric system because operations, planning, pricing, and reliability are dependent on how open-access markets are designed and instituted. For this reason, it will not only support wholesale electric markets but also retail markets where applicable.
- **Optimizes asset utilization and minimizes operations and maintenance expenses**—Assets will be managed in concert so that, as a system, they can deliver functionality at a minimum cost. For example, advanced sensing and robust communications will allow early problem detection and corrective action.

With the principal characteristics driving the development of the modern grid, key technology areas will emerge to enable desired performance. A focus on

technology and innovation will be encouraged and is, in fact, required to achieve the functional specifications of the principal characteristics. The key technology areas proposed are the following:

- **Integrated communications across the grid**—High-speed, fully integrated, two-way communications technologies will establish the infrastructure needed to enable the modern grid to become a dynamic, interactive "mega-infrastructure" for real-time information and power exchange. Its open architecture will create a plug-and-play environment that securely networks smart sensors and control devices, control centers, protection systems, and users.
- **Sensing, metering, and measurement**—New digital technology applications will accommodate a variety of inputs, deliver a variety of outputs, and maintain interfaces among generators, grid operators, and customer portals. They will function to enhance power measurement, provide outage detection and response, evaluate equipment health and grid integrity, eliminate meter estimations, provide energy theft protection, enable consumer choice and demand response, and facilitate congestion relief. In addition, new smart sensors will be applied to various grid-monitoring functions.
- **Advanced grid components**—The next generation of power system devices will take advantage of new material technologies, nanotechnologies, advanced digital designs, etc., to produce higher power densities, better reliability, and improved real-time diagnostics to greatly improve grid performance. These technologically advanced devices will include superconducting transmission cable, fault current limiters, composite conductors, Flexible AC Transmission Systems, advanced energy storage, distributed generation, advanced transformers and circuit breakers, and smart loads.
- **Advanced control methodologies**—Grid monitoring will be an essential element of reliability and security. Advanced control methodologies, such as computer-based algorithms, will support distribution and substation automation, adaptive relaying, energy management, market pricing, grid modeling and simulation, advanced visualization systems, and other grid elements. They will also integrate with asset management processes and technologies to further optimize grid operations and planning.
- **Decision support and human interfaces**—In many situations, the time available for operators to make decisions has shortened to seconds. Thus, the modern grid will require the wide, seamless, real-time use of applications and tools that enable grid operators and managers to make decisions quickly. This includes the role of artificial intelligence to support the human interface, operator decision support (e.g., alerting tools, what-if tools, course-of-action tools) semi-autonomous agent software, visualization tools and systems, performance dashboards, advanced control-room design, and real-time dynamic simulator training.

The Modern Grid Initiative identified its proposed principal characteristics and key technology areas by taking a systems approach to determining root issues and

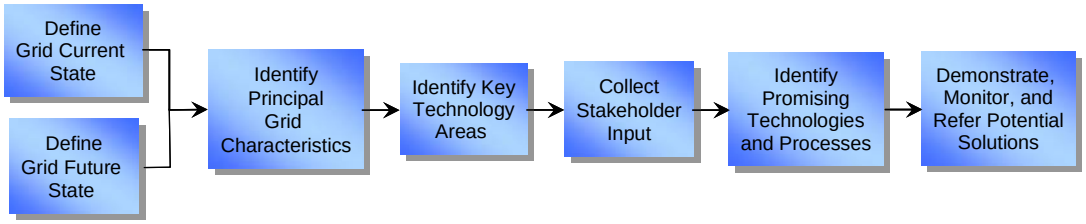
structuring a model that serves the whole through its component parts. The initiative is now in the process of conducting an aggressive stakeholder outreach effort to further refine these concepts and identify and address key regional and national issues related to modernizing the grid.

After coordinating with the GridWise Alliance as a key industry stakeholder group committed to the same objectives, the Modern Grid Initiative is proceeding to broaden stakeholder support and input primarily through a series of stakeholder summits occurring through fiscal year 2006.

Perform Gap Analysis

A gap analysis compares how an organization, process, or, in this case, system is currently functioning versus how stakeholders envision it functioning in the future. The analysis helps define the areas of improvement—gaps—that must be addressed to move to the future state.

The Modern Grid Initiative is following the gap analysis process as shown:

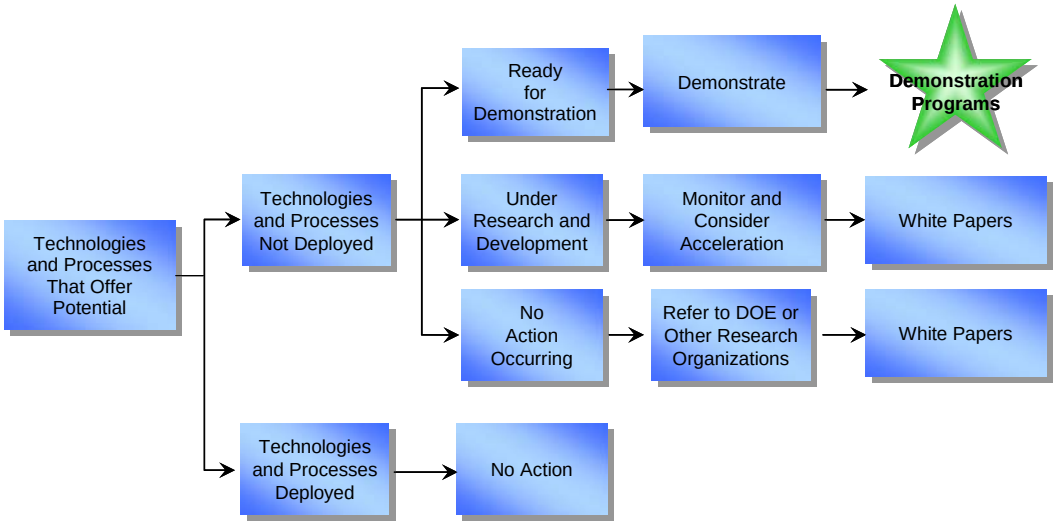


Modern Grid Initiative Gap Analysis Process

The modern grid gap analysis will drive R&D strategies and regional demonstrations of integrated technologies and processes to accelerate the effective development of the grid. This approach will ensure a consistent relationship among evaluated needs, integrated technologies and processes, and R&D planning to optimize existing R&D successes and initiate new R&D efforts.

Identify Needs

From the gap analysis, technology and process needs and promising solutions are identified. These include technologies that are through the R&D phase and ready for demonstration, current R&D that deserves attention and possible acceleration, and areas of potential R&D that require increased emphasis. The following figure illustrates this examination.



Modern Grid Initiative Technology and Process Gap Analysis

Technologies and processes in need of development fall under three categories:

- **Ready for demonstration**—These approaches have been successfully developed, but they have yet to be demonstrated. Technologies and processes under this category will be considered for demonstration.
- **Under research and development**—These approaches are currently in R&D but are not yet ready for demonstration. They require increased emphasis and perhaps funding. The Modern Grid Initiative will bring attention to these technologies to accelerate R&D and move them into demonstration and ultimate deployment.
- **No action occurring**—These approaches are not currently in R&D, but they hold promise. Again, the Modern Grid Initiative will direct the attention of DOE or other research organizations toward these technologies and processes to accelerate R&D.

Demonstrate Technology and Process Integration

The next step within the Modern Grid Initiative will be to design and perform regional demonstration projects based on the developed vision, gap analysis, and identified needs. The first step in this process will be a smaller scale developmental field test that will aid in the understanding of specific issues involved in creating successful regional demonstration projects.

As the initiative expands, NETL expects to launch fully integrated demonstrations of promising technologies and processes in various locations around the country. These demonstrations will establish enhanced performance, scalability, broad applicability, and a clear path to the full deployment of a suite of solutions that show compelling benefits. Each demonstration will involve a full spectrum of

national and regional stakeholders, as well as multiple funding parties where DOE's contribution represents less than 50%.

The size, structure, and goals of each project will vary to maximize impact to the participants and the region in which the project is located. Demonstration project teams will share results and lessons learned among regional participants and make both available for dissemination and broad discussion.

The demonstration program is expected to:

- Measure the regional impact and benefits of applying new, integrated technologies and processes to the grid in six targeted areas:
  - Reliability
  - Security
  - Economy
  - Power quality
  - Efficiency and environmental quality
  - Safety
- Demonstrate the broad applicability of these technologies and processes and, using modeling and simulation, project their benefits at the national level
- Analyze and demonstrate scalability
- Enhance technology transfer and commercialization
- Maximize cooperative funding
- Leverage grid refurbishment needs (existing plans)

The fundamental steps of the program are:

- **Program Definition**—The needs identified through the technologies and processes gap analysis will provide input to program definition. Stakeholder input will fully define the scope and objectives of the demonstrations.
- **Program Funding**—A significant level of non-DOE participation in these projects is expected by grid owners and operators, utilities, local and regional governments, and vendors. Funding will be determined as part of the program definition and planning process.
- **Program Plan**—The program plan will contain objectives and metrics, design specifications, and other technical requirements needed to implement the demonstrations, as well as the results of modeling and simulation analyses performed to predict the program's outcome. Also through modeling and simulation, expected program benefits will be extrapolated to predict their impact on grid performance at the national level.
- **Project Management and Deployment Assistance**—A project team will be chosen for each demonstration project to include personnel from the appropriate stakeholder groups. Project teams will be responsible for project execution and the communication of interim and final test results.

The program's principal benefits will include objective analysis and quantification of results, the effective coordination and communication of results across regions and stakeholders, reduced costs to individual participants through cost-sharing, and a credible basis for new policies, standards, and incentives. The program will significantly enhance the likelihood that the tools, technologies, processes, and systems needed for a fully modern grid will be deployed. DOE's investment is expected to catalyze a much greater investment by program participants and industry in general.

What a Typical Demonstration Project Might Look Like

A 3-year project with $5 million from DOE and $10 million from non-DOE partners builds on a communications backbone, such as wireless or broadband over power lines, and includes smart technologies, such as diagnostics, digital controls, load control, and remote switching. It also includes a spectrum of decision-making support tools, such as smart agents, data mining and visualization, advanced models and simulators, and rapid detection.

During the life of the project, many or all of these and other tools and technologies are operated on an actual transmission and distribution system with quantified and analyzed benefits to regional transmission organizations, utilities, and consumers quantified and analyzed.

Evaluate Demonstration Results

NETL, in cooperation with project funders, participants, and interested stakeholders, will collect, analyze, trend, and evaluate the results of the regional demonstrations. These evaluations will consider technical results and financial implications, both of which will be extrapolated to the national level using modeling and simulation technologies.

Using these results, business cases will be developed that consider both the societal benefits and benefits to investors. These business cases are expected to lead to the identification of the technologies and processes that are most important to achieving the modern grid vision. Specific actions needed to stimulate their deployment will be identified.

Communication to all stakeholders will be broadly implemented through the Modern Grid Initiative website, working group interfaces, presentations, white papers, and other communication vehicles.

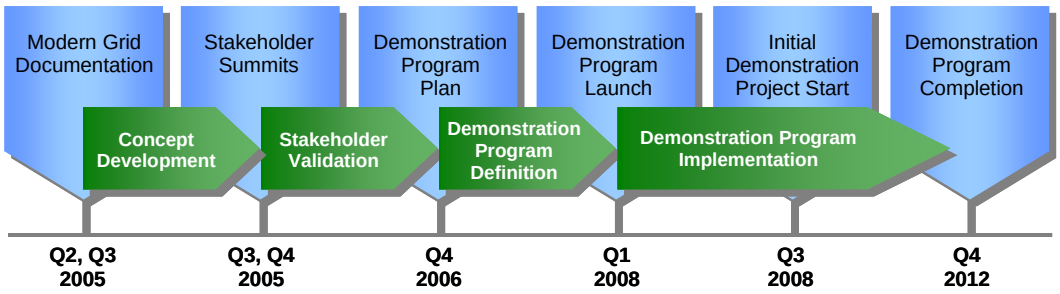
Stimulate Deployment

The business cases are expected to identify specific areas where aggressive deployment is needed. In addition, specific barriers to widespread deployment will be identified. Actions

needed to remove these barriers and enable widespread deployment will be identified and sponsored by NETL and OE. Some of the areas in which assistance might be solicited include:

- **Rule changes**—Legislative actions may be needed to correct statutes that are inconsistent with the vision of the modern grid.
- **Regulatory changes**—Revision to federal and state regulations may be needed to resolve interstate inconsistencies among public utility commissions and improve alignment between the Federal Energy Regulatory Commission and the states.
- **Standards adoption**—New and revised standards that simplify deployment may be necessary to facilitate the deployment of modern grid technologies by the appropriate stakeholders.
- **Financial incentive**—Financial incentives funded by state and federal government may be needed to stimulate deployment, particularly for the solutions that have significant societal benefit.
- **Consumer involvement**—Consumers are expected to become increasingly involved as they receive information about demonstration results that hold promise for investment and cost-saving opportunities.
- **Investment opportunities**—Focus on deployment is expected to create new opportunities for investors, vendors, consumers, utilities, and other stakeholder groups.

Timeline



Modern Grid Initiative Timeline

The timeline describes the Modern Grid Initiative's development at a high level. The goal of the program is to reach the stage where the nation has a set of detailed modern grid design specifications. This achievement enables a consistent vision and set of standards throughout the utilities, consumers, vendors, regulators, researchers, and trade associations that constitute the electric grid industry.

To achieve a national set of detailed modern grid design specifications, it is important to prove and demonstrate the design concepts through integrated technology and process demonstration projects. The demonstration program will do this.

CALL TO ACTION

Creating the modern grid will take a monumental effort by all stakeholders. With a clear vision, we can generate the alignment needed to inspire passion, investment, and movement toward that vision.

To achieve this, your input is needed to more clearly define the vision of the modern grid. Your acceptance, which will ultimately lead to stakeholder alignment, is essential to getting traction and making progress toward achievement of the modern grid.

To take action in support of the Modern Grid Initiative, provide feedback to what you've read. You can do this through:

- Modern Grid Initiative regional summit meetings, where you can personally provide your input
- The Modern Grid Initiative website, where you can interact with team members to resolve questions and issues
- Your leadership as a working group member, in which you can take an active role in the implementation of the Modern Grid Initiative

We want your thoughts. Visit our website at www.themoderngrid.org to find out when and where you can attend a stakeholder summit, how to speak directly with a team member, and how to become involved in a working group.