Profiling and Mapping of Intelligent Grid R&D Programs

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PRODUCT DESCRIPTION

This report is the first of its kind to analyze research and development (R&D) programs whose goal is to improve the intelligence of the electric power infrastructure. The study assesses ten selected grid R&D programs, characterizing their vision, mission, governance, budget and funds spent to date, promotion activities, and technical program portfolio, including main objectives, completed or ongoing projects, deliverables, and accomplishments.

Results & Findings

This report delivers information, profiles, and maps for use in distinguishing results of wide-ranging research on smart grids and for identifying collaborative opportunities. Benefits of this knowledge include increased coordination among R&D programs, reduced research costs through collaboration, and more widespread application of findings among vendors and utilities. The report highlights the commonalities and differences of the following programs:

- IntelliGrid
- The Modern Grid Initiative
- GridWise
- Advanced Grid Applications Consortium
- Power Systems Engineering Research Center
- Consortium for Electric Reliability Technology Solutions
- California Energy Commission—Public Interest Energy Research
- New York State Energy Research and Development Authority
- European Union fifth and sixth Framework Programs
- Galvin Electricity Initiative.

Challenges & Objective(s)

The results of this study are intended to encourage dialogue between R&D programs and to identify joint, or “handshake,” actions that define common principles for collaboration. Key objectives were to identify results that can be applied by other research organizations and stakeholders, understand how the results might complement another program’s efforts, identify coordination actions to minimize project overlaps, and clarify the positioning of each program. The report will be of interest to individuals with responsibilities in smart grid research, from the executive to the project manager.

Applications, Values & Use

Because the information in this report is dynamic in nature, status reports will be available to update smart grid initiative results. In this way, this report and the following updates will help implementations of the latest ideas, concepts, requirements, architecture, and technologies for early adopters of smart grid initiatives.

EPRI Perspective

By leveraging collective knowledge, the electricity industry can solve problems too large for individual organizations to tackle alone. For more than 30 years, EPRI has proven the effectiveness of a well-managed, collaborative approach to industry-funded R&D. This project addresses an industry need for a comparison of smart grid R&D programs.

Approach

The project team analyzed information that is publicly available or was made available for the purpose of the study. The team's protocol was to evaluate and summarize the information to populate a template profile and map, send individual draft profiles to program representatives for review, conduct interviews whenever possible, and incorporate feedback. Common reference metrics were used in developing the program profiles to avoid any side effects in characterization. The reference metric categories were uses and applications, services to enable applications, and infrastructure. The team split these categories into subcategories, enabling development of a comprehensive map of R&D efforts and results for each program.

Keywords

Intelligent grid
Smart grid
Collaborative research
Mapping
IntelliGrid

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EXECUTIVE SUMMARY

Technology advances have made it possible to create an intelligent electricity grid that predicts and heals power problems before they get out of hand. The intelligent grid promises to give energy providers substantial advances in power reliability and customer services.

Several new research and development programs have been formed in recent years with the goal of improving the intelligence of the electric power infrastructure. These programs, along with other established R&D organizations, are addressing the technical, economic, and policy barriers to creating a smarter grid. An abundance of research has bolstered the confidence of industry stakeholders, who now recognize that transformation of the grid indeed can be accomplished.

At the same time, these stakeholders—which include utilities, manufacturers, standards organizations, and public agencies—have noted how challenging it can be to distinguish between the various research programs and to grasp the results they offer. The stakeholders are looking for a clear picture of program efforts and results. They also are asking for a greater level of coordination among the programs.

In January 2006, EPRI IntelliGrid launched the *Profiling and Mapping of Intelligent Grid R&D Programs* project to assess and characterize these research programs, and to position the expected and delivered results on a map of intelligent grid research. The project delivers information that can be used to help in understanding the results of wide-ranging research on smart grids, and to identify opportunities for collaborative activities that will enhance the integration of technical results.

Program Integration

This report presents analysis and positioning of 10 major R&D programs that have the shared goal of transforming the electric power delivery system into the intelligent grid. It also highlights the commonalities and differences between the programs, which were selected for their significant contributions to the transformation of the electric grid. As the following list shows, they include public, private, national, and international efforts.

1. IntelliGrid Consortium—Founded by EPRI in 2001, IntelliGrid seeks to create a new electric power delivery infrastructure that integrates advances in communications, computing, and electronics to meet the energy needs of the future. Its mission is to enable the development, integration, and application of technologies to facilitate the transformation of the electric infrastructure to cost-effectively provide secure, high-quality, reliable electricity products and services.

2. The Modern Grid Initiative—Established by the U.S. Department of Energy (DOE) in 2005 through the Office of Electricity Delivery and Energy Reliability and the National Energy Technology Laboratory, this program focuses on the modern grid as a new model of electricity delivery that will bring a new era of energy prosperity. It sees the modern grid not as a patchwork of efforts to bring power to the consumer, but as a total system that utilizes the most innovative technologies in the most useful manner.

3. GridWise™—Funded by the Distribution Area Program of the DOE Office of Electricity Delivery and Energy Reliability, this organization includes the GridWise Alliance, a group of power industry representatives who support the vision of the intelligent grid, and the GridWise Architecture Council, an association of experts who seek to articulate guiding principles for an information architecture.

4. Advanced Grid Applications Consortium (GridApp™)—Formed by Concurrent Technologies Corporation in 2005, and sponsored by DOE, GridApp applies best utility technologies and practices to modernize electric transmission and distribution operations.

5. Power Systems Engineering Research Center (PSERC)—Established in 1994, this association of universities works with the electric power industry to find innovative solutions to the challenges facing the industry and to educate the next generation of power engineers.

6. Consortium for Electric Reliability Technology Solutions (CERTS)—Created in 1999 and funded by DOE and the California Energy Commission, CERTS researches, develops, and disseminates new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system and the functioning of a competitive electricity market.

7. California Energy Commission – Public Interest Energy Research (CEC–PIER) Program—The PIER program is designed to enable sustainable energy choices for utilities, state and local governments, and large and small consumers in California. Established by the CEC in 1996, it provides advanced energy innovations in hardware, software systems, exploratory concepts, supporting knowledge, and balanced portfolio of near-, mid-, and long-term energy options for a sustainable energy future in California.

8. New York State Energy Research and Development Authority (NYSERDA)—This public benefit corporation was formed in 1975 to assist in the modernization of New York's aging transmission and distribution system to meet the needs of the 21st century.

9. European Union 5th and 6th Framework Programs – Sustainable Energy Systems and Electricity Networks of the Future—These endeavors of the European Commission fund R&D activities on sustainable energy systems in framework programs. In 2006 they launched the SmartGrids Technology Platform to: 1) increase the efficiency, safety, and reliability of the European electricity transmission and distribution system by transforming the current electricity grids into an interactive service network, and 2) remove obstacles to the large-scale deployment and effective integration of distributed and renewable energy sources.

10. Galvin Electricity Initiative—Founded in 2005 by the former CEO and son of the founder of Motorola, this program applies the concepts of total quality management to the electric power industry, with the goal of developing one or more configurations of a “perfect” power delivery system to meet the needs of the rapidly evolving digital economy and society.

Figure 1
R&D programs analyzed in this project

Program Analysis

This report contains analysis of each of the 10 selected grid R&D programs, characterizing their vision, mission, governance, budget and funds spent to date, promotion activities, and technical program portfolio, including main objectives, completed or ongoing projects, deliverables, and accomplishments.

Analysis has been based on information that is publicly available or was made available for the purpose of the study. The information was evaluated and summarized to populate a template profile and map. Individual draft profiles were then sent to program representatives for review and feedback. Interviews were conducted and comments taken into account whenever possible.

Because each program has its own rationale, often with implicit language and meanings based on its individual culture, common reference metrics were used in developing the profiles to avoid any side effects in program characterization. These reference metrics were applied to each program to assess its nature in three categories: uses and applications, services to enable applications, and infrastructure. The categories were then split into sub-categories, as illustrated in the graphic below. This resulted in a comprehensive map of R&D efforts, positioning each program and its results.

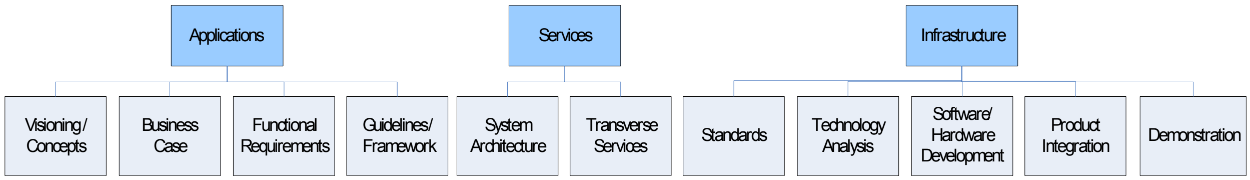

Figure 2
Categories and sub-categories of reference metrics

Key Results

Initial findings revealed complex positioning of the grid R&D programs, each covering a wide area of sectors and focusing on the various requirements of application, architecture, or technology issues, depending on program objectives. The outline of the R&D program map below illustrates the intricate network of deliverables these programs offer. The report provides details on the nature of each deliverable as it corresponds to the colored boxes in the map. This information can be used to identify applications for research results and to uncover opportunities for collaboration.

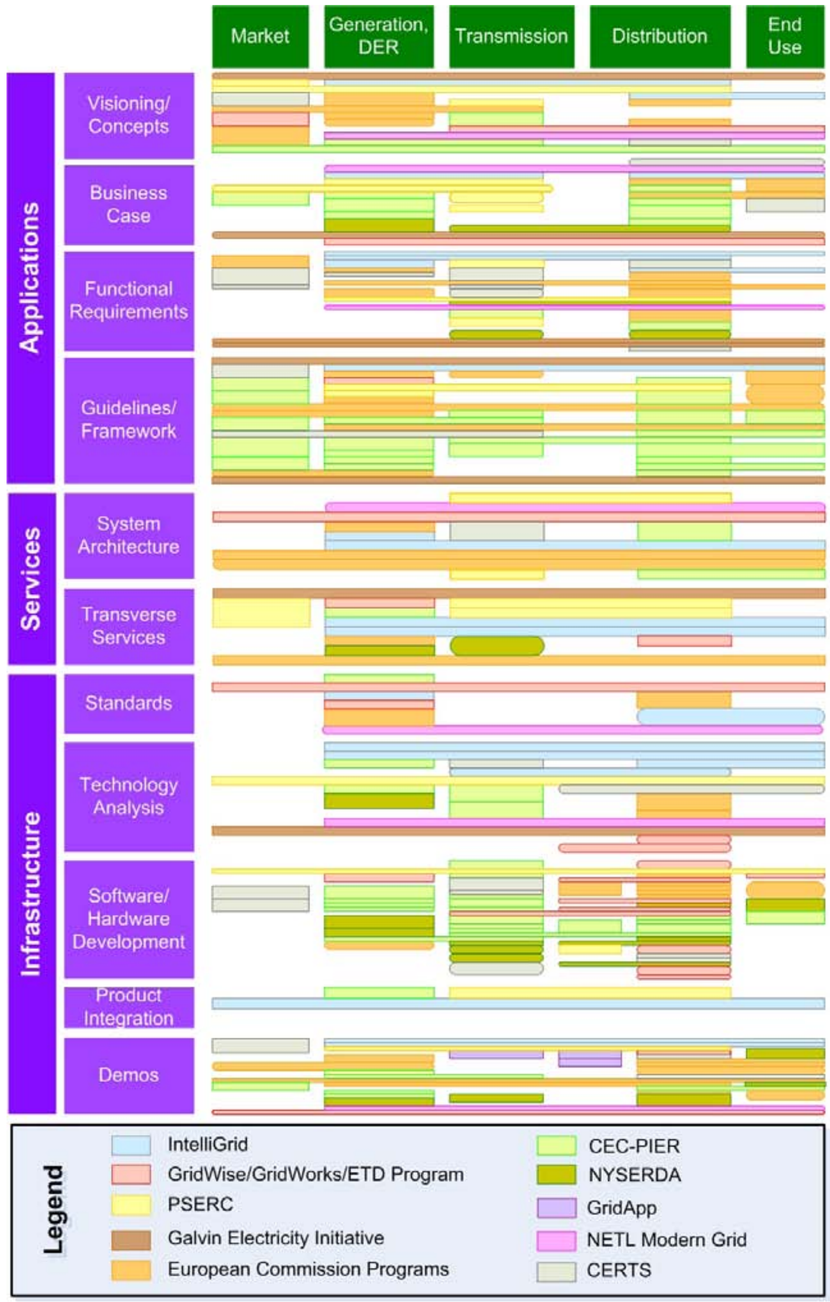

Figure 3
Intelligent grid R&D map

From this map, IntelliGrid, GridWise, CEC–PIER, CERTS, and the European Commission programs were short-listed for further comparison, based on number of projects or significance of results. The following graphic, which was developed to promote discussion and to clarify positioning, shows the interrelationships between the R&D efforts of these programs.

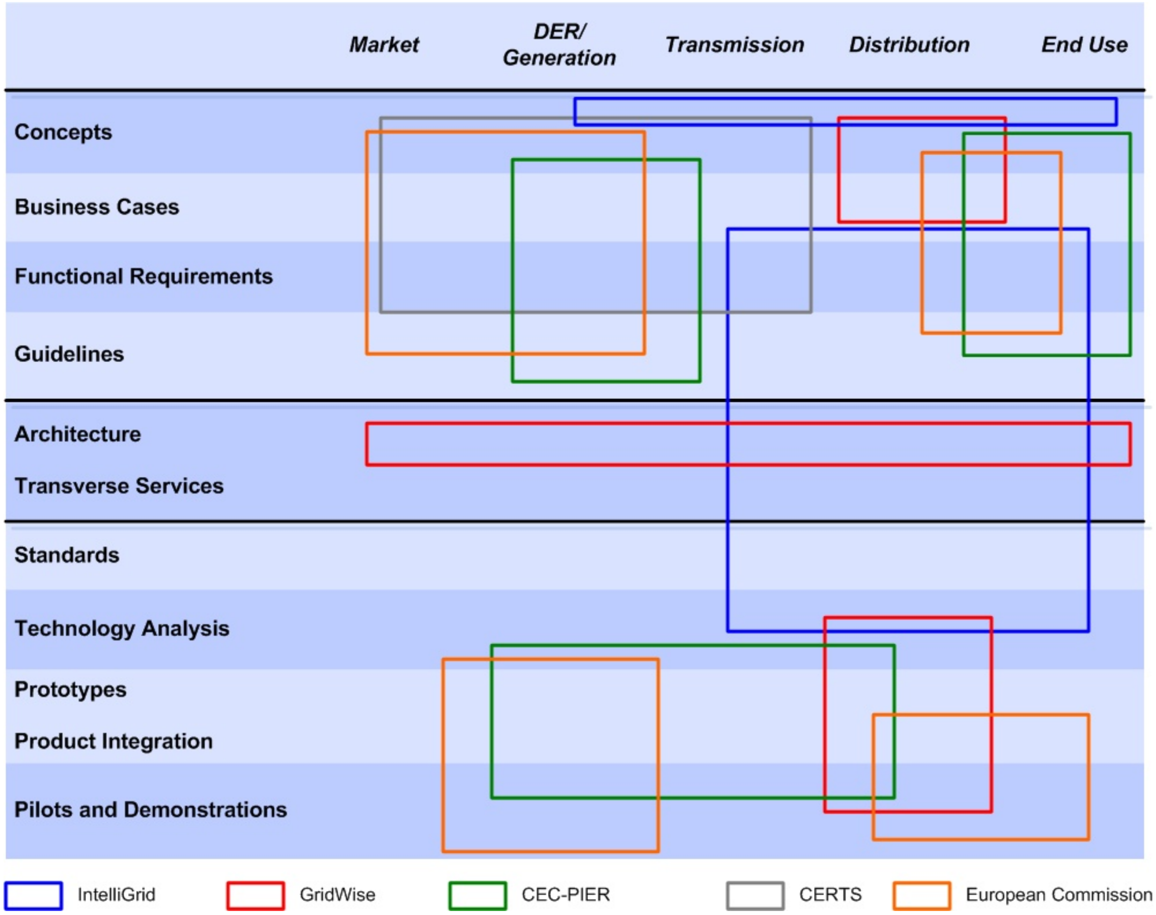

Figure 4
Interrelationships of grid R&D programs, short list

Budget Analysis

Further analysis involved the use of publicly available, cumulative budget information to compare the efforts of each program. Following are two samples of several budget graphs contained in the report. These illustrate relative allocated funding, as estimated for each industry sector and each category in the study. The units of these graphs are weighted, rather than in U.S. dollars, since the purpose of this analysis is to determine the commonalities and differences between programs while preserving the confidentiality of numbers disclosed by each organization.

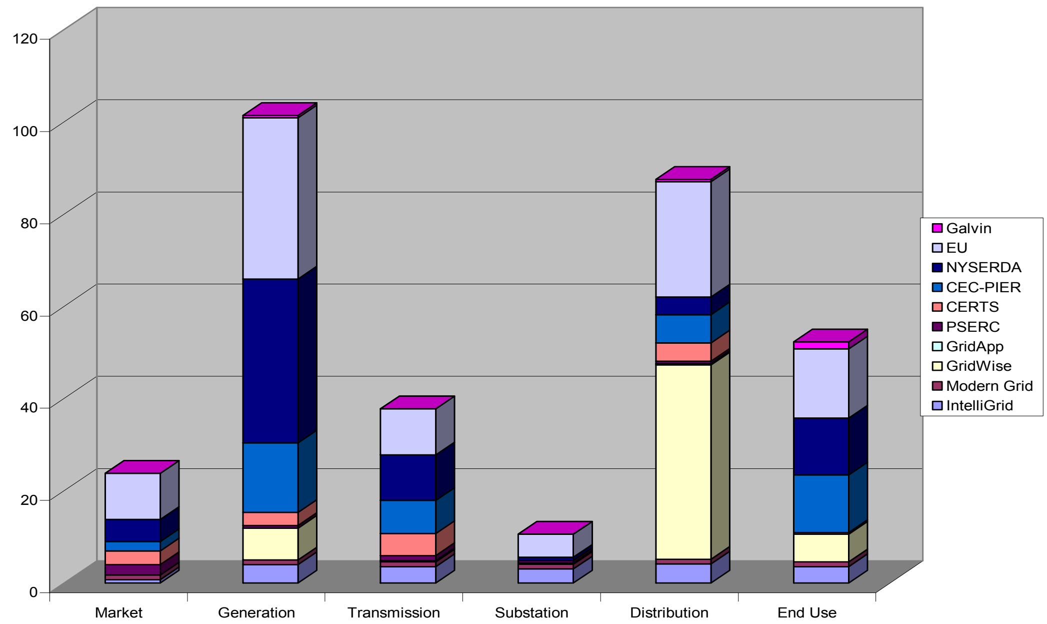

Figure 5
Relative comparisons of program funding, by sector of application

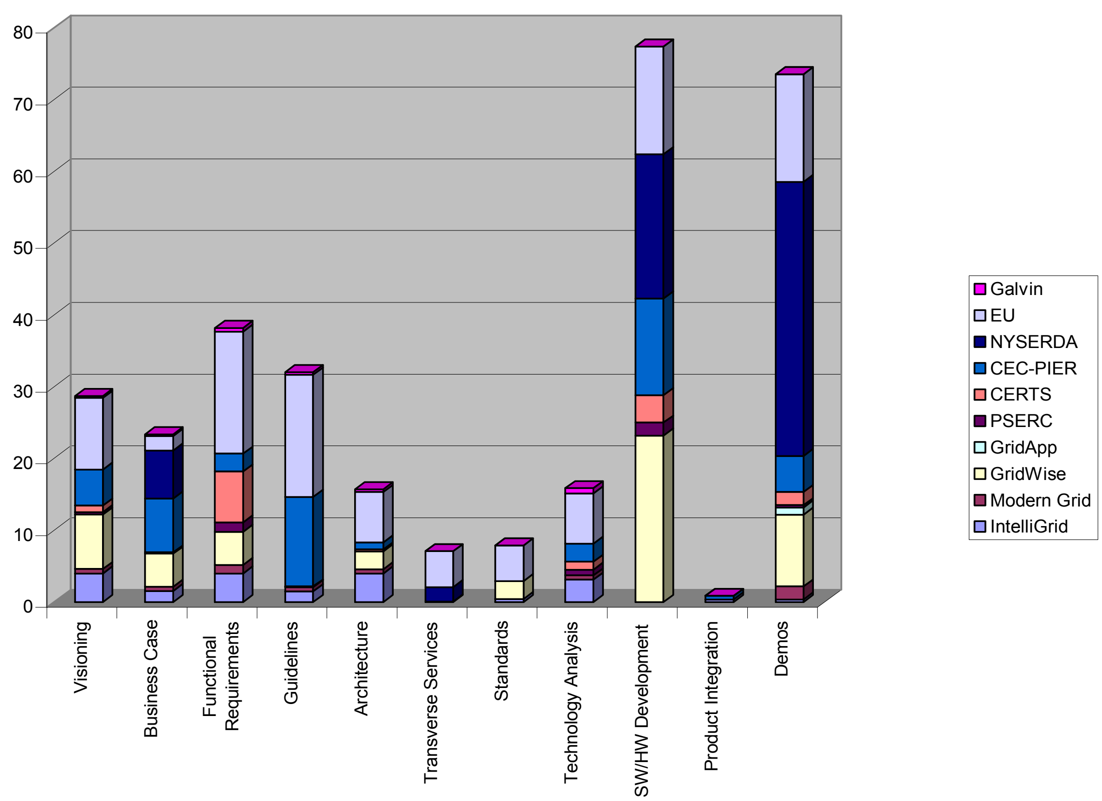

Figure 6
Relative comparisons of program funding, by systems engineering sub-category

Application of Results

The results of this study are intended to encourage dialogue between intelligent grid R&D programs and to identify joint, or “handshake” actions that define common principles for coordination and collaboration. Current handshake actions are discussed in the report.

The key objectives of the study are to

- Identify research results that can be applied by other research organizations and stakeholders
- Understand how each program’s results might complement another’s efforts
- Identify coordination and collaboration actions to minimize project overlaps
- Clarify the positioning of each program

Future Results

The information contained in this report is dynamic in nature. Future versions are planned to update program profiles and mapping. Online tools also will be used to facilitate real-time updates.

The next phase will add several research organizations that were not included in the initial mapping project. Also planned are analyses of intelligent grid R&D programs in Canada, Asia, and Europe. Information on the activities of other public research organizations, manufacturers, electric utilities, and standards bodies will help to improve the positioning of worldwide research and further align developers of the intelligent grid.

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1 SCOPE OF THE STUDY

Technology advances have made it possible to create an intelligent electricity grid that predicts and heals power problems before they get out of hand. The intelligent grid promises to give energy providers substantial advances in power reliability and customer services.

Several new research and development programs have been formed in recent years with the goal of improving the intelligence of the electric power infrastructure. These programs, along with other established R&D organizations, are addressing the technical, economic, and policy barriers to creating a smarter grid. Most of the programs are investigating the use of intelligent technologies to increase power system performance and resiliency; others are embracing the systems view and end-use perspective.

An abundance of research has bolstered the confidence of industry stakeholders, who now recognize that transformation of the grid indeed can be accomplished. At the same time, these stakeholders—which include utilities, manufacturers, standards organizations, and public agencies—have noted how challenging it can be to distinguish between the various research programs and to grasp the results they offer. The stakeholders are looking for a clear picture of program efforts and results. They also are asking for a greater level of coordination among the programs.

In January 2006, EPRI IntelliGrid launched the *Profiling and Mapping of Intelligent Grid R&D Programs* project to assess and characterize these research programs, and to position the expected and delivered results on a map of intelligent grid research. The project delivers information that can be used to help in understanding the results of wide-ranging research on smart grids, and to identify opportunities for collaborative activities that will enhance the integration of technical results.

Profiling and Mapping of Intelligent Grid R&D Programs evaluates a cross-section of public, private, national, and international efforts. The programs are: 1) IntelliGrid Consortium, 2) The Modern Grid Initiative, 3) GridWise, 4) Advanced Grid Applications Consortium, 5) Power Systems Engineering Research Center, 6) Consortium for Electric Reliability Technology Solutions, 7) California Energy Commission – Public Interest Energy Research Program, 8) New York State Energy Research and Development Authority, 9) European Union Framework Program on Sustainable Energy Systems and Electricity Networks of the Future, and 10) Galvin Electricity Initiative.

This report presents the results of the study, which concluded in July 2006.

Program Integration

Broadly defined, integration means *to make into a whole by bringing all parts together; to unify*. In engineering terms, it implies *the process of combining components, or products, into larger assemblies*.

This project brings together information provided by 10 intelligent grid R&D programs representing the public and private sectors across United States and Europe. The objectives of this report are to chronicle the work of these programs and to catalog how resources may be mobilized.

The following four key questions underlie the study:

1. What is the focus of each program?

2. How can research results from each program be applied, adopted, and bundled?

3. Overall, how do the programs complement each other, and how are they distinct?

4. Are there any gaps between programs that point to future research needs?

In conducting this study, it is not the intent of IntelliGrid to influence the work of peers. IntelliGrid has gathered and is publishing this information to increase the public wealth, so that all stakeholders may share the same level of understanding and make best decisions.

2
PROGRAM INTEGRATION APPROACH

This report presents analysis and positioning of 10 major R&D programs that have the shared goal of transforming the electric power delivery system into the intelligent grid. It also highlights the commonalities and differences between the programs, which were selected for their significant contributions to grid transformation.

Analysis has been based on information that is publicly available or was made available for the purpose of this study. The information was evaluated and summarized to populate a template profile and map. Individual draft profiles were then sent to program representatives for review and feedback. Interviews were conducted and comments taken into account whenever possible. It should be noted that some individuals indicated that their organizations could not be characterized within this framework. Their comments are enclosed in the relevant profile.

Application of Results

The results of this study are intended to encourage dialogue between intelligent grid R&D programs and to identify joint, or "handshake," actions that define common principles for coordination and collaboration. Current handshake actions are discussed in Chapter 14 of this report.

The key objectives of the study are to

- Identify research results that can be applied by other research organizations and stakeholders
- Understand how each program's results might complement another's efforts
- Identify coordination and collaboration actions to minimize project overlaps
- Clarify the positioning of each program

Project Process

To achieve these objectives, the study implemented the following five-step process (illustrated in Figure 2-1):

1. Analyze each program, drafting a profile of key technical accomplishments and development plans.

2. Develop a map of the program's contributions to the transformation of the electric power delivery system.

3. Submit the draft profile and map to the program representative for review and comment.

4. Incorporate the received comments into a revised program profile and map.

5. Communicate the outcome to program representatives and refine the analysis. This includes conducting a workshop to share and discuss profiles and maps with program representatives, raise awareness about the contributions of each program, and identify actions to improve program integration.

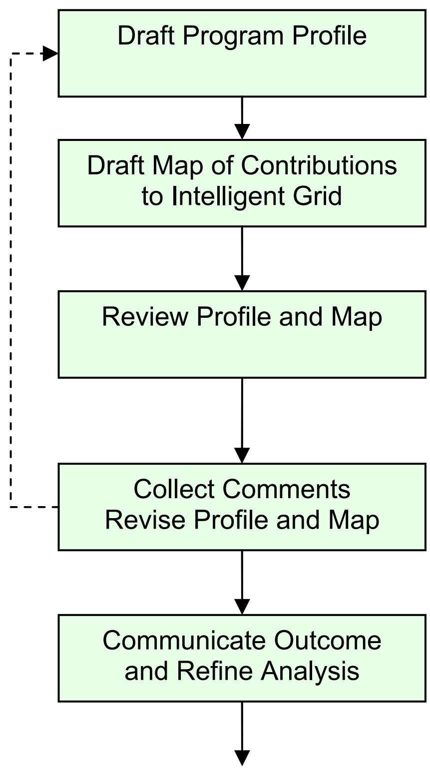

Figure 2-1
Five-step project process

Programs Studied

Following are the intelligent grid R&D programs that were selected for study in the initial profiling and mapping project. The next phase will add other several research organizations. Also planned are analyses of intelligent grid R&D programs in Canada, Asia, and Europe.

1. IntelliGrid Consortium—Founded by EPRI in 2001, IntelliGrid seeks to create a new electric power delivery infrastructure that integrates advances in communications, computing, and electronics to meet the energy needs of the future. Its mission is to enable the development, integration, and application of technologies to facilitate the transformation of the electric

infrastructure to cost-effectively provide secure, high-quality, reliable electricity products and services

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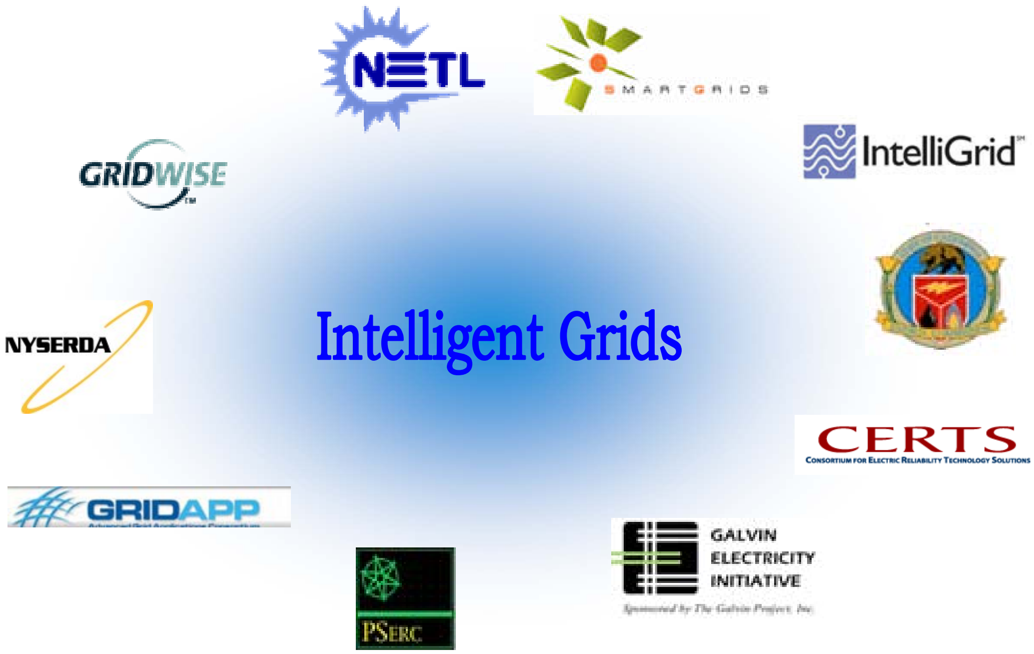


Figure 2-2
R&D programs analyzed in this project

Program Analysis

Each R&D program was analyzed to characterize its: 1) vision of the intelligent grid, 2) mission (and any specific focus), 3) governance, 4) budget (spent to date), 5) promotion activities, and 6) program portfolio, including main objectives, completed or ongoing projects, deliverables, and accomplishments.

Reference Metrics

Because each program has its own rationale, often with implicit language and meanings based on its individual culture, common reference metrics were used in developing the profiles to avoid any side effects in program characterization. These reference metrics were applied to assess the nature of each program in three categories: Applications, Services, and Infrastructure. The following questions and guidelines helped to define the categories:

Applications: 1) What new uses and applications does the program identify? These may range from big picture to more detailed applications. 2) What has the program discovered? It could be a technical result, such as a specification for a new function, or a business result, such as a business case for a new application.

Services: What services has the program developed to support new applications? These may be technical, such as a new computer architecture, or non-technical, such as technology transfer.

Infrastructure: What are the products the program has developed or enabled? These will be technical in nature and may range from the theoretical, as in a product standard, to the concrete, such as a new piece of equipment.

The answers to these questions allowed the categories to be split into sub-categories, as shown in Figure 2-3. This resulted in a comprehensive map of R&D efforts, positioning each program and its results.

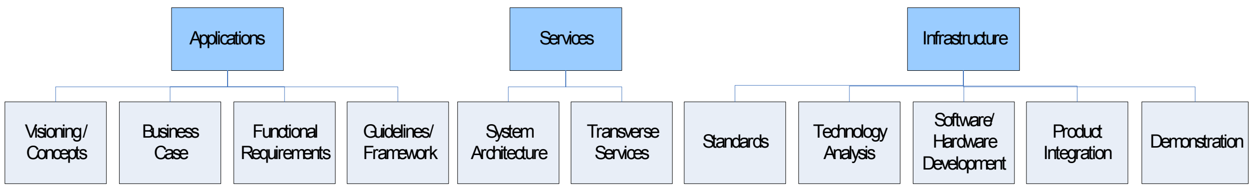


Figure 2-3
Categories and sub-categories of reference metrics

Table 2-1 provides an overview of the reference metrics used in this study and gives product examples for each category. A program-specific table has been developed for each program profiled in this report.

Contribution to the Intelligent Grid

Table 2-1
Reference metrics analysis

Category and Sub-Category	Program Contribution
Applications	
Visioning and Concepts	• Vision-level definition of new functions • System concepts
Business Case	• Cost-benefit analysis, or full business case • Applied to new functionalities of the smart grid, or to technology that does not already exist
Functional Requirements	• Definition of functions • Use cases
Guidelines and General Framework	• Recommendations to develop new applications • Systems view of applications, to combine applications or share resources between applications
Services (Bridge Between Products and Needs)	
System Architecture	• Object models of information, within each entity or exchanged between entities • Principles applied in terms of design to accommodate a need • Reference design that can be applied to every context and need
Transverse Services	• Methods or techniques to facilitate building of combination technologies • Technology transfer requirements for envisioned services, such as knowledge of Unified Modeling Language or management of Enterprise Application Interface • Organizational changes to benefit from new applications
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	• International and national standards • User groups that make technologies more standardized
Technology Analysis	• Analysis of technology developments, such as power electronics storage or end-use electronic devices
Software and Hardware Development	• New hardware prototypes • New software applications
Product Integration	• Solutions to manage interoperability, compatibility, and maintenance of a set of products
Demonstration	• Field-testing of new functionalities in existing or new equipment

Program Mapping

Information gathered in the reference metric analysis was then positioned on a map to show the contributions of each R&D program. As Figure 2-4 shows, the X-axis represents the functional sector of application. Sectors are: 1) Market/Regulation; 2) Generation, including Distributed Energy Resources; 3) Transmission; 4) Substation; 5) Distribution; and 6) End Use. The Y-axis contains the categories and sub-categories, as defined in the reference metrics analysis. This axis represents the maturity of the research topic, ranging from idea to implementation.

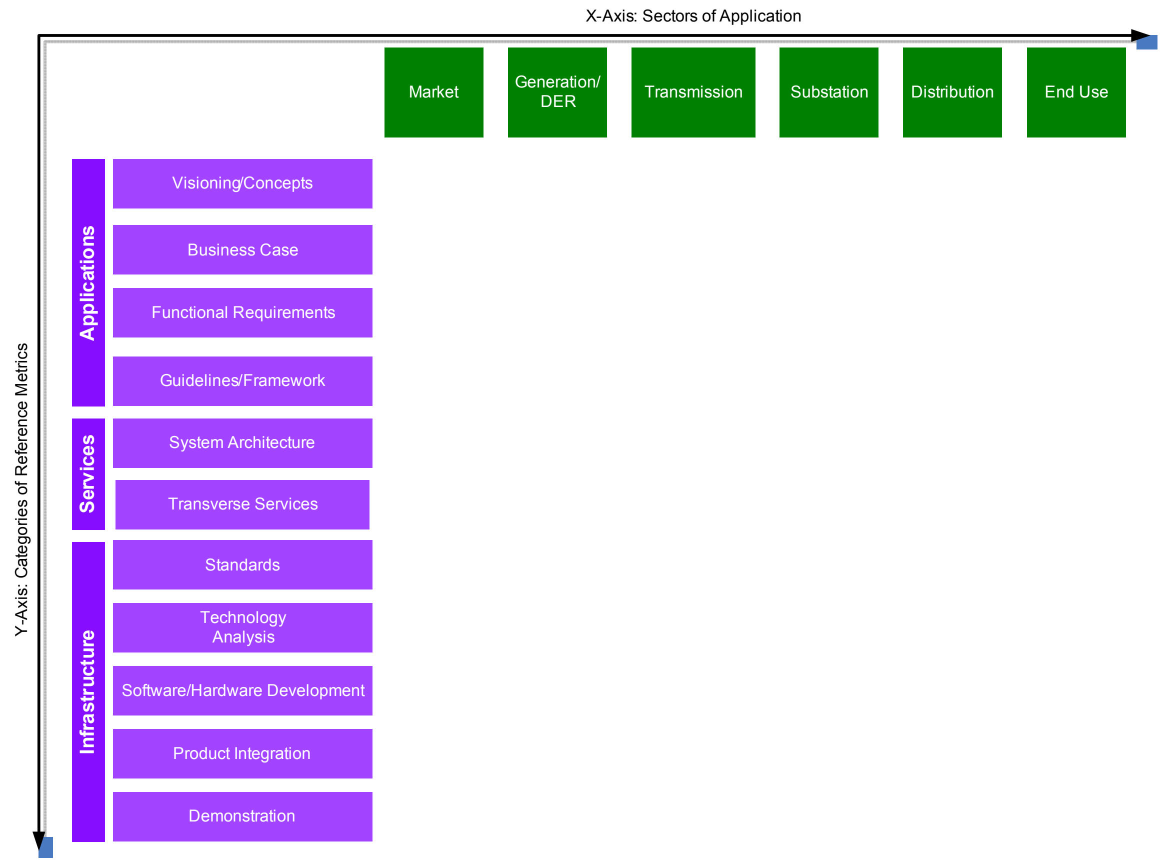


Figure 2-4
Template of program map

Notations

Projects are represented on the map by rectangles, using a unique color per program. As Figure 2-5 shows, a squared rectangle signifies results or deliverables that already are available; a rounded rectangle represents ongoing projects with expected results or deliverables.

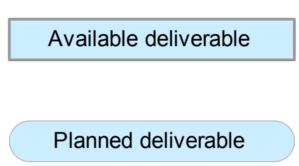


Figure 2-5
Map notations for available and planned deliverables

3
INTELLIGRID

The information contained in this program profile comes from published documents on the IntelliGrid Consortium. The profile has been reviewed by Don Von Dollen, IntelliGrid Project Manager at EPRI. For more information, please visit www.epri.com/IntelliGrid.

Vision

The IntelliGrid vision is: “A new electric power delivery infrastructure that integrates advances in communications, computing, and electronics to meet the energy needs of the future.” [1]

Mission

IntelliGrid was founded by EPRI in 2001 to enable the development, integration, and application of technologies to facilitate the transformation of the electric infrastructure to cost-effectively provide secure, high-quality, reliable electricity products and services. [2]

Governance

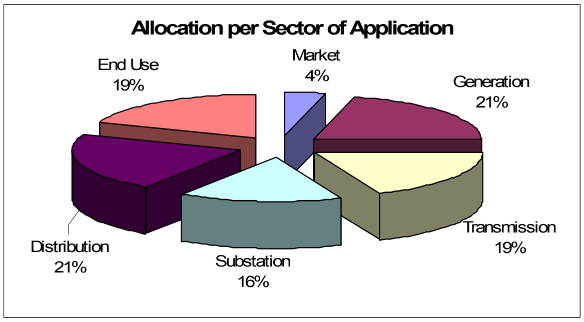
Current members of the Consortium are: NYPA, PPGC, SRP, EDF, LIPA, TXU, ABB, Hitachi, Kansas City Power & Light, Public Service New Mexico, Tri-State G&T Arkansas Electric Cooperative, Great River Energy, Richmond Power & Light, Dairyland Power Cooperative, Golden Valley Electric Association, Hoosier Energy Rural Electric Cooperative, Lincoln Electric, Hetch Hetchy Water & Power, California Department of Water Resources, KEPCO/KEPRI. The program is managed by EPRI.

Budget

2001–2005: $19M

2006: $3M

Figure 3-1 shows the distribution of the research budget (2001–2005) among the sectors of application and systems engineering categories used in this study.



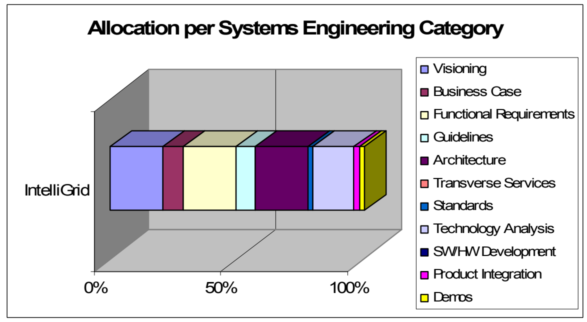


Figure 3-1
Distribution of the IntelliGrid R&D budget (spent to date)

Promotion

- Website established
- Presentations made at major industry conferences
- Public Advisory Group established
- Monthly status report (for partners only)
- Press releases
- Publication of articles in trade press
- Brochure developed (in process of being updated)

Research Projects

The portfolio is composed of four projects: 1) IntelliGrid Architecture, 2) Fast Simulation & Modeling, 3) Communications for Distributed Energy Resources (DER), and 4) Consumer Portal. A new project on Advanced Monitoring Systems began in 2006, and demonstration projects kicked off in 2006: [1]

IntelliGrid Architecture

This project is developing an industry-level architecture for communications and distributed computing systems that effectively integrates advanced intelligent equipment. The architecture consists of a method to build functional requirements that are compatible with the IntelliGrid vision, along with key functional requirements and recommendations to the industry. The current focus of the project is on implementing Phase 1 recommendations in several applications, including an automatic meter infrastructure for TXU and distribution automation for SRP. These demonstrations guide IntelliGrid efforts to codify the standards-based approach and develop equipment that meets power industry needs. The project also is developing an industry model to serve as a powerful tool for documenting and specifying complex advanced automation and consumer communication systems.

The California Energy Commission (see Chapter 9) and the GridWise Architecture Council (see Chapter 5) are applying results from the project to their own research. CEC has employed IntelliGrid Architecture guidelines and recommendations in its reference design for demand response, and GridWise has built its "standards landscape" using key standards from the project. Southern California Edison also has applied the IntelliGrid Architecture systems engineering approach in its Advanced Metering Infrastructure (AMI) project. SCE is applying the use-case-based methodology to ensure that all aspects of an AMI system—meters, communications infrastructure, and enterprise software—are evaluated in a rigorous manner that results in high-quality, traceable, and defendable requirements.

Fast Simulation & Modeling

The Fast Simulation & Modeling (FSM) project is designed to provide the algorithmic and mathematical underpinnings and look-ahead capability for a self-healing grid—one that is capable of automatically anticipating and responding to power system disturbances while continually optimizing its own performance. FSM will aid decision-making by providing grid operators with accurate state estimation of the grid in real time, enabling them to optimize operations and predict grid behavior based on historical and real-time data.

This project is developing an open platform for software, following the normal requirements, design, development, and testing phases. EPRI is contributing to the requirements phase by leveraging utility advisors to create a robust set of functional requirements that support follow-on design and development work.

The project has been separated into two complementary connected activities during the requirements definition phase: 1) D-FSM, which focuses on distribution system operations, and 2) T-FSM, which concentrates on transmission system operations. Functional requirements for D-FSM and T-FSM have been completed at a high level, with detailed specifications for voltage and reactive power management function. A cost-benefit analysis and computational architecture for T-FSM also have been defined.

Project objectives for 2006–2008 include completion of a roadmap for FSM, functional specifications for pivotal components, definition of key interfaces, development of a prototype for specific functions, and demonstration projects.

Communications for Distributed Energy Resources

One of the major hurdles to the deployment of DER has been the lack of industry standards for interconnecting these devices with electric power systems. In response, IEEE approved a standards project with the participation of EPRI, DOE, and numerous other stakeholders to develop foundational interconnection standards for DER. The resulting 1547™ Standard was issued in July 2003. This initial standard is now being followed by a series of additional standards, recommended practices, and guidelines within the IEEE 1547 family. This project supports the working group chair for one of the follow-up documents—the guide on monitoring, information exchange, and control for DER in electric power systems (IEEE WG P1547.3). The project also has launched a new IEC working group (WG 17 under TC-57) to expand the IEC

61850 communication architecture to DER, with the possibility of expanding to other distribution system technologies later. IntelliGrid continues to support the Convener (leader) role for this new working group.

Consumer Portal

The consumer portal is a new concept that enables two-way communications between consumers and stakeholders, including distribution operators, load-serving entities, and service providers. It allows the consumer to become an actor in energy markets and to receive a wide range of services. The consumer portal also provides new benefits for management and monitoring of the distribution system, with applications that include automatic meter reading, demand response, real-time pricing, theft detection, remote disconnect, energy management, DER interface and control, and outage detection. In addition, the portal will be designed to accommodate the numerous protocols and standards in place for non-energy services.

Consumer portal development builds on the foundation established in the IntelliGrid Architecture design, and it deploys many of the tools and standard approaches created in the DER/ADA project. Portal development centers on standardizing information for consumer functions and methods for implementing applications. The functional requirements for several consumer portal functions have been completed, and key principles and design criteria have been published.

Advanced Monitoring Systems

This new IntelliGrid project was launched in 2006. The first phase features a technology assessment to identify possible new approaches for sensors that could apply to the power system. These sensor technologies will then be matched with the needs of specific applications. To provide a focus for these evaluations and to prevent dilution of research efforts across a wide array of applications, the project is addressing substation applications, especially condition-based maintenance. The second phase will develop a roadmap for integration of sensor technologies into substation applications involving asset management and condition-based maintenance. The final phase will include sensor integration development efforts and performance assessments. Demonstrations will be structured to illustrate the benefits and integration issues for sensor technologies in these applications.

Demonstration Projects

IntelliGrid demonstration projects must

- Demonstrate an application that provides the power system with a new capability or greatly enhances a current capability, and also promotes the IntelliGrid vision of coupling intelligence with power system operations—e.g., integration of communications, distributed computing, monitoring, control, etc.
- Comply with IntelliGrid Architecture methods, such as the requirements-driven process and requirements documentation, and IntelliGrid content by developing applications that employ

open standards, implementing well-defined points of interoperability, applying recommended technologies, etc.

- Be scalable for full deployment; transferable for use by others; and produce a result that paves the way for additional implementations, either through technical discovery, proof-of-concept, regulatory easement, or systems integration.
- Be visible on the power grid and possibly include equipment or software either on the grid itself or at customer premises.
- Provide tangible results with clear benefits to utilities, consumers, and society.
- Have a duration of 24 to 36 months.
- Document and share results with others.
- Highly leverage funding from other sources.

The following IntelliGrid demonstration projects are currently under way:

- Southern California Edison – AMI
- TXU – AMI Enterprise Software Integration
- Polish Power Grid Operator – T-FSM
- LIPA – Advanced Automation
- EDF – D-FSM
- Alliant Energy – Distribution Monitoring System
- Salt River Project – Transfer Station Equipment Monitoring

Accomplishments to Date

- Final Report of IntelliGrid Architecture (recommendations, functional requirements, technical analysis) – August 2004
- IntelliGrid Architecture website updated – August 2004
- Two DER object models (diesel and fuel cells) drafted; DER/ADA Object Model Report – December 2003
- Studies of Distribution Operations to Aid in Determining Object Models for Distributed Energy Resources – December 2003
- Detailed test plan document for developmental laboratory testing phase of the project – July 2004
- Two international standards working groups (IEC and IEEE) on object models for DER created and led by IntelliGrid
- Inventory of Utility Communications – March 2004
- Business Case Assessment for Energy Service Portals – March 2004

- Energy Service Portal Development – Assessment and Recommendations – December 2003
- T-FSM High-Level Requirements – Spring 2004
- T-FSM Functional Requirements and Architectural Requirements – March 2005
- D-FSM High-Level Requirements – December 2004
- D-FSM Engineering Requirements: Document Guidelines – December 2005
- Sensor Systems State of the Art – December 2003
- Guidelines for using IntelliGrid Architecture for procurements, RFPs, and evaluating proposals
- Guidelines for conformance to the IntelliGrid Architecture
- Technology assessment of sensors for substation applications
- Consumer Portal data object models report

Contribution to the Intelligent Grid

Table 3-1
Reference metrics analysis for IntelliGrid

Categories	IntelliGrid
Applications	
Visioning and Concepts	• Self-healing grid concept (set of new functions developed in FSM) • Definition of key concepts of a consumer portal
Business Case	• Business case analysis of consumer communications portal for energy services • T-FSM cost-benefit analysis
Functional Requirements	• Definition of voltage and reactive power management advanced functions in FSM tools • Definition of four use cases of a consumer portal (load control defined with UML, automatic meter reading and fast reserve service defined in text format) • Draft use cases of IntelliGrid functions (structure of functions, taxonomy, actors) • Study of distribution operations for DER to define information requirements (under normal conditions)
Guidelines and General Framework	• IntelliGrid Architecture (iA) recommendations to define an information architecture for the intelligent grid
Services (Bridge Between Products and Needs)	
System Architecture	• DER object models defined for diesel and fuel cell engines • iA recommendations and principles to define a system architecture
Transverse Services	• iA principles to specify support services (enterprise management, data management, platform, security, communications, etc.) • Workshops and training to define use cases of the intelligent grid (technology transfer)
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	• IEC TC57/WG17 and IEEE 1547.3 created and led to define standards of object models for DER • UCA/IntelliGrid users group • Contribution to International Standard for Consumer Portals (ANSI C12; IEC TC57 WG10, 14)
Technology Analysis	• iA recommendations of technologies that will satisfy needed properties of the intelligent grid • State-of-the-art trends of communications in utility systems Inventory of Utility communications • Technology analysis for developing a consumer communications portal • *Technology analysis of sensors for the intelligent grid*
Software/Hardware Development	• None
Product Integration	• iA identification of some key technologies to facilitate field device integration and enterprise management integration
Demonstration	• IntelliGrid implementation: Demonstration of iA use cases; application of iA system architecture principles • *IntelliGrid demonstrations*

Legend: Italics indicate an expected deliverable of a planned project.

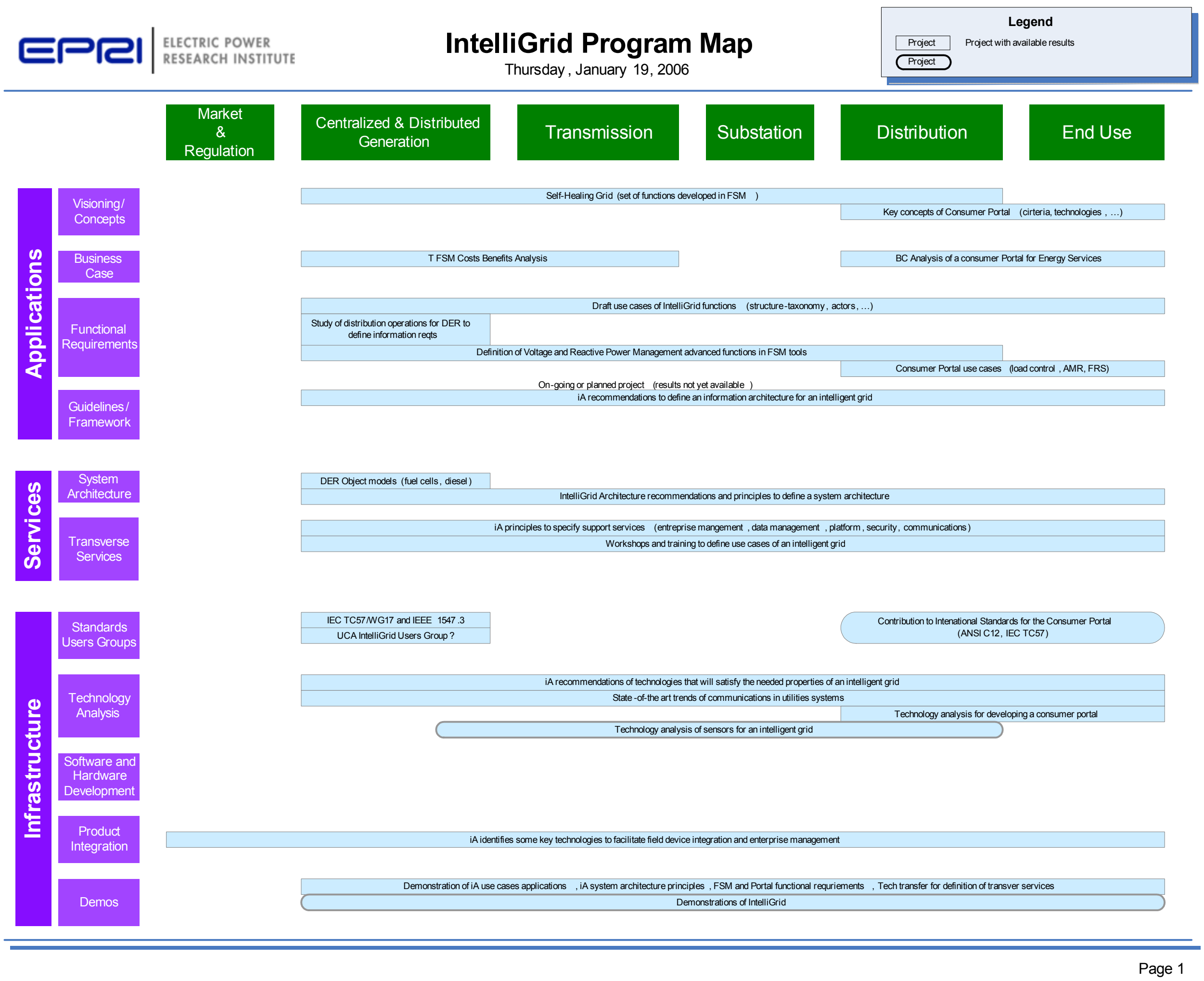


Figure 3-2
IntelliGrid program map

4
THE MODERN GRID INITIATIVE

The information contained in this program profile comes from published documents on The Modern Grid Initiative. The profile has been reviewed by Steve Pullins, Vice President, Energy Solutions at Science Applications International Corporation. For more information, please visit www.themoderngrid.org.

The U.S. Department of Energy (DOE) established The Modern Grid Initiative in 2005 through its Office of Electricity Delivery and Energy Reliability (OE) and National Energy Technology Laboratory (NETL).

Vision

"The modern grid is a new model of electricity delivery that will carry to a new era of energy prosperity. The modern grid is not a patchwork of efforts to bring electricity to the consumer, but a total system that utilizes the most innovative technologies in the most useful manner." [5]

The Modern Grid Initiative defines its vision in the first stage of its project plan. To date, five primary elements form the basis of the Modern Grid Initiative vision: key success factors, performance, principal characteristics, key technology areas, and metrics. [6]

Mission

The Modern Grid Initiative is facilitating the development of a common vision for the modern grid and, based on that vision, is planning a series of regional integrated technology demonstration projects to accelerate promising technologies and processes in the electricity sector. [6]

The initiative is looking at the new infrastructure through its whole structure and will not segment its modernization through the traditional sectors of application (Generation, Transmission & Distribution, and End Use). Therefore, integration will play an important role in the program.

Members/Governance

DOE OE is funding the initiative and provides sponsorship, guidance, direction, and coordination with related DOE and federal programs.

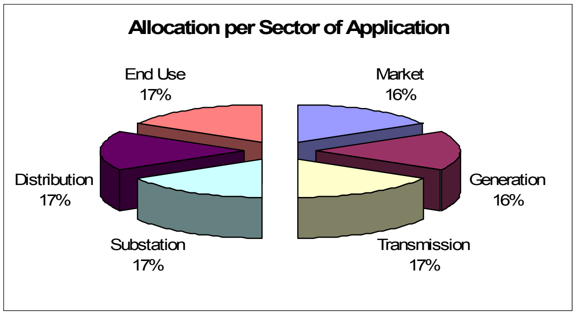
DOE NETL is coordinating modern grid conceptualization, facilitating stakeholder outreach, managing demonstration projects, and providing technical expertise. Stakeholders will be actively involved in providing content, reviewing documentation, participating in demonstration projects, and providing project funding.

Budget

Budget: $6M from DOE ($5M of earmark in 2006, $1M of earmark in 2007)

Expected additional funding: $20M from DOE, with same amount from private sector

Figure 4-1 shows the distribution of the research budget (spent to date) among the sectors of application and systems engineering categories. Allocation of the 2006–2007 budget is slated to be homogenously split among application areas. Systems engineering allocations are planned as follows: Vision (10%), Business Case (10%), Functional Requirements (20%), Guidelines (10%), Architecture (10%), Technology Analysis (10%), and Demonstration (30%).



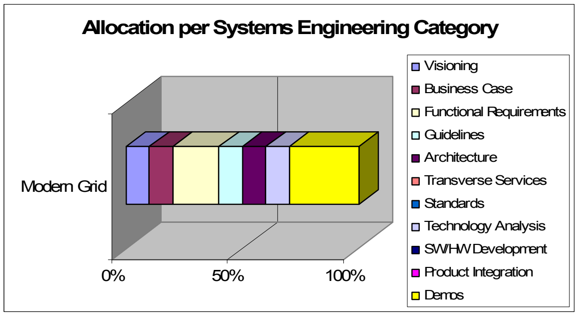


Figure 4-1
Distribution of The Modern Grid R&D budget (spent to date)

Promotion

- Workshop, "Developing the Modern Grid," sponsored by DOE and NETL in November 2005
- Series of summits throughout the U.S.: Regional summits to engage stakeholders, and a national summit to share information collected from the regional summits and solicit feedback.
- Website: www.themoderngrid.org

Research Efforts

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 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 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 where the projects are located.

It is envisioned that the demonstration program will consist of 10–15 projects carried out over five 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. [7]

The initiative has identified six steps, shown in Figure 4-2, to advance the development of its program:

1. Develop a vision, defining it through the grid's principal characteristics and key technology areas.

2. Perform a gap analysis.

3. Identify needs (technologies, processes, and areas of research).

4. Demonstrate technology and progress integration.

5. Evaluate demonstration results, and extrapolate the results and benefits to the national level.

6. Stimulate deployment.

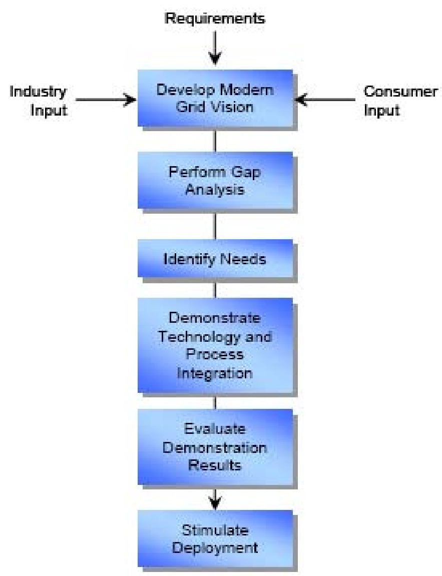


Figure 4-2
The Modern Grid Initiative project plan

Vision and Concepts

The first version of the vision was published on May 1, 2006, and it is currently being presented and discussed through regional summits. The proposed vision takes a systems approach with five interrelated components. It states: "By determining what the system (grid) must deliver (performance), we can identify its key characteristics (principal characteristics). This directs our creation of solutions (key technology areas) that will change the grid in a way that is measurable (metrics) and delivers the overall goals (key success factors) previously identified." [6]

The five components, summarized in Figure 4-3, are described in detail in the May 2006 document.

Figure 4-3
The Modern Grid systems view

Gap Analysis and Identification of Need

Gap analysis will compare how the system is currently functioning versus how stakeholders envision it functioning in the future. When identified, technologies and processes in need of development will fall under three categories:

- Ready for demonstration: The initiative will consider technologies for demonstration.
- Under research and development: The initiative will bring attention to these technologies through white papers to accelerate their readiness for demonstration.
- No action occurring: The initiative will direct the attention of DOE or other research organizations to accelerate R&D.

According to the initiative timeline shown in Figure 4-4 and NETL direct inputs, the concept, gap analysis, and needs analysis are expected to be finished by the end of 2006.

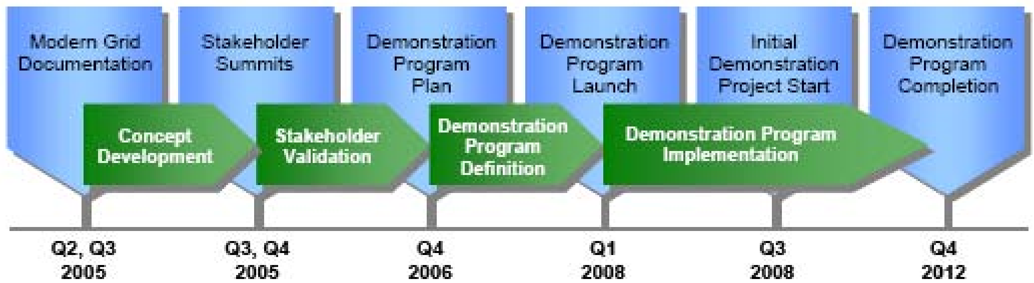


Figure 4-4
The Modern Grid timeline

Demonstration of Technologies and Process Integration

The first step at this stage will be to define smaller-scale developmental field tests (DFTs) that will aid in the understanding of specific issues involved in creating successful regional demonstration projects. These demonstrations—with an average budget of $1 million to $2 million—will employ the systems view developed earlier and apply identified technologies and processes. A first DFT at AEP was ready for procurement in June 2006 and will be commissioned in February 2007. A second DFT is currently being studied and may be ready for procurement in February 2007.

A valuation tool is being developed to provide an estimation of the benefits of regional demonstrations. This tool also will define the benefits of generalizing a demonstration for application nationally. The first application of this product will be ready for developmental field testing at the end of 2006.

Regional demonstrations will be large, integrated demonstration projects—with a budget of approximately $30 million—and will be commissioned by Spring 2008. This demonstration program will be carried out over five years, and it will ultimately produce a set of modern grid design specifications for the nation. It also will support the creation of standards and guidelines for the utilities, consumers, vendors, regulators, researchers, and trade associations that constitute the electric grid industry. [7]

Accomplishments to Date

- The Modern Grid Initiative: Description of the initiative and its project plan.
- Modern Grid v1.0: A Systems View of the Modern Grid: Description of the vision and principal components of the initiative. Appendices A and B in this document show, respectively, the seven principal characteristics of the modern grid and the five technology areas (Integrated Communications; Advanced Sensing, Metering, and Measuring; Advanced Grid Components; Advanced Control Methodologies; and Decision Support and Human Interface).

These documents are posted at www.themoderngrid.org.

Contribution to the Intelligent Grid

Table 4-1
Reference metrics analysis for The Modern Grid Initiative

Categories	The Modern Grid Initiative
Applications	
Visioning and Concepts	• Modern Grid concepts and vision
Business Case	• *Benefit evaluation tool*
Functional Requirements	• *Identification of need (functional specifications)*
Guidelines and General Framework	
Services (Bridge Between Products and Needs)	
System Architecture	• *Guideline for system architecture*
Transverse Services	
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	• *Codification of modern grid concepts and ideas into laws and rules (mainly working with NSLegislature, NASEO, NARUC)*
Technology Analysis	• *One of the first stages of the program is to conduct a gap analysis of the need for integration of technologies, with five technology areas covered*
Software and Hardware Development	
Product Integration	
Demonstration	• *Creation of regional demonstrations to integrate regional themes toward generalization for the nation*

Legend: Italics indicate an expected deliverable of a planned project.

5
GRIDWISE

The information contained in this program profile comes from published documents on GridWise and The GridWise Alliance. The profile has been reviewed by Eric Lightner at the U.S. Department of Energy and by Rob Pratt and Carla Raymond at Pacific Northwest National Laboratory. For more information, please visit www.gridwise.org.

The term GridWise™ is used in reference to the vision that the U.S. Department of Energy (DOE) has for the power delivery system of the future. The GridWise program is funded by the DOE Office of Electricity Delivery and Energy Reliability in its Distribution Area program; The GridWise Alliance, an association of industry members who support both the vision and the program; and the GridWise Architecture Council, an association of experts who seek to articulate the guiding principles of an information architecture.

The GridWise R&D program is composed of the GridWise Program at DOE, GridWise demonstration projects (with both public and private funding), and the GridWise Architecture Council. The GridWise Alliance, funded by the industry, does not develop research projects. Figure 5-1 describes the relationships between the actors involved in the GridWise programs. A more comprehensive map of these relationships is included in Appendix A.

Vision

DOE states that GridWise has four different meanings:

- *Belief*: Information technology will transform the planning and operation of the power grid.
- *Concept*: Realization of a modern grid utilizing an information superhighway supporting a smart, dynamic, flexible, plug-and-play environment.
- *Strategy*: To meet the increasingly sophisticated demands of today's businesses and consumers with greater security, fewer disruptions, and faster recovery; to support a growing economy and save billions of dollars.
- *Brand*: Created to unite a fragmented industry behind a common goal. [11]

No vision statement has been published by DOE per se, although GridWise at PNNL has stated that its vision is to modernize the nation's electric system, from central generation to customer appliances and equipment, and to create a collaborative network filled with information and abundant market-based opportunities. "Through GridWise, we can weave together the most productive elements of our traditional infrastructure with new, seamless plug-and-play technologies. Using advanced telecommunications, information, and control methods, we can create a 'society' of devices that functions as an integrated, transactive system." [10]

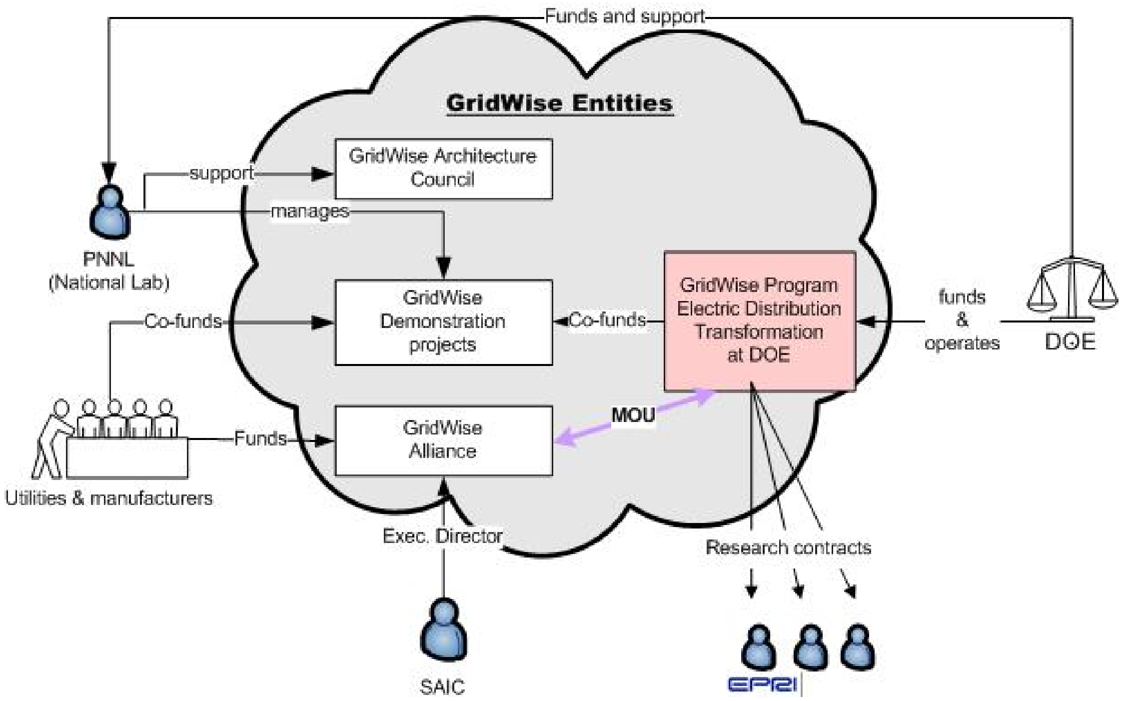


Figure 5-1
GridWise actors, entities, and relationships

Mission

The mission of the DOE Distribution Integration program (as of FY07) is to modernize distribution grid infrastructure and operations, from distribution substations (69 kV and down) to consumers, with two-way flow of electricity and information. [13]

Governance

The DOE Office of Electricity Delivery and Energy Reliability is the funder of the GridWise Program at DOE. This research program is national (USA).

The GridWise Alliance, whose goal is to spread the GridWise vision, is a separate organization linked to DOE with a Memorandum of Understanding. The GridWise Alliance counts 19 members from the electric power industry—AEP, AREVA T and D, Battelle, Beacon Power Corp., Bonneville Power Administration, ConEd, Duquesne Broadband, EnergySolve Companies, EPRI, GridPoint, IBM, Ice Energy, PJM Interconnection, RDS, RockPort Capital Partners, SAIC, Sempra Utilities, Site Controls, Tennessee Valley Authority. It has no funded research projects.

The GridWise Architecture Council is a separately governed entity of volunteer Information Technology experts and specialists.

Budget

The budget of the Distribution program at DOE for fiscal year 2006 is $17.9M, including $11.9M in Congressional earmarks. Allocation of the FY2006 budget is presented in Figure 5-2.

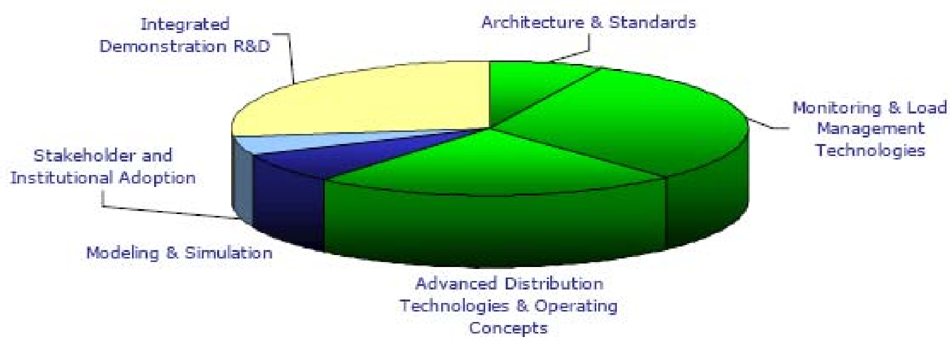


Figure 5-2
Allocation of FY2006 budget in the DOE Distribution program

Based on the FY2006 budget allocation and project funding over the past three years, an estimated allocation has been made of the DOE Distribution program budget among the sectors of application and systems engineering categories used in this study. Estimated total spending in the last four fiscal years is $55M.

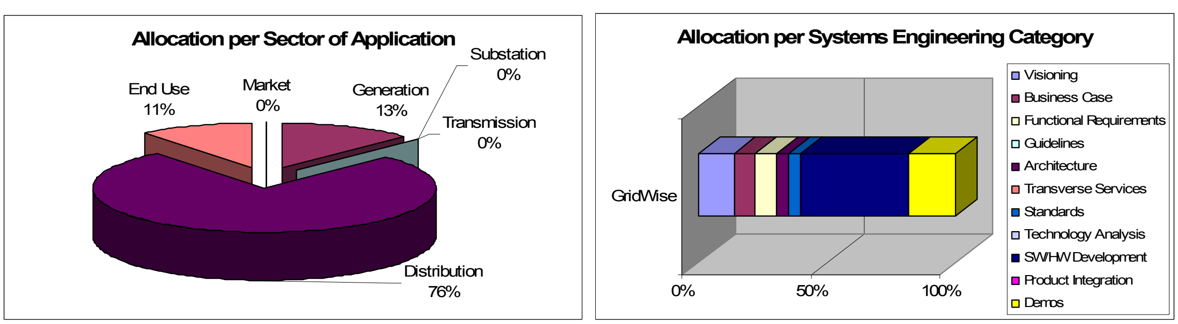


Figure 5-3
Distribution of the GridWise R&D budget (spent to date)

Promotion

DOE and the The GridWise Alliance have initiated the following promotional activities:

- Websites established

- Monthly newsletter (*SmartGrid News*) with broad distribution launched
- Presentations made at major industry conferences
- Frequent press releases
- Frequent publication of articles in trade press
- Brochures developed

Research Programs and Projects

The Distribution program area at DOE consists of

- The GridWise Program. This program was created to modernize the grid with sensors/communications/IT/controls for intelligent, secure electric delivery.
- The Electric Distribution Transformation (EDT) Program. This program aims to integrate DER and load management to respond to customer needs for differentiated electric delivery services in power quality and power reliability. [13]

Because the DOE Distribution program area contributes to the mission to modernize the grid, both GridWise and EDT have been included in this GridWise profile.

DOE has defined four strategic directions for its research projects:

1. Architecture and Communication Standards: Flexible, adaptive; secure access to abundant information; seamlessly crossing enterprise boundaries.
2. Monitoring and Load Management Technologies: End users empowered to participate; loads as resources.
3. Advanced Distribution Technologies and Operating Concepts: High asset utilization and reliability; just-in-time capacity additions; dynamic reconfiguration.
4. Modeling and Simulation: Predicting power and end-use systems interacting with customer and market behavior.

GridWise Program

GridWise historically has engaged its research efforts in two main activities:

- Grid Friendly™ Appliance (GFA). This is a silicon chip that will be built into appliances to temporarily turn off the appliance when grid frequency drops below a set threshold. This action may prevent cascading failures (blackouts) from occurring on the power system. Prototypes of this chip have been developed and are demonstrated in the GridWise demonstration testbed.
- GridWise Architecture Council. This volunteer body of information technology experts and specialists was created in late 2004. Its purpose is to establish broad industry consensus in

support of the technical principles enabling the vast scale of interoperability required to transform electric power operations into a system that integrates markets and technology and enhances socio-economic well-being and security. In 2005 it defined its Constitution, with statements of principle to enhance interoperation of information systems across the electric system. Technical strategy, demonstrations, and industry engagements are planned for the next stages.

In 2006, the GridWise program portfolio is composed of

- Pacific Northwest GridWise Testbed Demonstrations ($2M DOE funding over two years): The Olympic Peninsula Distributed Resources demonstration will integrate in-the-field demand response and backup generators to test T&D congestion mitigation during peak periods. The Olympic Peninsula will also test a market-based customer response in a 'virtual market,' with real-time bidding and five minutes clearing price (both demand and supply). The GFA Controller demonstration will equip 150 homes with the GFA on water heaters and clothes dryers to test the ability to automatically reduce load in response to stress on the grid.
- GridWise Architecture and Standards: This project will provide facilitation support to the GridWise Architecture Council and standards development.

Electric Distribution Transformation Program

- Advanced Protection Methods on SCE's Circuit of the Future: The objective of this project is to improve the detection and isolation of circuit faults on the distribution system to minimize both frequency and duration. The project will design and test new protection with and without fault current limiter, and will add new fault sensing and prediction techniques. The planned tasks are: existing protection scheme assessment (scheduled for 2006 to mid-2007), protection scheme development with fault current limiter (2007 to mid-2008), and prediction scheme (2006–2008).
- Integrated Distribution Management System (IDMS) Project: The goal is to create a unique interface (network view) of a common real-time operational distribution model at Alabama Power. The IDMS will integrate applications such as distribution automation, geographical information system, and outage management system into SCADA.
- Development and Demonstration of Advanced Monitoring Systems for Fault Location, Analysis, and Prediction: This project focuses on two areas: development of a public disturbance library to help in the development of algorithms; and new monitoring technologies, including a distribution fault anticipator (DFA) device. Two demonstrations are planned: one of the DFA at TXU; the other of a feeder application at AEP. A database of potential intelligent applications will be delivered at the end of the project.
- Cable Diagnostic Focused Initiative: This project seeks to clarify concerns on aging cable fleet and to define the benefits of cable system diagnostic testing.
- Distribution Systems Fault Analysis: The goal of this project is to create a decision-support tool to predict the location of low impedance and momentary and permanent faults in distribution power systems. The project is developing a module that is easily pluggable into simulation software.

- Integrated Control of Next-Generation Power Systems: This project's objective is to develop an autonomous smart circuit using multi-agent systems to enable intelligent control of current flows (i.e., energy management system). Expected outcomes are an assessment of the multi-agents strategy and a demonstration pilot.
- Advanced Integration of Distributed Energy Resources (DER): This project has deployed a communications platform and software tools to enable planning and operations of aggregated DER. The project is developing procedures and R&D for marketing aggregated DERs in the energy market. This project also includes demand response management with participation on the Midwest ISO market. The main objective of the project is to develop and demonstrate communication and control solutions to enable participation of a large number of DERs. Presently, 26 DERs can be aggregated at LMP node in the running experiment (with 18MW of DER capacity owned by customers). The project has developed a market model for DER participation with the Midwest ISO. Functionalities developed in this project, such as contingency analysis and reconfiguration for restoration program, are provided in the Distribution Engineering Workstation.
- Load Control Reliability: This project will investigate two areas—real-time load control methodologies, and stability assessment operation and control tools—to evaluate the impact of the distribution system on transmission stability. Real-time control of load to contribute to primary reserve is also included in the scope of this project.
- Distribution Utility Integration Tests Project: The objectives of this project are to assess key issues of high penetration of DER (up to 80%) and their impact on distribution utility service, and to develop test resources to validate potential solutions. A tests facility, hosted by PG&E, has been built to test residential photovoltaic converters and cells, and commercial DR (photovoltaic converters, microturbines). Most compliance tests verify equipment performance for basic islanding, intentional islanding, and harmonic distortion.
- Microgrid Design, Development, and Demonstration (GE): This project will develop fundamental algorithms and architectures for microgrids, and will demonstrate a subset of these technologies. There will be two types of microgrids (envisioned in the range of a few MW): off-line (for remote places), and online. New local controls of DER and supervisory controls will be engineered. Laboratory tests and field tests are planned in the later stage of the project.
- Value and Technology Assessments to Enhance the Business Case for CERTS Microgrids: This project is described in the CERTS section of this report.
- Standards Development and Validation/Testing: The objective of this project is to harmonize national and international standards for interconnection and integration of DER. IEEE (1547) is the main standards body participating in this project.
- Regional Implementation of IEEE 1547: The project objective is to develop a consistent set of nationwide procedures based on IEEE 1547 to develop small-scale DER integration with multi-state collaboration.
- 3G System of the Future: Infotility has been funded by DOE over the past two years to develop a system of adaptive, intelligent software components using the GridAgent framework. Requirements, design, and a platform have been developed. GridAgents will be used to implement new control strategies developed by ConEd in its 3rd Generation flagship project to coordinate the controls in a low-cost solution. The project also will look at

migration strategies and at integrating de facto standards with existing hardware (IEC 61850).

- Two GridApp projects are partially funded by DOE in 2006: Enhanced Distribution System Monitor, and Autonomous Storm Detector. They are described in the GridApp section of this report.
- The Modern Grid Initiative**,** funded by DOE in 2006–2007, is described in the Modern Grid Initiative section of this report.

The following projects were terminated in 2005:

- A project led by Areva launched in 2003 developed a concept of advanced communications and control systems that enable retail energy companies to capture value at end-use and power system levels, to minimize operating risks, and to maximize benefits through coordinated operation of DER. Communication interfaces were developed to integrate Areva products.
- A project led by Connected Design aimed to demonstrate and commercialize an advanced DER communication and control system capable of seamless integration with large-scale DER installations (interoperability).
- A project led by NXGEN installed load management monitoring and control systems at 100 customer premises. Goals were to demonstrate that real-time electricity metering, monitoring, and non-intrusive load management could benefit commercial markets, and to develop a new market model that would quantify customer benefits and system benefits.

Accomplishments to Date

- GridWise: The Benefits of a Transformed Energy System, Report – September 2003
- Estimating the Benefits of the GridWise Initiative, Phase I Report – May 2004
- Avoiding Distribution System Upgrade Costs Using Distributed Generation – PNNL Article, 2004
- GridWise Standards Mapping Overview – March 2004
- GFA chip prototype developed for appliances
- IEEE 1547.1 Standard for Conformance Test Procedures of DER, published in 2005
- Regional implementation: Small generation tariffs agreed for PJM and interconnection agreement of DER planned in 2006, as part of the Mid-Atlantic Distributed Resource Initiative
- Field demonstrations of four DER aggregation designs to reduce peak load (including demand response and dynamic pricing), field demonstration of DER participation in distribution operations (both planning and real-time), including demand response and market participation
- Developed a concept of advanced communications and control systems with real-time pricing and DER optimization for distribution operations; a few interfaces developed
- Designed and developed distributed intelligent agents for DER dispatch

Contribution to the Intelligent Grid

Table 5-1
Reference metrics analysis for GridWise

Categories	GridWise
Applications	
Visioning and Concepts	• *Market mechanism for DER participation (M)* • *GridFriendly Appliance (GFA) concept (D)*
Business Case	• Estimation of benefits of a GridWise electric system with three major features (demand-response, improved quality and reliability, energy efficiency) for generation, transmission, distribution, and customers • Analysis of avoided distribution system upgrades using distributed generation (backup generators and mainly reciprocating engines) on 18 case studies
Functional Requirements	
Guidelines and General Framework	• Regional implementation of IEEE 1547 to facilitate DER integration (G)
Services (Bridge Between Products and Needs)	
System Architecture	• *GridWise Architecture Council Constitution: Key principles for an interoperable system architecture (all domains)*
Transverse Services	• *Public library and database of fault disturbances (D)* • *Distribution utility integration tests facility for DER and system testing (D,G)*
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	• GridWise Standards Mapping Overview (summary of all standards in Generation, T&D, End Use) • IEEE 1547.1 conformance test for DER published; IEEE 1547 participation (G)
Technology Analysis	• *Protection scheme assessment for SCE circuit of the future (D)* • *Cable system diagnostic testing initiative (D)*
Software and Hardware Development	• GFA prototype chip developed for appliance (D) • *Protection scheme development for SCE circuit of future (D)* • *Integrated Distribution Management System interfaces (D)* • *New monitoring technology development for fault location and prediction (including DFA) (D)* • *Distribution system fault analysis to predict low impedance fault(D)* • *Integrated control of next-generation power systems with multi-agents technology (D)* • *Real-time load control and stability assessment operation and control tools development* • Interfaces, communication platform, and software tools to enable planning and operations of aggregated DER; market model for participation of DER on MISO market (G, M) • New controls and supervisory controls for microgrids (D) • GridAgent platform developed to be applied in 3G project on new control solutions (D)
Product Integration	
Demonstration	• Olympic Peninsula distributed resources demonstration: *Demand*-response and backup generators integrated in a virtual market for congestion relief (deployment in progress) (all domains) • *GFA demonstration testbeds (D)*

Legend: M=Market, G=Generation, T=Transmission, S=Substation, D=Distribution, E=End Use. Italics indicate an expected deliverable of a planned project.

6
ADVANCED GRID APPLICATIONS CONSORTIUM

The information contained in this program profile comes from published documents on the Advanced Grid Applications Consortium. The profile has been reviewed by James Crane at Exelon Corporation and Chuck Tremel at Concurrent Technologies Corporation. For more information, please visit www.gridapp.org.

The Advanced Grid Applications Consortium (GridApp™) was created in 2005 by Concurrent Technologies Corporation (*CTC*). *CTC* is an independent, non-profit, applied research and development professional services organization that leads the development of highly innovative and effective solutions for clients. *CTC* delivers tailored solutions without bias for specific technology and is committed to helping government, industry, and non-profit organizations gain and sustain a competitive advantage. *CTC* is being funded by the DOE Office of Electricity Delivery and Energy Reliability for this effort.

Vision

The GridApp vision, as defined by GridApp Consortium members, is to be the premier organization utilized by electric industry stakeholders for the demonstration, validation, integration, and transition of new grid-related technologies into broad industry deployment.

Mission

The GridApp mission is to utilize a core set of electric industry stakeholders to identify and apply best utility technologies and practices to modernize electric transmission and distribution operations. GridApp supports advanced development of high-impact technologies that can have integration and validation completed within 18 months and can be positioned for broad industry application.

Governance, Membership, and Participation

There are currently two levels of membership—charter and sponsor.

There are six charter member seats. Each utility charter member contributes a technology as a core project, along with in-kind support to complete the integration and validation phase. DOE funding through its contract with *CTC* is available for cost share. Current charter members include American Electric Power, Southern California Edison, Exelon, Southern Company, FirstEnergy, and Concurrent Technologies Corporation.

There are eight sponsor member seats. Each sponsor member contributes annual membership fees to support strategic projects. Current sponsor members include PPL Electric Utilities, Idaho Power, Detroit Edison, Portland General Electric, and Salt River Project. Additional sponsor members are being sought.

GridApp™ is governed by a board of directors, consisting of the charter members, and a steering committee, consisting of all consortium members.

Budget

DOE funds GridApp through its contract to *CTC*. To date, GridApp members are performing or have completed projects in excess of $2.2M, which includes utility cost share. For this study, distribution of the GridApp budget was assumed to be shared evenly in the transmission, substation, and distribution domain areas with a single focus on demonstration.

All of the efforts in this program are focused on integration and application projects that have a clear path to commercialization and broad industry deployment. The goal is to have an equal number of transmission- and distribution-related projects; however, the available projects that the steering committee believes to be most relevant are the projects that will go forward.

Promotion

The kick-off meeting of GridApp for charter members was held in February 2005. Outreach meetings for sponsor members were held on May 26, 2005 and November 8, 2005. Ongoing efforts are under way to secure three additional sponsor members with viable grid technology integration projects.

A website has been launched to disseminate information related to the activities of the GridApp Consortium. [16]

Research Projects

GridApp develops fast-track projects for engineering development, demonstration, verification, and validation of selected, high-impact technologies and practices to have technology integration completed in less than 18 months.

GridApp has identified high-impact technologies that are being considered for GridApp support. They can be classified in three domains:

1. T&D Monitoring and Management Technologies
   - Fault analysis and fault location
   - Distribution and transmission automation
   - Substation monitoring and data collection
   - Phasor measurement units for wide-area monitoring and control
   - Vegetation management
   - Dynamic rating of overhead lines
   - Novel load/demand management
   - Monitoring for condition-based maintenance of equipment
   - Novel communication technologies
2. New Devices
   - Advanced conductors (lighter weight, higher temperature, higher strength, low sag, superconducting, etc.)
   - Cost-effective solid state equipment
   - Energy storage
3. System Integration
   - System engineering for enhanced performance
   - System state estimation
   - Reactive power and voltage management
   - Load prediction and modeling
   - Protection and coordination schemes
   - Data integration and management
   - Physical and cyber infrastructure security

GridApp works on the application of technologies that are either not implemented by others or to finish their commercialization into broadly deployed products. Intellectual property rights remain with the member that brings the technology.

An electric infrastructure technology database has been developed to identify technologies and their integrated platforms for monitoring and managing electricity delivery. The database classifies technologies in domains of application and will offer information on their cost, maturity, intellectual property, and points of contact when fully completed. Any technology could be added to the database by any registered user of the database (registration is free of charge).

Projects are operated at three levels:

1. Core projects are contributed by charter members and require approval by the GridApp board of directors.

2. Strategic projects are selected by the steering committee from all proposals submitted by sponsor or charter members.

3. Elective projects can be proposed and funded by GridApp members on an opt-in basis. These projects are fostered but not funded by the GridApp Consortium.

A working group of technical representatives from GridApp member firms participates in each core and strategic project. It is anticipated that projects receiving GridApp™ support will be related to high-impact technology areas identified throughout the consortium development.

One Core Project Completed

Exelon has completed its "Distribution Center (DC) in a Box" project. [14] This project has designed an integrated 10 MVA substation completely enclosed "in a box" (about 7 feet square) with no exposure of energized parts, more aesthetically appealing, and no spill containment required. The cost is two-thirds of a traditional distribution center ($200k savings), and maintenance costs are lower than at a traditional substation.

Three Core Projects Launched

- Southern California Edison (SCE) has launched its Synchronized Phasor Measurement Power Systems project. This project uses the SCE Power System Outlook (PSO) software to monitor stress on the transmission system and provide real-time viewing of system conditions.
- Southern Company has started an Automatic Restoration project. This project will develop S&C IntelliTEAM II modules for interoperability with legacy equipment.
- FirstEnergy has begun an Autonomous Storm Detector project. [15] This project will automatically change relay settings based on weather conditions.

Three Strategic Projects Launched

- Portland General Electric has developed its GenOnSys for data collection, reporting, and control of distributed resources. This project will incorporate the International Electrotechnical Commission (IEC) Component Object Model (COM) into the GenOnSys database structure.
- Idaho Power has initiated a project using its Advanced Capacitor Control System (ACCS) for distribution circuits. The system monitors the VAR loading on substation transformers and sends on/off signals to line capacitors to maintain a VAR schedule on the substation bus.

- Detroit Edison has launched a TripSaver™ Dropout Recloser project. GridApp support will provide advanced engineering and utility input into the development of the S&C distribution reliability device. When released, this product will have a high impact on utility metrics related to temporary outages. When utilized properly the S&C TripSaver technology is expected to dramatically advance distribution reliability.

Two Elective Projects Launched

- *CTC* has launched a GridApp-related project focused on distribution systems fault analysis. The goal of this project is to integrate an intelligent, operational, decision-support software tool to predict the location of low impedance, momentary, and permanent faults in distribution power systems. The aim is to create a stand-alone software tool that can be easily integrated in other network fault analysis software platforms.
- An arc flash detection tool assessment was performed to determine the viability of development of a portable device that can protect personnel working in close proximity to an arc flash occurrence. Although viable, additional research, time, and funding would be needed to move this device to commercialization.

Accomplishments to Date

- “DC in a Box” developed and tested, and technology demonstration held (Exelon)
- Technology database developed and available on GridApp website
- Southern California Edison held training on its Power Systems Outlook software related to its Phasor measurement project
- FirstEnergy developed and deployed numerous autonomous storm detectors in 2006. Technology demonstration is scheduled for November 2006.

Contribution to the Intelligent Grid

Table 6-1
Reference metrics analysis for GridApp

Categories	Advanced Grid Applications Consortium
Applications	
Visioning and Concepts	
Business Case	
Functional Requirements	
Guidelines and General Framework	
Services (Bridge Between Products and Needs)	
System Architecture	
Transverse Services	
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	
Technology Analysis	• Electric infrastructure technology database captures information on relevant technologies (M, G, T, S, D, E)
Software and Hardware Development	• Integrated substation in a box (DC in a Box) with lower cost of procurement and maintenance and low environmental impact (S) • Autonomous storm detector to increase availability during storm conditions (hardware and software developed) (S) • TripSaver™ Dropout Recloser will increase distribution reliability (D) • GenOnSys enhancement will improve data collection, reporting, and control of distributed resources (G, D)
Product Integration	
Demonstration	• Synchronized Phasor Measurement Power Systems project uses Southern California Edison Power System Outlook (PSO) software to monitor stress on the transmission system and provide real-time viewing of system conditions (T, S) • The Automatic Restoration project will develop S&C IntelliTeam II modules for interoperability with legacy equipment (D) • Advanced capacitor control system (ACCS) for distribution circuits will improve power factor correction on the transmission side of substations (D) • Distribution systems fault analysis tool will improve prediction of the location of faults in distribution power systems (D)

Legend: M=Market, G=Generation, T=Transmission, S=Substation, D=Distribution, E=End Use. Italics indicate an expected deliverable of a planned project.

7
POWER SYSTEMS ENGINEERING RESEARCH CENTER

The information contained in this profile comes from published documents on the Power Systems Engineering Research Center (PSERC). The profile has been reviewed by and incorporates revisions from Vijay Vittal, Ph.D., who chairs PSERC. It also includes a concluding comment, expressing the views of PSERC on this study. PSERC provided a map of their program activities, which is included in the report as Appendix C and was used to identify PSERC projects in the program map in Chapter13. For more information, please visit www.pserc.org.

Vision

"The electric power industry is evolving from its historical business structure. Challenges for success in this demanding business environment are being raised by new market structures and ways of doing business, new technologies, the demands of customers for customized services, strategic choices between centralized and decentralized technologies, institutional changes creating mega-RTOs, a graying industry that needs well-trained power engineers, and new environmental priorities. Yet, the basic function of the industry—to produce and to deliver power, safely and reliably—has not changed. The challenges call for new strategies, technologies, analytical capabilities and tools, and operating practices, along with sound public policy guidance." [17]

Mission

The Power Systems Engineering Research Center (PSERC) draws on university capabilities to creatively address these challenges. Under the banner of PSERC, multiple U.S. universities are working collaboratively with industry to

- Engage in forward-thinking about future scenarios for the industry and the challenges that might arise from them.
- Conduct research for innovative solutions to these challenges using multidisciplinary research expertise in a unique multi-campus work environment.

- Facilitate interchange of ideas and collaboration among academia, industry, and government on critical industry issues.
- Educate the next generation of power industry engineers.

The mission statement used by PSERC is: "Universities working with industry to find innovative solutions to challenges facing the electric power industry and to educate the next generation of power industry engineers." [17]

Members

13 U.S. universities (leader is Cornell), and 35 industrial members

ABB AREVA T&D American Electric Power American Transmission Company Arizona Public Service British Columbia Transmission Co. CAISO CenterPoint Energy Duke Energy Entergy EPRI Exelon FirstEnergy Corporation GE Energy Institut de recherche d'Hydro-Quebec (IREQ) ISO New England Korea Electric Power Research Institute MidAmerican Energy Midwest Independent Transmission System Operator (MISO)	National Grid USA National Rural Electric Cooperative Assoc. New York ISO New York Power Authority NxtPhase Pacific Gas and Electric PJM Interconnection PowerWorld Corp. RTE-France Salt River Project Siemens, Energy Management and Information Systems Southern Company Steel Tube Institute of North America TXU Electric Delivery Tennessee Valley Authority Tri-State Generation and Transmission U.S. Department of Energy Western Area Power Administration

Budget

$3.7M for 2002–2004, $1.68M budget in 2005, and close to $2M in 2006.

Figure 7-1 shows the distribution of the research budget (spent to date) among the sectors of application and systems engineering categories.

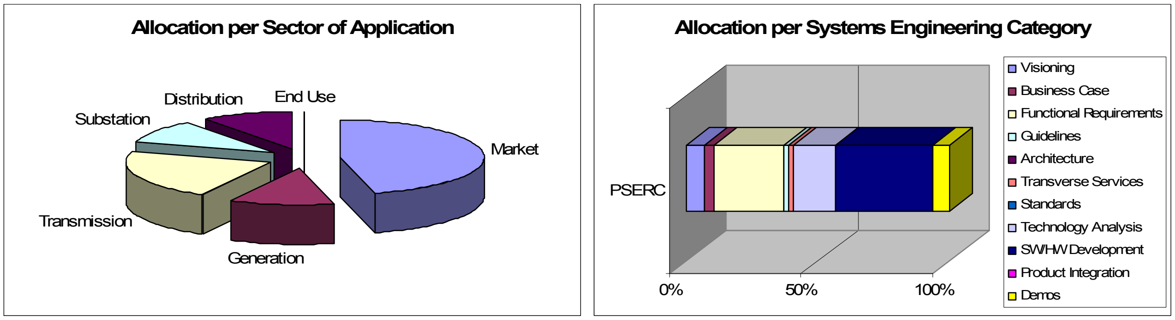


Figure 7-1
Distribution of the PSERC R&D budget (spent to date)

Promotion

- Website updated frequently with program results
- Presentations made at scientific conferences
- Presentations made at Industrial Advisory Board meeting
- Poster session at Industrial Advisory Board meeting
- Web conferences and seminars organized on research categories
- Short courses offered on completed research topics

Research Projects

The research program is divided into three areas: [18]

Market Stem

The primary research goal in this thrust area is to focus on short- to medium-term issues concerning the interaction between the technical and economic aspects of the restructured industry, given the current technological landscape. In particular, this stem focuses on a new market-based paradigm that will replace the traditional functional timeline leading from years to cycles prior to real time, which includes long-term demand forecasting, capacity planning and expansion, maintenance, short-term forecasting, scheduling, dispatch, and real-time control. It has six ongoing projects, as of December 2005.

Research under this stem emphasizes the design and analysis of market institutions, mechanisms, and computational tools that will facilitate coordination, efficient investment, operational efficiency, and system reliability while recognizing the economic and technical realities of the electric power industry. The scope of work under this stem can be broken down by subject area and by methodological approach recognizing the fact that some approaches may be better suited for certain problem areas.

These general goals are pursued by means of the following methodological approaches that complement and support each other:

- Analytical methods that can be further classified into
  - Theoretical analysis focusing on conceptual abstract modeling and analysis, employing techniques of operations research, systems analysis, microeconomics, stochastic modeling, game theory, and auction theory.
  - Empirical analysis focusing on interpretation of empirical data and on estimation and validation of theoretical models using econometric methods, financial engineering approaches, statistical analysis, and data mining.
- Computational methods employing numerical methods and agent-based models to simulate and forecast market outcomes under realistic modeling of the electric power system in conjunction with behavioral models of economic agents that control various aspects of the system and interact in the marketplace.
- Experimental economic approaches employing controlled laboratory experiments with live and artificial agents in order to explore decision patterns under alternative rules and system conditions, and to test behavioral assumptions upon which such rules are founded.

Systems Stem

Systems research focuses on all aspects of operations of complex dynamical systems with emphasis on power systems. The basic premise is that restructuring of the electric power industry leads to larger and more complex operational entities (ISO, RTO) than previous structures. At the same time, alternate energy sources (solar, fuel cells, wind, etc.) are expected to increase their penetration in electric energy systems. Power electronic devices (FACTS) are also expected to have an increased presence in electric energy systems and improve the controllability and complexity of the system. Environmental issues and constraints are expected to play a bigger role in power systems operations and planning. The complexity of “systems” problems increases nonlinearly with system size, new technology options, and environmental constraints. At the same time, advances in information technology, communications, and mathematics demand that systems problems be re-examined and formulate new approaches. Restructuring is leading to large and complex operational entities (such as Independent System Operators or Regional Transmission Organizations), while small-scale, dispersed generation technologies are increasing their penetration in power systems. The challenge is to develop new operations frameworks and approaches that will effectively cope with the growing complexity of a restructured industry. Systems research concentrates on all aspects of operation of complex, dynamical systems. There are five ongoing projects in this stem as of December 2005.

The Systems Stem supports development of new frameworks and approaches that will effectively cope with the complexity and mega-scale issues of the restructured industry. The general categories are

- Development of new framework and methodologies for operations planning, optimization, and system reliability/security and risk management of the restructured electric industry.

- Development of new frameworks for communications and control, data management, system monitoring, self healing, and self restoration of mega-scale systems.
- Addressing issues of computational complexity arising in operation and control of complex mega-scale systems.
- Development of fundamental mathematical framework to address operation, control, and protection of distributed energy resource systems in an autonomous or non-autonomous operation (grid-connected).

T&D Stem

The electric utility industry is experiencing major changes from its historical business structure of a vertically integrated utility to a combination of several different models. However, the basic function of the industry—to produce and to deliver power, safely, and reliably—has not changed. The T&D Stem, with nine ongoing projects as of December 2005, has been organized to address issues in the following research areas:

- Data Integration and Enhanced Functions: A key element in the electric power infrastructure is the T&D substation. To ensure reliability and to gain additional value, the assets must be managed in new ways using available data as well as expanded data sets. Opportunities exist to capture and better utilize presently available data from relays, DFRs, and other IEDs to better monitor assets, locate faults, and perform new functions. Additional opportunities exist to improve sensors, increase communications, capture new information, and present information in new ways to enhance the performance.
- Managing an Aging Infrastructure: The T&D infrastructure is aging and being stressed as loads have increased. New methods need to be developed to better assess the condition of assets, especially methods that can be used without taking the asset out of service. Additional study is needed that is aimed at understanding the impact of increased loading and aging of assets such as transformers, breakers, conductors, underground cable, etc.
- Distribution and Transmission Automation: Technology improvements and increasing need to better manage assets have facilitated the implementation of substation automation. The use of automation increases the availability of information and the ability to improve control over the system. However, more work is required to better manage the information and develop methods and algorithms to automate systems to improve system performance and reliability.
- New Devices and Related Control Concepts: Opportunities exist to study the increasing amounts of available data and identify new phenomena that can lead to the development of new devices and operating practices. Universities have played a major role in the development of foundation theories that have led the industry to new devices and systems in the past. Additionally, universities are positioned to view broad issues impacting the power delivery industry.
- New Paradigms: Existing monitoring, control, and protection systems are driven by established practices that have been proven in the utility market. However, opportunities to evaluate new control or protection systems exist that leverage the availability of more information and new devices. Universities are positioned to have a broad and unbiased view, and may identify new control and protection paradigms.

Accomplishments to Date

The three stems have numerous projects in the various domains presented below. Reports for completed projects are available at www.pserc.org.

Market Stem	
M-1	Costing and Pricing of Ancillary Services
M-2	Market Mechanisms
M-3	Market Interactions and Market Power
M-4	Market Redesign: Incorporating the Lessons Learned for Enhancing Market Design
M-5	Software Agents for Market Design and Analysis
M-6	Modeling Signals for Transmission Adequacy
M-7	Structuring Markets for Demand Responsiveness
M-8	Reliability Assessment for Interconnected Grids
M-9	Market Structures to Reduce Seams and Enhance Investment
M-10	Uncertain Power Flows and Transmission Planning
M-11	Market Structure and Compensation Schemes
M-12	Reliability, Electric Power, and Public Vs. Private Goods
M-13	Agent Modeling for Integrated Power System

Systems Stem	
S-1	Visualization of Power System and Components
S-2	Integrated Security Analysis
S-3	Visualization of Power Systems
S-4	Voltage Collapse Margin Monitor
S-5	Coordination of Line Transfer Capability
S-6	Identification and Tracking of Parameters for a Large Synchronous Generator
S-7	Avoiding and Suppressing Oscillations
S-8	Impact of Protection Systems on Reliability
S-9	Automated Operating Procedures for Transfer Limits
S-10	State Estimation and Optimal Measurement
S-11	Steady State Voltage Security Margin Assessment
S-12	Robust Control of Large Power Systems
S-13	Comprehensive Power System Reliability
S-14	Risk-Based Transmission Maintenance
S-15	State Estimation for Synch. Generator Parameters
S-16	Security Enhancement through Direct Non-Disruptive Load Control
S-17	Techniques for the Evaluation of Parametric Variation in Time-Step Simulations
S-18	Visualization of Power System and Components
S-19	Detection, Prevention and Mitigation of Cascading Events
S-20	New Implications of Power System Fault Current Limits
S-21	On-Line Transient Stability Assessment
S-22	Enhanced State Estimators
S-23	Optimal Placement of Phasor Measurement Units for State Estimation
S-24	Allocation of Static and Dynamic VAR Resources
S-25	Effective Power System Control Center Visualization
S-26	Risk of Cascading Outages
S-27	On Line Stability Determination and Control

T&D Stem	
T-1	Corona Discharge Deterioration of ADSS Cable
T-2	Differential GPS Measurement of Overhead Conductor Sag
T-3	On-Line Peak Loading of Substation Distribution Transformers Through Accurate Temperature Prediction
T-4	Electrical Transmission Line Insulator Flashover Predictor
T-5	Intelligent Substation
T-6	Condition Monitoring for In-Service Nonceramic Insulators and Underground Cables
T-7	Redesign and New Interpretation of Power Acceptability Curves for Three Phase Loads
T-8	Investigation of Fuel Cell Operation and Interaction within the Surrounding Network
T-9	State Estimation via Substation Monitoring
T-10	Accurate Fault Location in T&D Networks
T-11	Monitoring Using Wireless Communications
T-12	Distribution System Electromagnetic Modeling and Design for Enhanced Power Quality
T-13	Grounding and Safety with OPGW
T-14	NCI Evaluation: Seals and Interfaces
T-15	GPS Measurement of Overhead Conductor Sag
T-16	Voltage Dip Effect on Loads in Electric Power System
T-17	Enhanced Reliability of Power System Operation Using Advanced Algorithms and IEDs
T-18	Microgrids Protection and Control
T-19	Automated Integration of Condition Monitoring with an Optimized Maintenance Scheduler for Circuit Breakers and Power Transformers
T-20	Smart Sensor Development for T&D
T-21	Distributed Electric Energy Storage and Generation
T-22	Advanced Digital Measurement and Protection Systems
T-23	Prioritizing Maintenance of Underground Cables
T-24	Distribution System Reliability Enhancement
T-25	Liquid Filled Power Transformers
T-26	Tool for Insulator Condition Assessment
T-27	Reliability Based Vegetation Management
T-28	Satellite Imagery for the Identification of Interference
T-29	Digital Protection System
T-30	Transient Testing of Protective Relays

Contribution to the Intelligent Grid

Table 7-1
Reference metrics analysis for PSERC

Categories	Power Systems Engineering Research Center
Applications	
Visioning and Concepts	• Study of new market mechanisms (M2, M3, M4, M7, M9, M11, M12) • Concepts investigated in market-power systems interactions and for new control devices • Detection, Prevention, and Mitigation of Risks of Cascading Events (M-12, S-19, S-26)
Business Case	• Cost-benefits analysis of ancillary services (M1) • Cost-benefits analysis of reliability (S-13) • Study of power flow revenue for transmission expansion planning • Economic Impact assessments of transmission enhancement

Table 7-1 (continued)
Reference metrics analysis for PSERC

Categories	Power Systems Engineering Research Center
Applications	
Functional Requirements	• Tests of numerous new functions (participation of load in security enhancements for instance in S16) by either a power system study or a study of effectiveness of the algorithm of the control (often simulation studies) (S2, S3, S5, S6) • Assessment of properties of the grid (reliability), new processes (risk-based maintenance), new interaction with operators (visualization), placements of PMUs, modeling of operational and market considerations (S11, S12, S13, S14, S19, S23, T7, T8, T9, T16, M8, S20, S24) Power Quality Issues (T7, T16) • Power Quality Issues (T7, T16) • Transmission planning process requirements with multiple market trading process (M6, M10)
Guidelines and General Framework	• Massively deployed sensor project (assess information, technologies and identify algorithms T-20) • Investigation of fuel cells operations (T-8)
Services (Bridge Between Products and Needs)	
System Architecture	• Optimal location of PMUs (S23, T18) • Data integration and information exchange of IED in EMS study (T-32)
Transverse Services	• Tools to evaluate transmission facilities and load participation in restructured market (M6) • Study of different techniques of simulation (parametric variation in time-step simulation, dynamic security assessment) (S17) • Risk-based maintenance resource allocation for distribution system reliability enhancement (T24)
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	
Technology Analysis	• Assessment of technologies (DER, storage), tools (TSA, VSA, visualization, sensors), communication technologies (S21, T1, T11, T22, T25)
Software and Hardware Development	• Visualization tool (sag conductor, stability), state estimation, various algorithms for protection, control, market (S2, S4, S7, S8, S9, S10, S11, S15, S18, T2, T3, T6, T10, T15, T19, T20, S20, S22, S25, S26, S27, T26, T27, T28, T29) • Tools for market (bidding agents) (M5) • Decision-making tool and guide for prioritizing cable maintenance (T28) • Sensors and automation prototype development (T-20, T-29)
Product Integration	• Study of the integration of tools for static, dynamic, voltage security analysis (S7)
Demonstration	• Demonstration of prototype to mitigate cascading events (S27, S19)

Legend: Red indicates the reference numbers of active projects on December 31, 2006.

Note: Although PSERC has reviewed this chapter including this table, PSERC has expressed the concern that a common requirement (a common table and map) to characterize research efforts might not represent fully its uniqueness, especially the human resources value this association brings.

PSERC Comment

PSERC is unique in that the products it delivers include “trained engineers.” This is an important distinction from other research institutions you are going to represent in the document and sets us apart.

Vijay Vittal, Ph.D., Chair of PSERC

8
CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

The information contained in this program profile comes from published documents on the Consortium for Electric Reliability Technology Solutions. The profile has been reviewed by Joe Eto at Lawrence Berkeley National Laboratory and includes additional comments from him in conclusion. For more information, please visit www.certs.lbl.gov.

Vision

The vision of the Consortium for Electric Reliability Technology Solutions (CERTS) is to

- "Transform the electricity grid into an intelligent network that can sense and respond automatically to changing flows of power and emerging problems.
- Enhance reliability management through market mechanisms, including transparency of real-time information on the status of the grid.
- Empower customers to manage their energy use and reliability needs in response to real-time market price signals.
- Seamlessly integrate distributed technologies—including those for generation, storage, controls, and communications—to support the reliability needs of both the grid and individual customers." [19]

Mission

CERTS was formed in 1999 to research, develop, and disseminate new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system and functioning of a competitive electricity market. [19]

Governance

The Office of Electric Transmission and Distribution (OETD) at the U.S. Department of Energy Department of Energy and the Public Interest Energy Research Program (PIER) fund the program.

Figure 8-1 shows the composition of the CERTS Steering Committee and Industry Advisory Board.

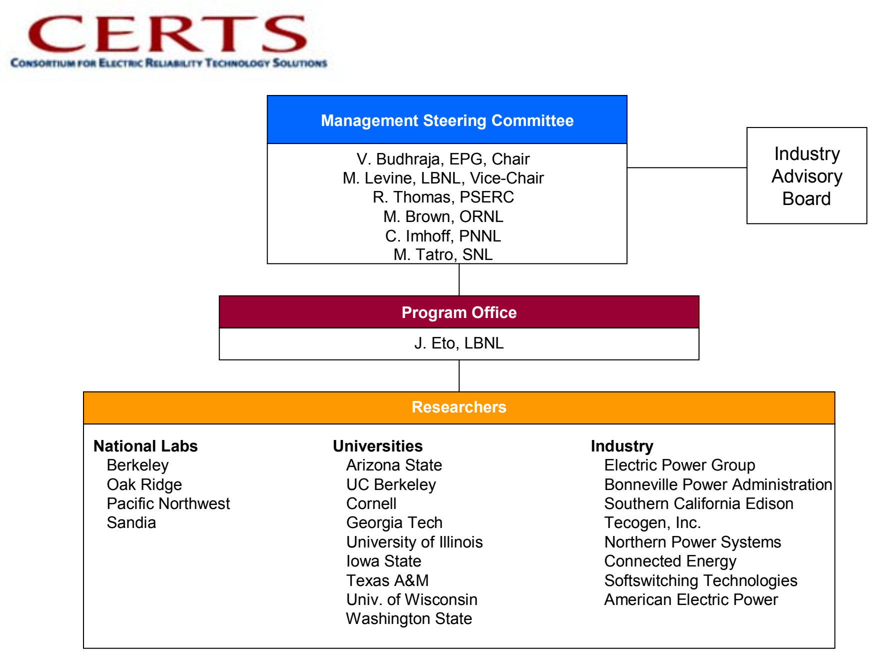


Figure 8-1
Governance of CERTS

In addition, CERTS is working collaboratively with a number of associations, such as: North American Electricity Reliability Council, California Independent System Operator, ISO-New England, New York ISO, PJM Interconnection, American Electric Power, Ameren, Entergy, First Energy, HydroOne, Midwest ISO, New York Power Authority, Southern Company, Southwest Power Pool, Tennessee Valley Authority, and the Federal Energy Regulatory Commission.

Budget

1999–2004 budget for the Real-Time Grid Reliability Management program: $12.6M

DOE funding for the domain area of Reliability is approximately $5M per year. CERTS is funded from that domain.

Figure 8-2 shows the distribution of the research budget (spent to date) among the sectors of application and systems engineering categories.

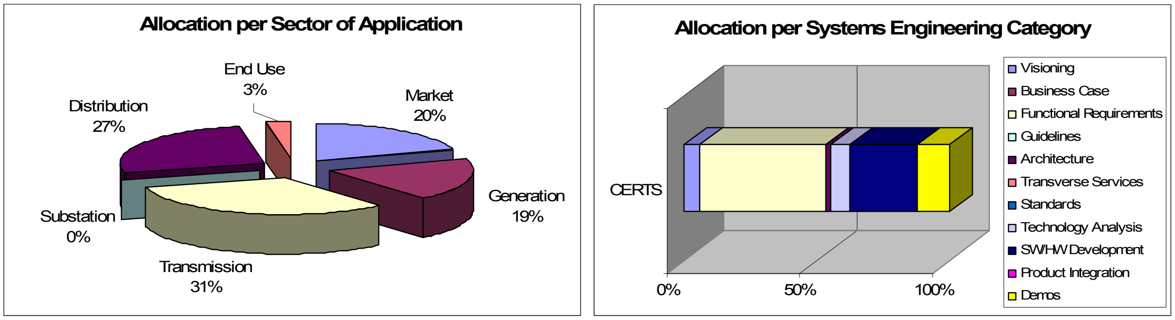


Figure 8-2
Distribution of CERTS R&D budget (spent to date)

Promotion

- Seminars and workshops
- Website
- Scientific articles

Research Projects

The CERTS research portfolio is organized into five programs:

Real-Time Grid Reliability Management

This program is developing tools and technologies that help monitor and operate the power system reliably in a competitive electricity market, and it is laying the groundwork for the transition to a smart, switchable network that can anticipate and respond automatically to emerging problems. Current work focuses on better use of existing assets, as opposed to development of new transmission design or equipment. Efforts include prototyping and demonstrating real-time reliability management tools, developing system security management tools, and conducting applied research on advanced measurement technologies and controls. Analysis and visualization tools are being developed to make use of existing data. These tools are being designed for the Phasor Measurement Project of the western region (Western Electricity Coordinating Council–WESCC) but could also be applicable to the eastern region. This program also includes the development of improved state estimator and situation awareness tools.

CERTS supports and funds the Eastern Interconnection Phasor Project (EIPP), covering all administrative costs for the start-up years of the project. EIPP provides a forum for utilities and research organizations to share information and best practices, and to develop collaboration projects on the observability of the eastern transmission grid using phasor measurements. EIPP does not fund research projects per se, but results from projects such as disturbance analysis and technology analysis are shared under the EIPP umbrella.

Reliability and Markets

This program is performing science-based analysis and demonstrations of options for increasing the effectiveness of market-based approaches for managing reliability. Current work focuses on evaluating market designs for reliability management using theoretical and experimental economics approaches, assessing the market's impact on the reliability of grid operations, and developing monitoring tools to detect market problems as they emerge. The program develops design tools to increase market competitiveness.

Distributed Energy Resources Integration

This program is developing tools and techniques to maintain and enhance the reliability of electricity service through a cost-effective, decentralized electricity system based on high penetrations of distributed energy resources (DER) (small, autonomous energy-generation, storage, and load control resources typically located at customer premises). Current work focuses on developing tools and data and conducting field tests of advanced system integration, protection, and a control concept called CERTS Microgrids. The Microgrids project has identified three main feasibility areas: power and voltage controller for DER, energy management system, and new protection schemes. Requirements, design, and tools have been developed, as have two main components—a power electronics converter for DER, and a static switch to provide connection and protection function between microgrids and the electric delivery grid. A first demonstration is currently ongoing at AEP.

Load as a Resource

This program is performing analysis and demonstrations to enable meaningful participation of load in competitive electricity markets, including experimental economic analysis of the effect of price-responsive load in reducing market prices and price volatility, assessments of emerging demand response programs and technologies for enabling customer participation in electricity markets, and demonstrations of the use of load to provide ancillary services, notably spinning reserve. The New York ISO offers a specific case study for which special case studies are made. The main demonstrations in this area are: use of spinning reserve of water resources (15MW pumps in California), and aggregation of small loads with interruptible load (air conditioning management, SCE).

Reliability Technology Issues and Needs Assessment

This program is monitoring and identifying technology trends and emerging gaps in electricity system reliability R&D to anticipate what efforts are in the public interest to enable the grid of the future.

The CERTS multi-year plan follows the strategy set in place in 1999 by "Grid of the Future" white papers, which were extensively discussed with stakeholders (http://certs.lbl.gov/Reliability_K1.html). The multi-year plan of the DOE Transmission Reliability program also provides guidance to steer the portfolio.

Accomplishments to Date

- Real-Time Grid Reliability Management (http://certs.lbl.gov/CERTS_P_RealTime.html)
- Reliability and Market (http://certs.lbl.gov/CERTS_P_RandM.html)
- Distributed Energy Resources Integration (http://certs.lbl.gov/CERTS_A_DER.html)
- Load as a Resource (http://certs.lbl.gov/CERTS_P_Load.html)
- Reliability Technology Issues and Needs Assessment (http://certs.lbl.gov/CERTS_A_Reliability.html)

Contribution to the Intelligent Grid

Table 8-1
Reference metrics analysis for CERTS

Categories	Consortium for Electric Reliability Technology Solutions
Applications	
Visioning and Concepts	• Low-voltage Microgrids concept with automatic reconfiguration and adaptable features (applicable for a few MVA) • Investigation of new market mechanism (locational pricing, metrics)
Business Case	• Development of economic model of customer DER adoption (CHP) (E) • *Cost-benefits analysis for Microgrids (D-E)*
Functional Requirements	• Study of microgrid electric infrastructure and control: power and voltage controller, EMS, protection • Study market mechanism efficiency for Load as a Resource (real-time pricing, NY ISO local case) • Survey of CA ISO need for demand response • Technical requirement of supplying spinning reserve from pumping system load (G) • Analysis of market mechanism (ancillary services, congestion settlement) • Proposal of new market mechanisms • Deep electrotechnical analysis of the Eastern Interconnection region with phasor data • *Numerous studies of security assessment (study of mitigation solutions)*
Guidelines and General Framework	• Framework to assess the cost of power interruptions and reliability • Design tool to increase market competitiveness
Services (Bridge Between Products and Needs)	
System Architecture	• Data requirements in specific functional areas (third-party load frequency control, PMU, etc.)
Transverse Services	

Table 8-1 (continued)
Reference metrics analysis for CERTS

Categories	Consortium for Electric Reliability Technology Solutions
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	
Technology Analysis	• *PMU exhaustive technology analysis in Eastern Interconnection Phasor Project (transmission)* • *I-Grid technology assessed (PQ monitoring)*
Software and Hardware Development[1]	• Development of reliability adequacy tools (3D visualization tool for Volt Var management, tool for ancillary services) • *Development of security assessment (reliability adequacy tool, congestion assessment), Var-voltage management tools, visualization tools, development of enhanced state estimators (visualization tool available and situational awareness tool under study in the Eastern Interconnection Phasor Project.* • Development of simulation platform to test economically and technically Microgrids implementation • Development of Microgrids prototype (two main components: a power electronics converter for DER, and a static switch to provide connection and protection of functions) • *Prototypes of new real-time controls planned before 2010* • Development of computational method for market study (locational price, ancillary services)
Product Integration	
Demonstration	• *Demonstration of Microgrids with AEP (power electronics converter, static switch between Microgrids and grid)* • Demonstration of several types of load resources demand-side management (aggregation of small residential load, AC management) and use of spinning reserve using water resources • Experimental economics approaches (controlled laboratory experiments and artificial agents modeling)

Legend: M=Market, G=Generation, T=Transmission, S=Substation, D=Distribution, E=End Use. Italics indicate an expected deliverable of a planned project.

[1] CERTS defines its development of software and hardware components as "pre-commercial" development. These projects are mainly requirements of components and mock-ups so that vendors will take up the task and develop commercial products.

Comments from CERTS

Following review of the CERTS profile, Program Manager Joe Eto noted that some questions and answers did not fit into the profile template and needed to be addressed to complement the information captured in this study.

1. *What is the CERTS vision of the relationship between market and regulation research work and new applications or opportunities created by new technologies?*

CERTS is working to develop and create new market concepts and functionalities as well as “load as a resource.” One relationship resides in the market simulation tool that CERTS is developing; another is covered through demand response demonstration projects.

2. *What new, commonly shared resources will be available in the next 10 years to enable new opportunities for electric delivery?*

Demand response and microgrid technologies will certainly be key. They will provide resources and infrastructure that will be available for electric delivery.

3. *What is the CERTS approach to bridging the gap between new applications and the availability of new commercial technologies?*

The CERTS approach is to work not only with vendors but with key players of industry that are RTO, ISO to identify problems, develop functional specifications, develop prototypes, and make the equipment developed by vendors. CERTS is working to show some proofs of concept and to develop pre-commercial equipment.

On the topic of prototypes, CERTS is developing only pre-commercial technologies (and testing them in demonstrations) so that vendors will take on the responsibility of developing the commercial products. CERTS projects, at the end of their lifecycle, include validated functional requirements for this purpose.

In terms of the broad view that CERTS takes in its research work, the approach is to anticipate and address barriers to new electric delivery. Moreover, CERTS is developing an asset management perspective in its research program.

9
CALIFORNIA ENERGY COMMISSION – PUBLIC INTEREST ENERGY RESEARCH PROGRAM

The information contained in this program profile comes from published documents on the California Energy Commission – Public Interest Energy Research (CEC–PIER) program. The profile has been reviewed by Linda Kelly and Laurie ten Hope at CEC–PIER. For more information, please visit www.energy.ca.gov/pier.

The California Energy Commission (CEC) established the Public Interest Energy Research (PIER) program in 1996. The program covers a wide area, from generation to end use.

Vision

The CEC–PIER vision statement is: "Sustainable energy choices for utilities, State and local government, and large and small consumers in California." [21]

Mission

The PIER program provides advanced energy innovations in hardware, software systems, exploratory concepts, supporting knowledge, and balanced portfolio of near-, mid-, and long-term energy options for a sustainable energy future in California. [21]

Governance

The CEC formed two groups to provide advice, expertise, evaluation, and accountability to the PIER program: the Policy Advisory Council, and the Independent Review Panel.

The Policy Advisory Council provides advice on program issues and future plans. It is comprised of members representing other government agencies, universities, industry organizations, and the broad public interest.

The Independent Review Panel conducts a comprehensive independent evaluation, including a review of the public value of the PIER program and the benefits of providing funds for technology development that otherwise would not be funded. Membership selection was a collaborative effort between PIER management, the CEC, and the California Council on Science and Technology. Members are named in the California PIER Independent Review Panel Final Report (June 2005). They include the vice president of Sandia's California Division, the former president and CEO of EPRI, and representatives from Lawrence Livermore National Laboratory, University of California, NASA, and California Institute of Technology.

Budget

The PIER program fund is supported through a surcharge on retail electricity sales. Revenues are collected annually from investor-owned utility ratepayers.

The budget for the program is $62.5M per year for 1998–2012. The program counts between 300 and 400 active projects. In 2005, it expanded its focus to include natural gas research (currently with a budget of $12M, and expected to grow to $29M in 2009).

Expenditures of the PIER program from 1997 to 2005 were $387M. The Energy System Integration (ESI) area, whose objectives are closest to smart grid research, represents an effort of $77M to date, with 122 active and completed projects. The charts in Figure 9-1 illustrate these budgets.

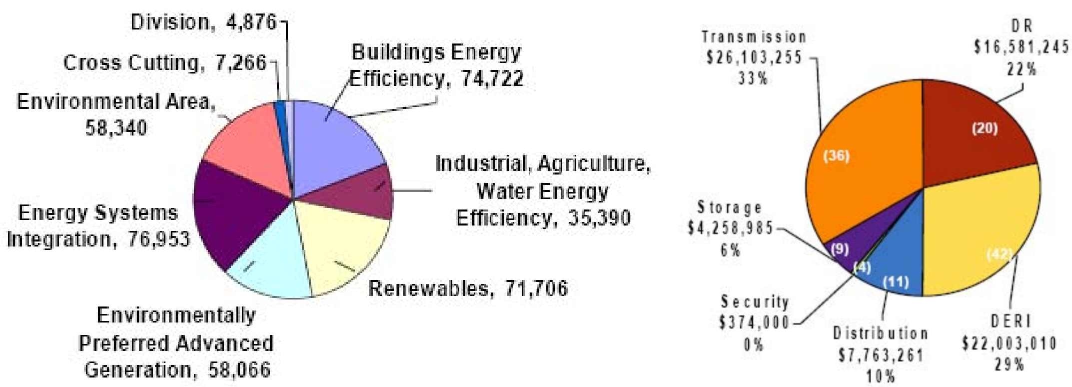


Figure 9-1
Expenditures of CEC–PIER program, 1997–2005 (left), and Energy Systems Integration program, to date (right)

Figure 9-2 shows the budget allocation among active projects in the ESI program for the categories selected for this study.

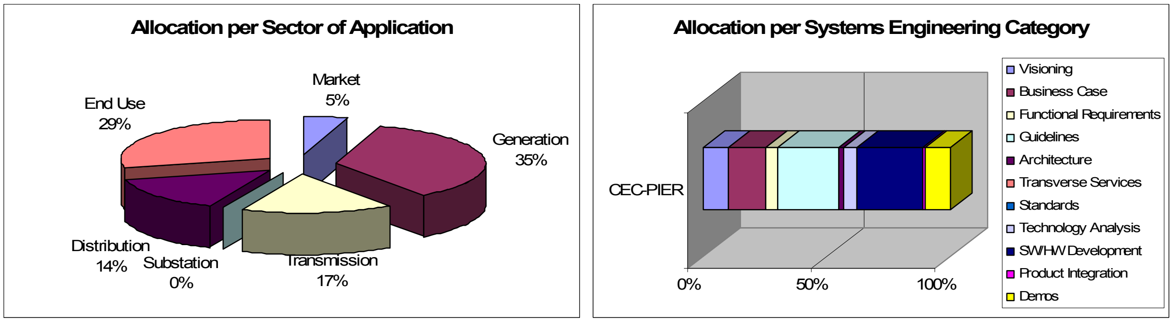


Figure 9-2
Distribution of CEC –PIER R&D budget for ESI program (spent to date)

Promotion

- Website established, with frequent updates
- Numerous seminars, conferences, and workshops

Research Program

The PIER program has identified five key energy issues: [21]

1. Affordable, comfortable, and energy-smart choices for daily life and a strong California economy.
2. Clean and diverse electricity supply that optimizes California's resources.
3. Clean and diverse transportation system in California.
4. Integrated electricity system that is reliable and secure.
5. Environmentally sound electricity system in California.

For each of these energy issues, the program has defined strategic objectives as well as primary, secondary, and tertiary solutions. Strategic objectives for the integrated electricity system issue (Item #4), which is the closest domain to this study, are

- Enable optimal integration of renewables, distributed generation (DG), demand response, and storage to the power system.
- Improve capacity, utilization, and performance of the transmission and distribution (T&D) system.
- Improve cost and functionality of components to integrate demand response, DG, and electricity storage into the system.
- Improve security and reliability of the electricity system.

- Support improvement of tariffs and regulations for demand response, DG, storage, and renewables.
- Facilitate transmission siting process.
- Develop knowledge base for future decision-making and informed delivery, integration, and infrastructure policy relative to electricity.

Primary solutions for an integrated electricity system are

- Increase the intelligence and responsiveness of the T&D system to more effectively enable optimal integration and use of renewables, demand response, DG, and storage.
- Support integration of intermittent and remotely located renewables into the system.
- Improve cost and functionality of demand response, storage, and DG integration components.
- Conduct analysis of appropriate market mechanisms for renewables, demand response, DG, CCHP, storage, transmission, distribution, and security (rates and tariffs, markets and utility planning, incentives, regulation, financial).
- Provide new technologies and tools to expand capability of existing T&D (real-time ratings and operations, better asset utilization).
- Develop an electric system (cyber and physical) that is resilient to natural and man-made events and is self-diagnosing and self-healing.

Structure of the Program

The program is divided in six program areas plus an innovation small grant program. The most relevant program to the transformation of electric delivery is the ESI program. Following is an overview of all seven programs.

1. <u>Buildings End-Use Energy Efficiency Program</u>: Focuses on lowering building energy use in both new and existing buildings in residential and commercial applications. The research supported by this program specifically targets the development or improvement of energy-efficient technologies, strategies, tools, and building performance evaluation methods. The technology area includes appliances, building systems, EMCS, envelope, HVAC, lighting, office equipment, refrigeration, and water heating. A total of 217 projects have been contracted.

2. <u>Industrial/Agricultural/Water End-Use Energy Efficiency Program</u>: Seeks to improve the energy efficiency of industrial processes, agricultural operations, and water and wastewater treatment plants. A total of 84 projects have been contracted.

3. <u>Energy-Related Environmental Research Program</u>: Conducts core research in air quality, aquatic resources, land use and habitat, and global climate change. A total of 68 projects have been contracted.

4. Environmentally Preferred Advanced Generation Program: Has the objective of facilitating widespread use of non-renewable DG and improving California's air quality. A total of 45 projects have been contracted (including 19 in the Energy Innovations Small Grant program).

5. Renewable Energy Technologies Program: Focuses on short-term and long-term research on renewable energy sources to alleviate congestion and to offer customers more affordable, improved reliability with a selection of choices. A total of 69 projects have been contracted.

6. Energy Innovations Small Grant Program: Provides up to $95,000 for hardware projects and $50,000 for modeling projects to small businesses, non-profits, individuals, and academic institutions to conduct research that establishes the feasibility of new, innovative energy concepts. Research projects must target one of the six PIER program areas. Makes up to four solicitations per year. A total of 174 projects have been contracted.

7. Energy Systems Integration Program: Conducts cross-cutting research critical to the improvement of the electricity infrastructure. The primary goal is to develop research opportunities that facilitate integration and development of innovative technologies to provide California with a more effective, efficient, and reliable electricity infrastructure. ESI research projects are structured in six areas:

   – Distributed Energy Resources (DER) Systems Integration area focuses on issues related to using relatively small-scale DER as part of the larger interconnected electricity grid. Issues addressed include interconnection standards and technology, grid impacts, and market integration. This area complements the PIER Renewable program and Environmentally Preferred Advanced Generation program. Both have R&D efforts on small--scale generation technologies. The largest project of this area is the Distributed Utility Integration Test (DUIT) Center, co-funded by private and public entities to facilitate DER testing. Fifty-four projects have been completed, and seven are active.

   – Demand Response to Electricity Prices and System Contingencies area is a coordinated initiative of the Buildings program and ESI program. This area conducts R&D on technologies and policies that facilitate demand response. It works on mapping activities and partnerships, and it has specific research projects, such as reference designs for equipment, and security and privacy issues for the DER communications network. Two projects have been completed, and two are active.

   – Transmission area focuses on system software tools and technologies that will enable the grid to be operated with a more precise view of its actual transfer capabilities, and will improve understanding of regulatory structure. Partnerships have been developed, in particular with the California ISO and with DOE in the CERTS program. Twenty projects have been completed, and four are active.

   – Strategic and Enabling Technologies area supports innovative and often long-range R&D. Enabling technologies have multiple applications and thus provide benefits in disparate areas, such as power electronics. Current topics in this area are energy storage and tools for market analysis and operation. Thirteen projects have been completed, and three are active.

   – Security Research area is currently under development. Four projects in previous areas are listed as completed on the CEC–PIER website.

Distribution area is also under development. Figure 9-3 shows a draft roadmap with strategic objectives and potential R&D activities. Ongoing work in the ESI program is currently focused on DER integration, valuation of distribution automation or pilots of DER and demand response. New project(s) on underground cable diagnostics and replacement issues will be launched in the near future.

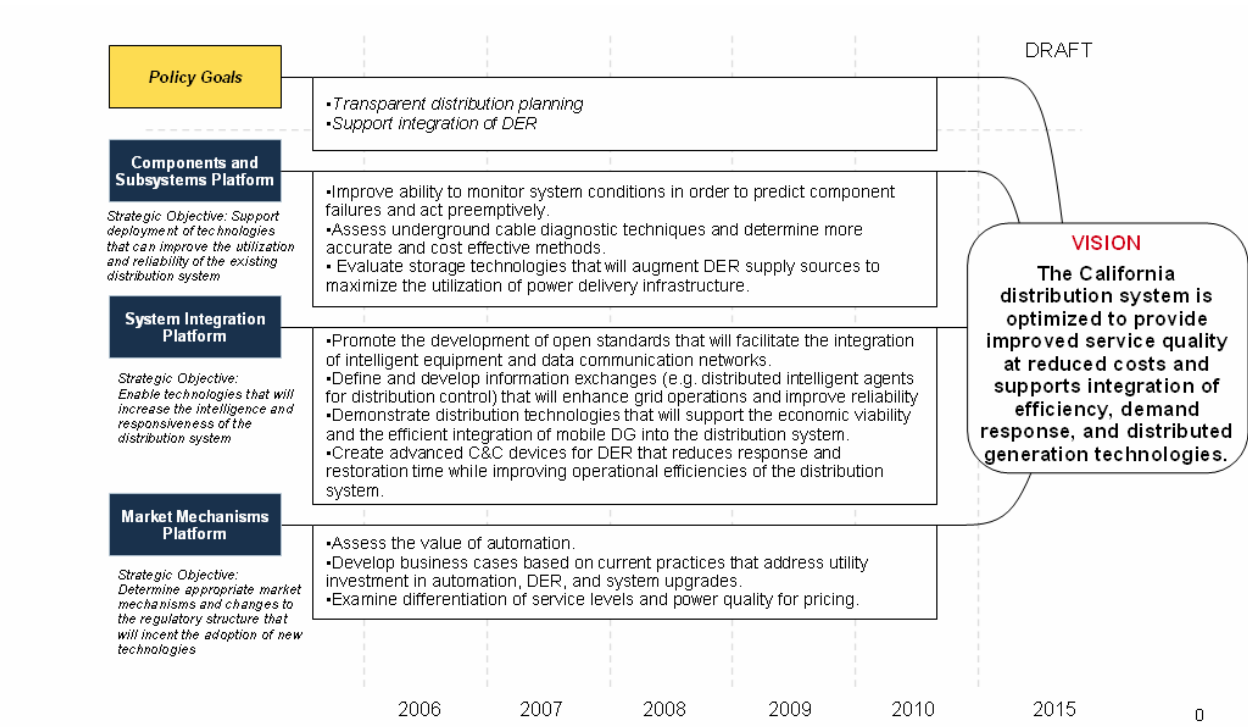


Figure 9-3
Draft roadmap of the Distribution area of CEC–PIER program

In addition to these research projects, many different initiatives are being led by the CEC to eliminate congestion and address the issue of peak demand through wise use of consumer load as a resource. This has been implemented through different concepts and visions promoted by the CEC. For one, a wide consultation and outreach of stakeholders has been accomplished to define an automatic metering infrastructure (AMI) for California. A new programmable communicating thermostat (PCT) concept is also in discussion to be embedded in the building code ruling, which is a mandatory regulatory rule for new buildings.

Accomplishments to Date

- Buildings End-Use Energy Efficiency Program

  Final Reports http://www.energy.ca.gov/pier/buildings/reports.html
  Tools http://www.energy.ca.gov/pier/buildings/tools.html
  Guides and Specs http://www.energy.ca.gov/pier/buildings/guides_and_specs.html

- Industrial/Agricultural/Water End-Use Energy Efficiency Program

  Final Reports http://www.energy.ca.gov/pier/iaw/reports/index.html
  Presentations/Papers http://www.energy.ca.gov/pier/iaw/presentations/index.html

- Energy-Related Environmental Research Program

  Final Reports http://www.energy.ca.gov/pier/environmental/reports.html

- Energy System Integration Program

  Final Reports http://www.energy.ca.gov/pier/esi/esi_reports.html
  Papers/Presentations http://www.energy.ca.gov/pier/esi/esi_papers.html

- Distributed Energy Resources Systems Integration

  Final Reports http://www.energy.ca.gov/pier/esi/der/strat_research4.html (none)
  Papers/Presentations http://www.energy.ca.gov/pier/esi/der/strat_research6.html

- Demand Response to Electricity Prices and System Contingencies

  Final Reports http://www.energy.ca.gov/pier/esi/pricing/strat_research_pricing4.html (none)
  Papers/Presentations http://www.energy.ca.gov/pier/esi/pricing/strat_research_pricing6.html

- Enhance Transmission and Distribution Capabilities

  Final Reports http://www.energy.ca.gov/pier/esi/trans/strat_research_trans4.html
  Papers/Presentations http://www.energy.ca.gov/pier/esi/trans/strat_research_trans6.html

- Strategic and Enabling Technologies

  Final Reports http://www.energy.ca.gov/pier/esi/setech/strat_research_disrupt4.html
  Papers/Presentations http://www.energy.ca.gov/pier/esi/setech/strat_research_disrupt6.html (none)

- Environmentally Preferred Advanced Generation Program :

  Final Reports http://www.energy.ca.gov/pier/epag/epag_finalreports.html
  Papers/Presentations http://www.energy.ca.gov/pier/epag/documents/index.html

- Renewable Energy Technologies Program

  Final Reports http://www.energy.ca.gov/pier/renewable/finalreports.html
  Papers/Presentations http://www.energy.ca.gov/pier/renewable/papers.html

- Energy Innovations Small Grant Program

  Final Reports http://www.energy.ca.gov/research/innovations/eisg_final_reports/index.html

Contribution to the Intelligent Grid

Only the ESI program has been included in this analysis. Any projects funded by CEC–PIER for the CERTS program are included in the CERTS section of this report.

Table 9-1
Reference metrics analysis for CEC–PIER ESI program

Categories	CEC-PIER Energy Systems Integration Program
Applications	
Visioning and Concepts	• New planning process for transmission grid in California (T,D) • Analysis of electricity generation and transmission interconnection for California (G,T) • AMI, PCT concepts for California (M to E)
Business Case	• Assessment of CHP market (G) • Economic and environmental assessment of energy storage systems integrated with renewable energy systems (G) • DER benefit assessment (D,G) • **Analysis on cost-effectiveness of DG interconnection, specific study of policy factors for CHP integration (D)** • **Evaluation of zinc/bromine battery for distribution operations** • **Evaluation of benefits for advanced distribution automation (D)** • Case study on RTP program experience (M,D,E)
Functional Requirements	• Technical assessment on distribution impacts of electric vehicle charging (D) • System assessment using network analysis software (T,D)
Guidelines and General Framework	• Technical requirement of supplying spinning reserve from pumping system load (G) • Congestion management requirement (T) • Assessment of transmission R&D for California (M,T) • Technical and financial feasibility analysis on energy management system for Microgrids control (G,D) • R&D plan on DER integration (M,T,D) • Guidebook for DG interconnection (D,G) • Investigation of barriers to DG interconnection (D,G) • Analysis on wind generation impacts to grid system operations (T,D) • Assessment of Southern California demand response programs and proposal of new demand response mechanisms (M,D,E) • Automatic zoning for zonal pricing (M) • Power quality guidelines for energy-efficient device application (D,E) • Guidebook for power quality (E) • Technical guidelines on programmable logic controller (G,D,E) • **Research plan and roadmap for demand response (M,D,E)** • **Innovative ratemaking treatment of DER for restructured and regulated markets (M,G)** • **Market research portfolio in the Center for the Study of Energy Markets (M)** • **Methodology for optimal placement of DER on distribution system (D)** • ***Underground cable diagnostics and replacements issues projects***
Services (Bridge Between Products and Needs)	
System Architecture	• **Demand Response Reference Design (D, E)** • **Network security and privacy investigation for large demand response communications network (D)**

Table 9-1 (continued)
Reference metrics analysis for CEC–PIER ESI program

Categories	CEC-PIER Energy Systems Integration Program
Transverse Services	• **Contribute to the development of the testing facility Distributed Utility Integration Test (G)**
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	• **Development of standards for DER interconnection (G)**
Technology Analysis	• **Assessment of DER Integration Technology (G)** • Survey of DER test facilities (G) • Synchronized Phasor Measurements Applications User Guide (T) • Technical assessment of FACTS devices (T)
Software and Hardware Development	• Specification and development of control and scheduling of DER using software intelligent agents – SmartDER (G) • Development of real-time monitoring and dynamic rating system for transmission lines (T) • Development of real-time voltage monitoring and VAR management system (T) • Development of supplier and control area performance monitoring system (T) • Development of PMU real-time monitoring system (T,D) • Development of satellite communications system (T,D) • Development of loop flow management (T,D) • Development of energy source stabilizer (G,T) • Development of alarm analyzing and voice recognition systems (S) • Development of composite reinforced aluminum conductor (T,D) • Development of sagging line mitigator (T) • Development of light activated surge protection thyristor • Development of power electronics for DG systems (G) • **Development of a software interface to shield application software (demand response) to actuators and sensors (E)** • **Development of a universal interconnect device for DER (G)** • **Tools for PMU measurements (voltage security assessment, etc.) (T)** • **Advanced low-voltage switches for soft (or rolling) blackout (T)** • Development of flywheel power system (G)
Product Integration	• Test of two microturbines operating in parallel (G)
Demonstration	• Evaluation of auto DR in large facilities (M,D,E) • Assessment of the impact of DG interconnection to grid (D,G) • Demonstration of flywheel power system (G) • **Demonstration of SmartDER with GridAgents – standby (G)** • **Testbed of DER and Demand Response in San Francisco (D)**

Legend: M=Market, G=Generation, T=Transmission, S=Substation, D=Distribution, E=End Use. Italics indicate an expected deliverable of a planned project. Bold characterizes active projects.

10
NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

The information contained in this profile comes from published documents on the New York State Energy Research and Development Authority (NYSERDA). The profile has been reviewed by Gunnar Walmet at NYSERDA. For more information, please visit www.nyserda.org.

The New York State Energy Research and Development Authority (NYSERDA) is a public benefit corporation created in 1975 by the New York State Legislature. NYSERDA derives its basic research revenues from an assessment on the intrastate sales of New York State's investor-owned electric and gas utilities, and voluntary annual contributions by the New York Power Authority and the Long Island Power Authority. Some 400 NYSERDA research projects help the State's businesses and municipalities with their energy and environmental problems. Since 1990, NYSERDA has successfully developed and brought into use more than 170 innovative, energy-efficient, and environmentally beneficial products, processes, and services. These contributions to the State's economic growth and environmental protection are made at a cost of about 70 cents per New York resident per year.

NYSERDA is in the initial stages of developing a new initiative to assist in the modernization of New York's aging transmission and distribution (T&D) system to meet the needs of the 21st century. [22] These planned activities have been taken into account to complement the positioning of the NYSERDA programs.

Vision

"A modernized electricity grid will enhance reliability, security, and end-use power quality; it will reduce environmental impacts and eliminate electric system constraints as impediments to economic growth." [22]

Mission

The mission of NYSERDA is to use innovation and technology to solve some of New York's most difficult energy and environmental problems in ways that improve the State's economy. [23]

The new T&D program will support activities to: 1) establish uniform statewide diagnostics for assessing T&D system reliability; 2) integrate advanced communication, control, and monitoring technologies, power electronics, and innovative technologies such as high-temperature superconducting cables and devices and advanced energy storage systems; 3) deploy remote sensors for continuous monitoring of the T&D infrastructure with real-time monitoring of real and reactive power; 4) use distributed energy resources as a means to delay the need for T&D infrastructure upgrades and provide support for critical areas on the distribution system; and 5) facilitate the delivery of electricity from renewable technologies such as wind, hydropower, and geothermal resources. [22]

Governance

The NYSERDA board of directors is composed of representatives from the public sector, electric power industry, and scientific community.

Budget

The average annual budget for research, development, and demonstration is $50M ([22] mentions $67,075k for 2005–2006). The following sectors of application receive more than 10% of the overall budget (sorted by decreasing order):

- Wholesale Renewables
- Distributed Power and Combined Heat and Power
- Next-Generation and Strategic Technologies
- End-Use Renewables

New T&D initiatives have a targeted annual budget of $2M.

Program Opportunity Notice funds 97% of the research projects. The value range averages $200,000, sometimes with an equal financial commitment from the contractor.

Figure 10-1 shows the distribution of the research budget (spent to date) among the sectors of application and systems engineering categories.

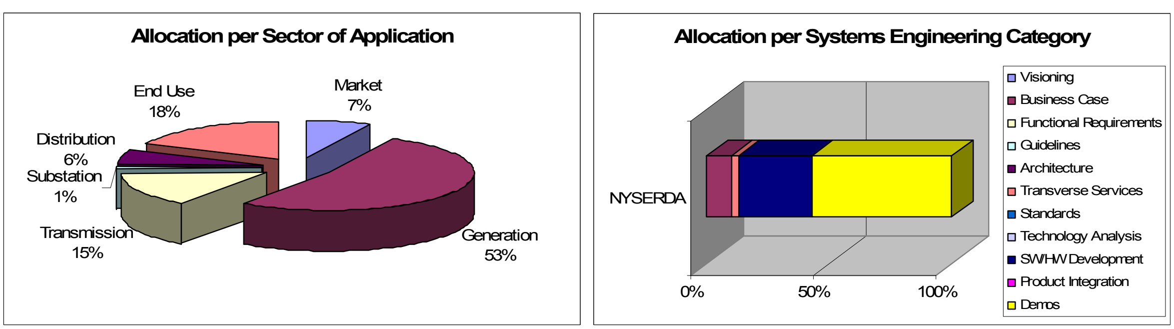


Figure 10-1
Distribution of NYSERDA R&D budget (spent to date)

Promotion

- Website

Research Projects

The NYSERDA R&D program is organized into five primary areas: Energy Resources, Transportation and Power Systems, Environment, Industry, and Buildings.

Energy Resources

The primary focus of this program is solar and wind energy, and promoting investment in and purchase of renewable energy. Activities range from providing assistance in developing new renewable energy technologies to helping teachers educate students about solar energy. NYSERDA teams with many renewable energy partners to develop programs and projects that help the State reduce environmental emissions associated with fossil fuels and to reduce reliance on energy imports.

Transportation and Power Systems

The Power Systems portion of this program is relevant to this study, and addresses a wide range of power generation, transmission, distribution, and conversion/storage issues. The three-year objectives of the program, as stated in the 2004 Strategic Plan, are to [22]

- Develop and commercialize three energy technologies that offer New Yorkers improved energy reliability and environmentally benign power generation.
- Reduce emissions from pre-2007 diesel engines.
- Promote advanced power generation and energy storage technologies. (Develop, demonstrate, and document the reliability as well as the environmental, peak load reduction, and improved power quality benefits of emerging electrical energy storage and power system monitoring technologies. Support product development activities in innovative, yet-to-be-commercialized, clean power generation technologies, such as fuel cells, kinetic hydro, quantum-well thermoelectric conversion, and power generation from bottoming cycles using waste heat.)

Examples of typical project areas and past and current projects are listed below, even though they are not all inclusive of the complete areas of interest and activity.

Power Generation Projects

- Combined Heat and Power (CHP) Generation: This project studied the technical potential of CHP and evaluated CHP economics for five size ranges. A large CHP pilot program is in operation: 67MW of CHP generation were installed and operational in 2003. [24]
- NYSEG Microturbine Demonstration

- Old Chatham Microturbine Demonstration
- High-Voltage Equipment Design Tool
- Demonstration of PEM Fuel Cell Systems

Power Transmission, Distribution, and Systems Projects

- High-Temperature Superconducting (HTS) Power Cable Demonstration: This project, developed in partnership with DOE (total budget $26M, with $6M from NYSERDA), is developing and demonstrating HTS power cable, which can carry three to five times more current than conventional (60kV) power lines and will help to meet the growing demand for power in major cities.
- High-Temperature Load Conductor Demonstration: This project is testing a new conductor to decrease overhead line sag.
- GridCom Monitoring and Control System Demonstration. [25] The objective of this project is to develop and demonstrate a prototype monitoring and control system for medium-voltage electric power distribution lines. The system will combine low-cost, easy-to-install sensor technology with software developed to detect and localize faults and to characterize power quality.
- Inverter Test Procedure Demonstration: The purpose of this project is to demonstrate a well-defined static inverter test procedure, in compliance with New York State Standard Interconnection requirements.
- Aggregating Distributed Generators: This project's objectives were to aggregate backup distributed generators by adding controls to make them dispatchable, to procure and install the equipment needed to interconnect each generator with the aggregator control room and enable communication from the control room to the New York Power Exchange, and to quantify economic and environment benefits. This project is complete.
- Arcing Fault Detection and Locating (University of Texas in Arlington)
- WISAN Sensors: The goals of the project were to design a wireless intelligent sensor and actuator network (WISAN), create an inexpensive set of instrumentation for the tasks of structural health monitoring (SHM), and develop an SHM method that is suitable for autonomous structural health monitoring. This project is complete.

Other Projects

- Design, Development, and Manufacture of High-Speed Foil Bearings

New Transmission and Distribution System Program

This program is being discussed with the New York authorities to address specific T&D issues in New York State. A workshop was organized in 2005 to collect guidance from the state's stakeholders, and an R&D plan is currently under development. (EPRI was hired in 2005 by NYSERDA to design this plan.) The program will begin in the second semester of 2006.

The objectives of the program are to develop collaborative R&D activities that benefit the stakeholders of New York State and that support a long-term (10+ years) vision for the future T&D system in the State. The first key technical targets in discussion are

- Increase network efficiency and throughput
- Improve reliability and enhance security (i.e., detect and protect against threats)
- Ensure public and worker safety
- Reduce environmental impacts
- Reduce O&M costs commensurate with reliability requirements
- Promote capital efficiencies
- Improve customer service
- Enable demand response, distributed resources
- Enable value-added services
- Improve training aids for employees

Potential projects for funding are currently under discussion. The first draft list of projects covers areas that include development of new algorithms, prototype equipment and software, and a business model. Following are examples:

- New operating tool with distributed intelligence to improve the anticipating properties of existing controls and to support operators in decision-making
- Algorithms to anticipate the failure of critical equipment controls
- Development of a fault anticipator
- Development of a fault current limitation device
- Identification of sources of disturbances (deployment of monitoring equipment with system-wide communication capabilities and development of software application)
- Asset management tool to assist in developing a repair/refurbish/replace strategy for aging transmission assets
- Specification of a new electric design for secondary network of distribution electric delivery
- Business model to sustain investments in T&D

Environment

The Environmental program develops and demonstrates energy-efficient technologies used in waste management and pollution control. The program supports research to understand and mitigate the environmental impacts of energy production and use.

Industry

The Industry program works with the manufacturing, agriculture, and high-technology industries to: 1) enhance the competitiveness of manufacturers, 2) encourage capital investment and employment growth, 3) introduce goods manufactured in New York into new markets, 4) encourage adoption of process changes that minimize waste, and 5) inspire development of innovative environmental products.

The program demonstrates and promotes adoption of process and productivity enhancements, pollution prevention and waste mitigation strategies, use of CHP, and various emerging energy technologies. Three-year objectives, as stated in the 2004 Strategic Plan, are to [1]

- Support development and implementation of energy-efficient and environmentally friendly industrial processes and products
- Increase market acceptance and penetration of clean, efficient distributed generation (DG) and DG-CHP systems
- Promote the early adoption of emerging energy technologies using hydrogen and high-temperature superconductivity

Examples of typical project areas and past and current projects are listed below, even though they are not all inclusive of the complete areas of interest and activity.

- Intelligent Communication and Control System for DG: The objective of this project is to study the feasibility of an intelligent communication and control system to enable remote monitoring and control of a universal interconnect device (UID) for DG systems. The UID will allow certain onsite generators to continue running in the event of a grid blackout. By incorporating into the device energy storage technology, such as a flywheel, the UID would be capable of storing energy to provide critical additional time during a grid outage, and would allow the DG system to separate from the grid and continue operation. This project is run by Connected Energy in partnership with Beacon Power Corporation and the Long Island Power Authority (LIPA).
- Broadband Energy Networks Demonstration: This demonstration conducts and manages a demonstration for the State Authority’s time-sensitive electric pricing and demand response program. Monitoring and control networks will be installed in businesses and homes to track energy consumption and control air conditioners, pool pumps, motors, electric hot water heaters, and other energy-consuming devices, varying their operation in response to changing electricity price and demand and user schedules. The purpose of the two-year funded demonstration is to confirm customer acceptance and satisfaction with systems for businesses and homes that will automatically vary the temperature of the space as well as the operating pattern of other electrical devices in response to information about user demand and the price of electricity.

NYSERDA also took a lead role in partnering with DOE and the Association of State Energy Research and Technology Transfer Institutions (ASERTTI) to establish performance testing protocols and a national database for DG technologies. The web-based database eventually will provide continuous system performance data on 30 NYSERDA-sponsored CHP demonstration sites.

Building

The three-year objectives of the Building program, as stated in the 2004 Strategic Plan, are to [1]

- Increase the use of low-sulfur/B20 biodiesel and other blended fuels
- Increase new product development and demand for fixtures and integrated controls for new and existing efficient light sources
- Introduce new building materials and components that increase energy and environmental efficiency in manufacturing and installation
- Introduce new energy-efficient control technologies providing improved power quality
- Demonstrate economic load reduction at wholesale and retail distribution levels

Program research is organized into five activities: 1) Heating and Cooling, 2) Lighting, 3) Building Envelope, 4) Controls and Meters, and 5) DG Combined Heat and Power. Examples of typical project areas and past and current projects are listed below, even though they are not all inclusive of the complete areas of interest and activity.

- Submetering Multifamily Buildings: The goal of this project is to install submetering for multifamily housing in the New York metropolitan area and the Long Island Power Authority service area to reduce building-wide electricity consumption by 18% to 26%.
- Radio-Frequency Thermostat: The goal of this project is to develop an innovative, battery-operated, wall-mounted, wireless thermostat with a radio-frequency (RF) link to control multiple baseboard heating units and/or multiple room air-conditioning units. Pre-production RF thermostats were designed, fabricated, and tested by ENERNET and an independent laboratory.
- Enabling Technologies for Price-Sensitive Load Management: The goal of this project is to help develop technologies that will expand the capability of New York ISO market participants to reduce electricity load from the utility grid in response to emergency or market-based price signals. Technologies include state-of-the-art communications, networking, advanced metering, and controls that are scalable, flexible, and responsive to rapidly evolving market conditions. Projects involving approximately 15MW of flexible customer load currently are being implemented across the state.
- Concentrating Photovoltaic Energy Systems for Integrated Intelligent Building Envelopes (Rensselaer University[2])
- Advanced Sensors and Controls for Energy Management Power Quality and System Reliability (Intech, Clarkson University[3])

[2] Project funded in 2004 but no information on the content of the work done

[3] Contracts signed in 2005 but no information on the content of the work done

Accomplishments to Date

For the Power Systems and Building programs, through 2004:

- Forty-eight PV installers and 12 small wind installers are now eligible to participate in the program, and 20 PV installers passed the NABCEP certification exam.
- Six academic and training programs are in process to be accredited by the Institute for Sustainable Power.
- Over 1300kW of photovoltaic power has been installed at 271 sites, and over 61kW of small wind power has been installed at seven sites.
- Three-year contracts are in place with five incubators across the state to support new renewable energy technology companies.
- NYSERDA has established a two-stage competitive program to share the risk of technology development, prototype construction, testing, demonstration, and manufacturing of new products and applications.
- Plug Power's GenCore 5T, a backup generator fuel cell product designed for the telecommunications market, achieved commercial status and Network Equipment Building System certification. The first commercial orders have been shipped.
- Lawrence Berkeley National Laboratory worked with the *New York Times* to determine the performance requirements of a completely automated daylight, lighting, and shading system for the *New York Times* building to be constructed in Times Square in Manhattan. The automated system was optimized in a 4,500-square-foot test site in Queens, New York. The project challenged lighting controls and window shading manufacturers to meet the performance requirements of the *New York Times* and transform the automated day lighting market.
- NuTech Lighting received Underwriters Laboratory and ENERGY STAR certification for its lightweight, polycarbonate, residential recessed canned lighting fixture for compact fluorescent lamps. The product is sold under the brand name of Genuine Hard Hat through an arrangement with Brownlee Lighting.
- Utility Systems Technology has achieved domestic and international sales of 40 Sag Fighters™, an advanced power conditioning technology for electronic, electrical, and manufacturing processes. The product, which was introduced in 2003 as a more efficient voltage sag mitigation technology, greatly reduces losses during standby modes and responds more quickly than conventional voltage support technologies.
- Time-sensitive, electric rate pilots are under way at two multi-family buildings—Clinton Hill and Waterside Plaza—which total approximately 2,700 units. Interim results from the two-year pilots show price-induced load shifting and annual energy cost savings of as much as 10%.
- The number of CHP demonstrations increased to 90 from 75. Thirty-one systems are operational and have a combined output of over 13MW. Notable projects include fuel cells at the Bronx Zoo, Grand Central Station, and Sheraton Hotel, and clean reciprocating engines at the new headquarters of the *New York Times* and Macy's department store.
- A web-enabled guidebook for siting and permitting DG resources was developed and issued.

Contribution to the Intelligent Grid

Table 10-1
Reference metrics analysis for NYSERDA

Categories	New York State Energy Research and Development Authority
Applications	
Visioning and Concepts	
Business Case	• Quantification of economic and environmental benefits of aggregation of distributed generators • *Business model to sustain investments in T&D*
Functional Requirements	• Design of a Wireless Intelligent Sensors and Actuator Network to monitor structural health of equipment • *Specification of a new electric design for secondary network of distribution electric delivery* • *Algorithm specification to anticipate controls failure of critical equipment*
Guidelines and General Framework	
Services (Bridge Between Products and Needs)	
System Architecture	
Transverse Services	• Definition of a test procedure for static inverter for distributed generators • *Asset management tool to assist in developing a repair/refurbish/replace strategy for aging transmission assets*
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	
Technology Analysis	• Establishment of performance testing protocols (DG) and database of DG technologies (with ASERTTI and DOE)
Software and Hardware Development	• Development of a "GridCom" monitoring and control system to improve fault location and power quality • Development of communication and control solutions to aggregate backup generators to make them dispatchable • Development of an arcing fault detection and location • Feasibility study of a universal interconnect device for distributed generators (including storage technology) • Development of a wireless RF thermostat to control multiple heating and AC units • *New tools for transmission operation to improve anticipation capabilities of controls and support decision-making of operators* • *Development of a fault anticipator* • *Development of a fault current limitation device* • *Identification of sources of disturbances (deployment of monitoring equipment with system-wide communication capabilities and development of software application)*
Product Integration	
Demonstration	• Demonstration of a "GridCom" monitoring and control system to improve fault location and power quality • Demonstrations of advanced CHP, microturbines and fuel cells • Demonstration of a time-sensitive electric pricing and demand response program (2005-2007) • Experiment of multi-family submetering

Note: Due to insufficient information, some projects described in the profile could not be categorized in this table, such as advanced sensors and controls for energy management power quality and system reliability, and PV energy systems for integrated intelligent building envelopes.

Legend: Italic indicates an expected deliverable of a planned project.

11
EUROPEAN UNION FRAMEWORK PROGRAMS ON SUSTAINABLE ENERGY SYSTEMS

The information contained in this program profile comes from published documents on the European Union Framework Programs on Sustainable Energy Systems and Smart Grids Research. The profile was sent for review to the Directorate-General for Research, who commented that there were discrepancies between the profile and reality. Attempts to characterize these differences or the nature of the differences with the European Commission were not successful. The commission has indicated that further information will soon be available in an article written collaboratively by the European Commission and the U.S. Department of Energy. For more information, please visit http://ec.europa.eu/energy.

The European Commission (EC) funds R&D projects and programs that are based on requests for proposal addressing its framework programs (FPs). Each FP is designed to cover a period of time, define a research focus, and structure European research activities. They are the main funding mechanism opportunities in Europe, with the EC covering half of the research budget.

Projects that are selected through FPs have their own schedules, and their durations can range from one to several years. The 5th Framework Program (FP5) ended in 2002, but several projects are still being completed. Currently, the 6th Framework Program (FP6) has an average budget of €20 billion covering five years, from 2002 through 2006.

This study focuses on the Sustainable Energy Systems priority area of FP5 and FP6.

The new 7th Framework Program (FP7) proposes to cover energy issues in nine priority areas over seven years (2006–2013). The areas are: 1) Hydrogen and Fuel Cells, 2) Electricity from Renewables, 3) Renewable Fuels, 4) Renewables for Heating and Cooling, 5) CO_2 Capture and Storage, 6) Clean Coal Technologies, 7) Smart Energy Networks (Integration of Renewable Energy Sources and Distributed Generation), 8) Energy Savings and Energy Efficiency, and 9) Knowledge for Energy Policy Making.

In addition, the EC uses a Technology Platform (TP) to bring interested stakeholders together to develop a long-term vision and create a coherent, dynamic strategy with a research agenda and deployment strategy to achieve that vision. The SmartGrids TP was formed in 2005 to address integration of renewable energy sources (RES) and distributed generation (DG). Figure 11-1 illustrates the framework program and technology platform mechanism.

This study focuses mainly on preliminary results of the SmartGrids TP to define the vision and mission of the European Union program.

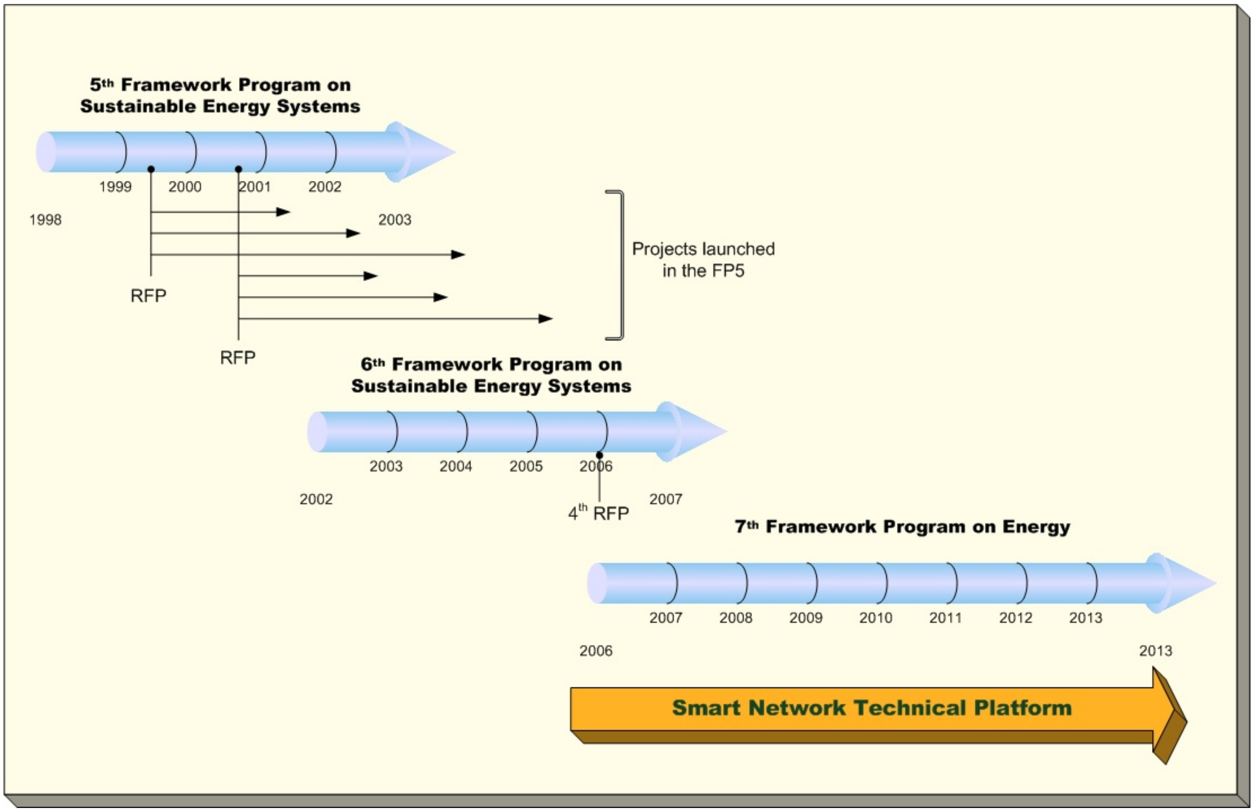


Figure 11-1
European Union Framework Programs and Technical Platform mechanism

Vision

The objective of FP7 is to transform the current fossil-fuel based energy system into a more sustainable one based on a diverse portfolio of energy sources and carriers. Complemented by research efforts in enhanced energy efficiency, the aim of FP7 is to address the challenges of security of supply and climate change, while increasing the competitiveness of European energy industries. This framework program will incorporate the vision and strategy being developed for the SmartGrids TP.

The main goal of the TP is to increase the efficiency, safety, and reliability of the European electricity T&D system by transforming current electricity grids into an interactive service network of customers and operators, and to remove obstacles to large-scale deployment and effective integration of distributed and renewable energy sources.

The TP is currently developing its vision and strategy. Results should be published before the end of 2006. Its vision is: [28]

“Europe’s electricity networks beyond 2020 will be

- *Flexible*: Fulfilling the needs of all customers and, on a wider scale, society at large.
- *Accessible*: Granting all applicants access to electricity assets, particularly for RES and high-efficiency local generation with zero or low-carbon emissions.
- *Reliable*: Assuring and improving security and quality of supply consistent with demands of the digital age.
- *Economic*: Providing best value through innovation, efficient energy management, and a level playing field for competition and regulation.

Mission

The mission of the EU programs is to promote sustainable development, ensure security and diversity of energy supply, improve industry competitiveness, and enhance economic and social cohesion by funding R&D that covers targeted technology areas in the 2010 horizon. [26]

Members

EU project participants are stakeholders in the European energy industry. The project portfolio is managed by Energy Production and Distribution Systems Commissioner of the European Commission Directorate-General Research Group. Some project results are public, while others remain private within the consortium created by the projects.

Budget

The total expenditure on European R&D projects for large-scale integration of RES and DG within FP5 (1998–2002) was approximately €130M, with an EC contribution of about €67M**.** [27]

The allocation in the three research priority domains are: New DER Architectures and Concepts (79%), Storage (7%), and Enabling Technologies (14%).

The initial plan for FP7 proposes a budget of €73 billion over seven years (2006–2013). The allocation for the Energy domain is not yet known.

Figure 11-2 shows the distribution of the research budget (spent to date) for FP5 and FP6 among the sectors of application and systems engineering categories.

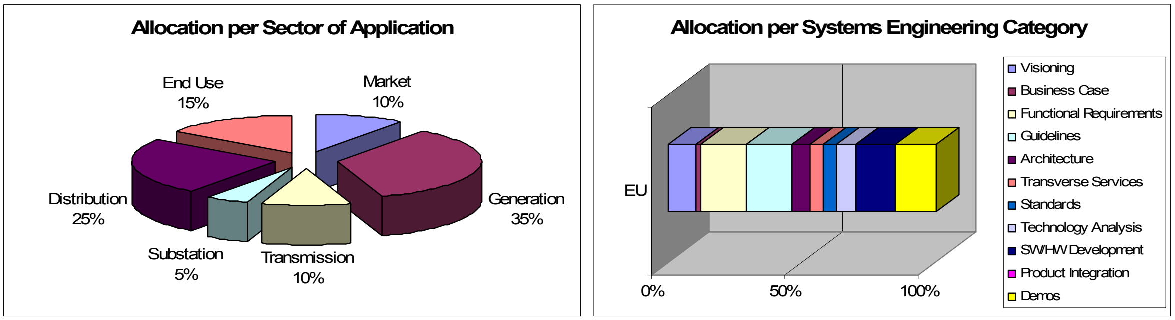


Figure 11-2
Estimated distribution of European SmartGrids R&D budget (spent to date)

Promotion

- Workshops
- Conference
- Website (most of European projects have a website)

Research Projects and Programs

FP5 – Cluster "Integration of Renewable Energy Sources and Distributed Generation"

This cluster of projects completed its fourth year of operation in 2005. It gathered more than 100 partners, with a total budget of €34 million, to research storage technologies for future grids, conditions for reliable grid operation, information communication technologies for operation and control of future grids, electricity trading, and socio-economic impacts. The seven projects included in this program are DISPOWER, DGNet, Microgrids, Crisp, DGFacts, Sustelnet, and Investire.

1. DISPOWER (DG with High Penetration of Renewable Energy Sources, 2002–2005, €17M): This project investigated economic and technical issues to increase penetration of RES. The project has developed
   - Strategies and concepts for grid stability and system control in DG networks (including load control)
   - Safety and quality standards (mainly state-of-the-art and recommendations)
   - Planning and design tools to ensure reliable and cost-effective integration of components in regional and local grids
   - Analysis of market issues and recommendations for integration of RES and DG
2. DGNet (European Network for Integration of RES and DG, 2002–2005, €2M): This consortium advocates the concept of DG and RES integration by increasing stakeholder awareness of increased efficiency and sustainability of technologies; removing technical,

business, regulatory, and cost-related barriers to new grid interconnections; and raising acceptance of intermittent RES and DG without risk to quality and safety. The project has produced

- State-of-the-art DG (technologies, suppliers, experience)
- Recommended practices
- Standardization, testing, and certification procedures
- Application definitions for DG and RES in electricity and environmental markets
- Recommendations for R&D, policy making, and market organization

3. Microgrids (Large-Scale Integration of Micro-Generation to Low-Voltage Grids, 2002–2005, €4.4M): The project investigated, developed, and demonstrated the operation, control, protection, safety, and telecommunications infrastructure of microgrids, and determined and quantified economic benefits.

4. CRISP (Distributed Intelligence in Critical Infrastructure for Sustainable Power, 2002–2005, €3M): This project focused on application of distributed intelligence to optimize market and control strategies. It specified and designed a decentralized control strategy implementing the concept of cells to manage fault detection and location on the grid. It modeled simulation of the electric delivery and communications infrastructure to control expected behavior. The project also developed a new concept of supply-demand matching using the agent-based electronics market to optimize market, generation, and storage resources. It developed and demonstrated algorithms in a two-year field test in The Netherlands that incorporated two wind turbines, combined heat and power (CHP), cold store, and dwelling and emergency generators. It also studied distributed voltage management, with two major results: a recommended stability indicator, and an improved automatic voltage regulator for the tap changer in the transformer. CRISP specified and developed new voltage and frequency controls to demonstrate in Sweden that grid cells could successfully disconnect and reconnect to the transmission grid. It studied the dependability and security of the communications infrastructure and made recommendations to address these issues. It modeled various electronics market scenarios to verify the effectiveness of specified supply-demand strategies. It also developed an electronics market power game to explain the concepts developed in the project.

5. DGFacts (Improvement of Quality of Supply in DG Networks through Integrated Application of Power Electronic Techniques, 2002–2005, €3.5M): The aim of this project was to solve the quality of supply problems arising from the integration of DG into the electric distribution networks. DGFacts introduced use of the FACTS concept in distribution systems by designing a set of modular systems—so-called DGFacts systems—to optimally improve the stability and quality of supply of each electric power distribution network according to its characteristics and requirements.

6. Sustelnet (€2M): Although technical developments are decentralizing the electricity infrastructure and services, no initiative previously existed to consider how to open the internal market to ensure effective participation of DG and RES. This project provides the analytical and organizational foundation for a new regulatory process that can achieve a level playing field between centralized and DG power supply. The institutional changes and

economics of supply are being analyzed to give a regulatory roadmap to a sustainable electricity system.

7. Investire (€1M): This thematic network reviewed and assessed existing storage technologies in the context of RES applications. It produced a summary of the state of the art and defined the requirements for energy storage in various RES applications. It carried out an evaluation of emerging technologies for intermittent RES applications. It also defined a roadmap covering requirements in technology improvement and standardization.

FP6 – Scientific Support to Policies in the Energy Sector

This cluster consists of six projects: EU-DEEP, IRED, RELIANCE, FENIX, CEERES, and TEAHA.

1. EU-DEEP (European Distributed Energy Partnership, 2003–2009, €29M): This project is developing five fast-track options to support the large-scale implementation of DER in Europe. These are described by business models addressing necessary DER technologies, energy market demand, financial means, and organization of actors. The project provides results of R&D on improved DER equipment for the five fast-track options, develops equipment specifications to connect DER, develops improved simulation software, provides market rule recommendations to public organizations, and leads a European competence group in this domain.

2. IRED (Integration of RES and DG, €1M): IRED aims to coordinate research projects addressing the issue of integrating RES/DG, and to share best practices among all stakeholders involved in these research activities.

3. RELIANCE (Coordination of Research to Optimize Reliability of Power Supply, 2005–2006): The goal of this project is to consolidate and integrate the R&D needs and efforts required to define a European transmission network that optimizes reliability through increased DG and RES. The project uses a systemic approach to build a vision, develop a scenario, and structure a roadmap according to expected evolutions.

4. FENIX (Flexible Electricity Networks to Integrate the Expected Energy Evolution, €15M, 2006–2009): The objective of this project is to conceptualize, design, and demonstrate a technical architecture and commercial framework for a large-scale virtual power plant (LSVPP). The project will: 1) develop local functions and responses that create opportunities for DG and demand side to support system operation, 2) design the LSVPP control and information interface, 3) undertake a proof-of-concept demonstration of feasibility, and 4) design a commercial framework to support system operation under the fully decentralized network architecture. Two large field demonstrations are planned in the U.K. and Spain in 2009.

5. CEERES (Large-Scale Integration of RES and Cogeneration into Energy Supplies): This consortium aims to increase the participation of new Central European member states in the goal of having large-scale electricity production from RES. Technical projects are not funded by this consortium.

6. TEAHA (The European Application Home Alliance, €5M, 2004–2007): This project aims to define a suitable middleware platform to allow seamless interworking of the wide variety of appliances found in home environments—from the 3-cent to the €300 device—across an array of network technologies. Three types of results are being produced: 1) an open middleware framework to ensure interoperability across heterogeneous networks, 2) a radio-frequency (RF) solution supporting TEAHA middleware for seamless interworking and 3) an ultra-low-cost power cord communication solution (planned to be lab tested) that will include a residential gateway subsystem. This project does not fold under the Sustainable Energy Systems program, but it has been included in this analysis for its relevance to consumer portal research.

Programs Under the 4th Calls for Proposal of FP6

EU framework programs fund research through their calls for proposal process. The 4th call for proposal for FP6, which closed on January 10, 2006, had a theme defined as ”Sustainable Development, Global Change, and Ecosystems” that involve sustainable energy systems and research activities with mid- and long-term impacts. The estimated budget is €20M.

1. CONCERTO II: This initiative is designed to manage energy demand and RES in ways that enable high-quality services for European citizens. An expected 20 Concerto II projects are being funded, each with an average budget of €3M. They should include a local community, and an actual implementation of RES and energy efficient measures, especially for buildings. These projects may last up to five years. The closing date for proposals was December 15, 2005.

2. GRID: This project began in January 2006 to coordinate research projects that are developing results on grid reliability and the wise use of information technologies. It will run for two years.

Other Projects Under FP6 or Other European Union Funding

Other projects not directly addressing electric delivery issues can have a significant impact on transformation of the grid. They are mentioned for information but are not included in this study.

- World Energy Technology Outlook 2050 – WETO-H2
- Case Study Comparisons and Development of Energy Models for Integrated Technology Systems – CASCADE MINTS
- Dissemination of External Costs of Electricity Supply: Making electricity external costs known to policy makers – MAXIMA
- European Sustainable Electricity: Comprehensive analysis of future European demand and generation of European electricity and its security of supply – EUSUSTEL
- Energy Corridor Optimization for the European Markets of Gas, Electricity, and Hydrogen – ENCOURAGED

- Renewable Energy in Developing Countries: Current situation, market potential, and recommendations for a win-win-win for EU industry, the environment, and local socio-economic development – RECIPES
- The European Regulation Forum on Electricity Reforms – SESSA (Market design, regulation, and sustainability)
- ABLE Project – Developing an advanced storage system, specially designed for small and medium-sized PV systems, to implement PV-solar home systems within the framework of national rural electrification schemes
- HVDC – Establishing a methodology and producing associated software and hardware tools to assess the potential technical, economic, and environmental benefits and impacts of high-voltage DC (HVDC) transmission in the largely HVAC electrical power T&D systems of the European transmission network
- Advanced lithium energy storage systems based on use of nano-powders and nano-composite electrodes/electrolytes (ALISTORE, €5M).
- Super-Coated Conductor Cable (SUPER3C, €4.5M)

Intelligent Energy – Europe

The Intelligent Energy – Europe (IEE) program of the European Commission supports intelligent energy use and increased use of renewables to speed up efforts to reach sustainable energy goals. The program spent a total of €250M for the period 2003–2006, co-financing international projects, events, and the startup of local and regional agencies. It covers four main fields:

- Energy efficiency and rational use of energy, in particular in buildings and industry (SAVE)
- Promotion of new and renewable energy sources for electricity, heat, and biofuels
- Energy aspects of transport, fuel diversification, biofuels, and energy efficiency
- Promotion of renewable energy sources and energy efficiency in developing countries

The 2006 request for proposal had a budget of €55.47M and placed a high priority on energy efficiency, with a portfolio allocation of €12.8M for SAVE. [35]

IEE has established a public dissemination database for non-technological projects supported by the European community in the field of energy efficiency and RES. It describes 700 projects from 1996 onward and provides searching features for wide dissemination. A list of IEE projects is contained in Appendix B; however, none were included in this study.

Accomplishments to Date

Most deliverables of the EU projects are available online at http://ec.europa.eu/energy.

Contribution to the Intelligent Grid

Table 11-1
Reference metrics analysis for European Union SES program

Categories	European Union Sustainable Energy Systems Program
Applications	
Visioning and Concepts	• New concept of grid stability and control (DER and load control) developed in DISPOWER • Modular FACTS concept for distributed generation (DGFacts) • *Flexible electricity network concept with large-scale virtual power plants (FENIX)* • New concept of supply-demand matching using agent-based market (CRISP) • Electronic market power game developed to explain the concepts (CRISP)
Business Case	• Socio-economic analysis of controllable loads (DISPOWER) • Economic benefits of microgrids (Microgrids) • Economic potential for peak demand reduction and energy efficiency (EFFLOCOM)
Functional Requirements	• Analysis of market issues regarding integration of DER (DISPOWER) • Generation control strategy defined with high penetration of DER (DISPOWER) • Application definition of DER (DGNet) • Specification of operation, control, and protection of microgrids (Microgrids) • *Specification and design of an architecture of large-scale virtual power plants (FENIX)* • Specification of load profiles in deregulated markets (EFFLOCOM) • Decentralized control strategy specified and applied on fault detection and location (CRISP)
Guidelines and General Framework	• Socio-economic analysis of controllable loads (DISPOWER) • Policy making and market organization recommendations for increased DER penetration (DGNet) • DG suppliers catalog (DGNet) • Tools and studies for distributed intelligence for sustainable power (CRISP) • Analytical and organizational framework for a different relationship between regulation and industry with DG supply (Sustelnet) • *Five fast-track scenarios for large-scale implementation of DER in Europe, market rule recommendations (EU-DEEP)* • *Vision and roadmap for optimization of reliability among European TSOs (RELIANCE).*
Services (Bridge Between Products and Needs)	
System Architecture	• Information exchange analysis for DER penetration (DISPOWER) • Security and dependability of communications infrastructure analyzed (CRISP) • *Coordination of electric delivery reliability and information technologies innovation (GRID)* • *An open middleware framework to ensure interoperability across heterogeneous networks for homes (TEAHA*)

Table 11-1 (continued)
Reference metrics analysis for European Union SES program

Categories	European Union Sustainable Energy Systems Program
Transverse Services	• DER laboratory test centers, training facilities (DISPOWER) • Communication and control simulation environment (CRISP)
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	• State-of-the-art quality and safety standards for DER (DISPOWER) • Testing and certification procedure for DER (DGNet) • Interconnection requirements in Europe for DG (DGNet)
Technology Analysis	• Review of available technologies for controlling grids with DER (DISPOWER) • State-of-the-art of DG (technologies, experience) (DGNet) • State-of-the-art storage technologies in the context of RES (Investire)
Software and Hardware Development	• Planning and design tool to increase DER penetration (DISPOWER) • Power quality hardware implementation for PQ management with DER (DISPOWER) • SCADA system and operator training simulator for DER (DISPOWER) • Modular FACTS systems for DG (DGFacts) • Tap load changer algorithm (for optimized voltage control) (CRISP) • *Equipment specification to connect DER, simulation software (EU-DEEP)* • *Adaptation of DMS-EMS for LSVPP (FENIX)* • *RF solution for seamless interworking and ultra-low-cost power cord communication solution for homes (TEAHA)*
Product Integration	
Demonstration	• Field demonstration of local area management of DER with mixed generation sources and controllable load (DISPOWER) • *Two demonstrations of large-scale virtual power plants in 2009 (FENIX)* • Six pilot projects of energy-efficient and controlled load management within competitive market (EFFLOCOM) • *Twenty demonstrations of RES and energy efficiency measures in local community (CONCERTO II)* • Demonstration of new supply-demand matching with DER, storage, consumers for two years (CRISP) • Connect-disconnect of microgrids to transmission grid demonstrated (CRISP) • Laboratory demonstration of a seamless interworking and ultra-low-cost communication solutions for homes (TEAHA)

Legend: Italic indicates an expected deliverable of a planned project.

12
GALVIN ELECTRICITY INITIATIVE

GALVIN ELECTRICITY INITIATIVE

Sponsored by The Galvin Project, Inc.

The information contained in this program profile comes from published documents on the Galvin Electricity Initiative. The profile has been reviewed by Clark Gellings and Kurt Yeager at the Galvin Electricity Initiative. For more information, please visit www.galvinpower.org.

Founded in 2005 by the former CEO and son of the founder of Motorola, this program applies the concepts of total quality management to the electric power industry, with the goal of developing one or more configurations of a "perfect" power delivery system to meet the needs of the rapidly evolving digital economy and society.

Vision

"The perfect energy system will ensure absolute and universal availability of energy in the quantity and quality necessary to meet every consumer's needs." [36]

The electric energy service system is defined in the Galvin Electricity Initiative as the entire electricity system, including end-use services ultimately provided by electricity. Figure 12-1 illustrates this concept.

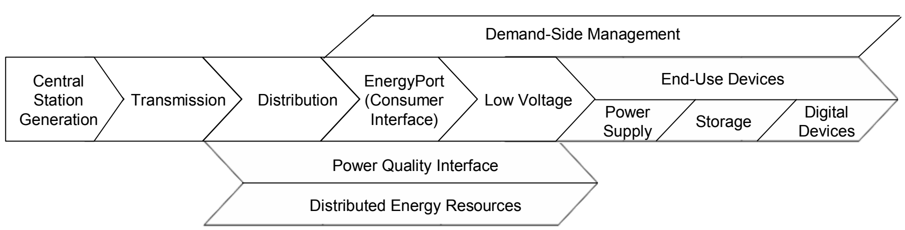


Figure 12-1
Electric system constituents, as defined by the Galvin Electricity Initiative

Mission

The mission of the Galvin Electricity Initiative is to create an actionable blueprint for transforming the U.S. electricity supply and service infrastructure into a resilient and adaptable system that can perfectly meet the needs of the rapidly evolving digital economy and society. [38]

The Galvin Electricity Initiative seeks to define the most confident systemic solution for achieving and maintaining an absolutely reliable and robust electric energy service capability most perfectly meeting 21st century consumer needs and expectations. In the context of this initiative, electric energy service is defined as the end-use service ultimately provided by electricity. This extends beyond today's consumer interface (e.g., presently the meter) between consumers and service providers to the energy-consuming device or appliance, and includes all elements in the chain of technologies that ultimately enable electricity to be transformed into such services as motive power; lumens of visual quality applied to the work surface, or digitized processes. [38]

The two key tenets of this initiative are the focus on the ultimate consumer and the engagement of entrepreneurial capability outside the electric utility industry.

Governance

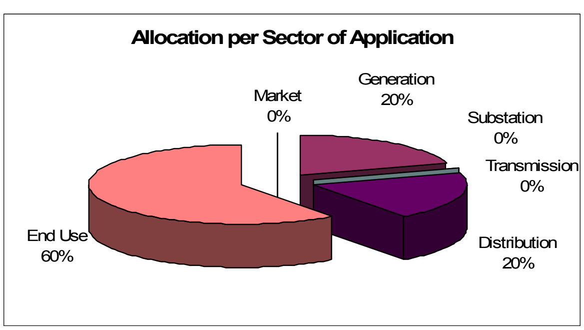
The initiative is not an association of members; rather, it involves potential stakeholders through workshops to gather requirements and guidance from a variety of commercial sources that would enable implementation of the initiative's configurations.

Budget

Estimated budget for Phase 1: $1M (executed in 2005).

Estimated budget for Phase 2: $1.5M (planned in 2006).

Figure 12-2 shows the distribution of the initiative's budget among the sectors of application and systems engineering categories. The charts provide a general indication of the focus of the program (rough estimation based on reports published to date).



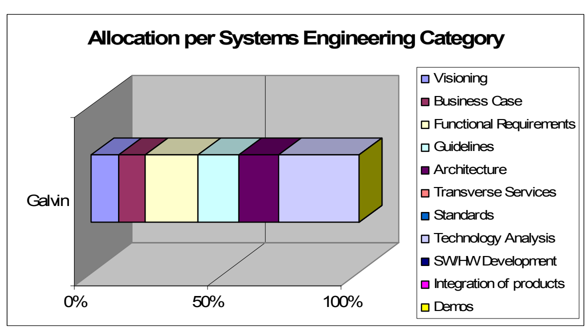


Figure 12-2
Distribution of the Galvin Electricity Initiative R&D budget (spent to date)

Promotion

- Public relations initiative
- Book publication

Research Projects

The initiative has defined two main objectives for its research projects: [36]

- To define a confident systemic solution for achieving and maintaining an absolutely reliable electricity service capability meeting 21st century consumer needs and expectations.
- To examine the opportunities for the marriage of this transformed electricity service capability and innovative electro-technologies to advance prosperity and quality of life.

The first users of the results of the Galvin Electricity Initiative will be technically oriented, mostly companies interested in microgrids and certainly manufacturers of solutions.

The Galvin Electricity Initiative is being executed in two phases: [37]

Phase 1

The Phase 1 effort focused on development of potential system configurations for the perfect power system that leverage identified **“**nodes of innovation,**”** representing the convergence of future customer needs and technological promise. This initial phase was based primarily on identifying technologies that would need to evolve to achieve and enable perfection. [39]

The initiative took a “clean sheet of paper” approach to the challenge of meeting the criteria of perfection. As a result, four potential power system configurations were identified:

- Portable power
- Building integrated (localized) power
- Distributed power
- Fully integrated power

The first notion developed is that consumers increasingly expect greater power portability. Once perfection in portability is defined, it provides elements of perfection that enable a dispersed perfect system. Dispersed systems can, in turn, be interconnected to form distributed perfect systems that can also be integrated to enable a fully integrated national Perfect Power System. The path defined is gradual, from the smallest configuration to the largest, even if some concurrent improvements could eventually happen.

Figure 12-3 shows project flows for Phase 1 and articulates questions that need to be addressed to change the existing paradigm and identify key innovation technologies.

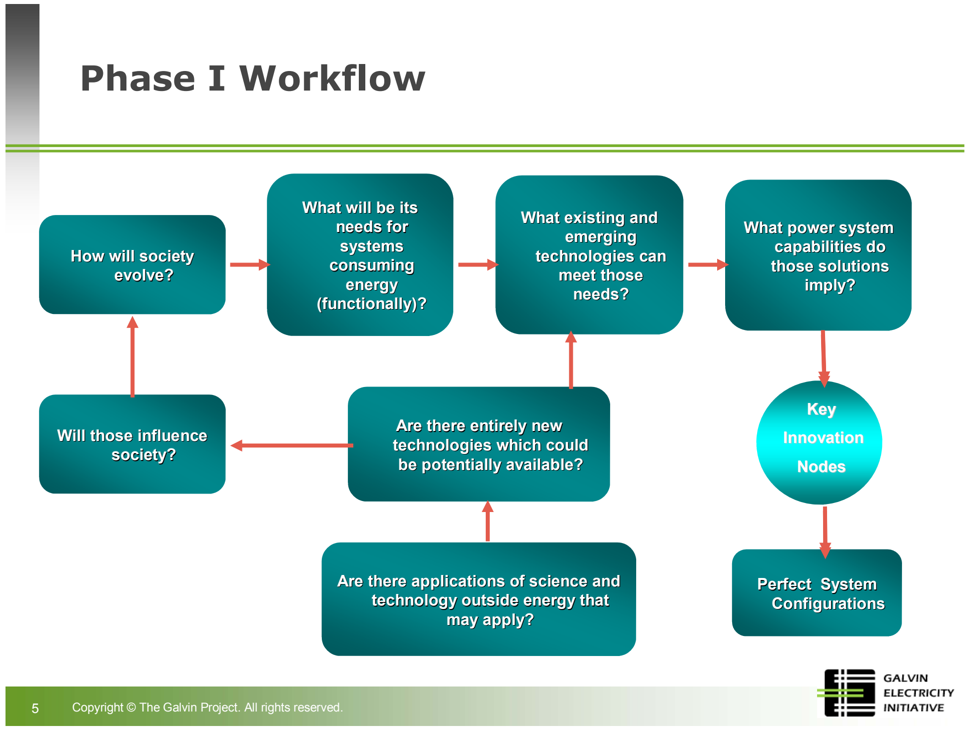


Figure 12-3
Project workflow for Phase 1 of the Galvin Electricity Initiative

The Assessment of Potential Energy Technology of Phase 1 describes how technologies will contribute to the development of a perfect system. It provides an overview of the major trends and innovations in the application area. The following technology areas, identified as key by the program, were studied in this task: lightning, space conditioning, indoor air quality, domestic water heating, water and wastewater treatment, waste management with biofuel production, manufacturing processes, information technology, transportation, distributed generation, electric energy storage, portable power, and power quality.

Barriers to implementing the perfect system were identified during workshops held in Phase 1. Some of the barriers were technical but most were related to policy, culture shift, and market structure.

This phase was completed in February 2006.

Phase 2

Phase 2 will further evaluate and conduct a definitive analysis of the power system nodes of innovation and potential configurations leading to the perfect power system. [39] As Figure 12-4 shows, Phase 2 will address these needs and results in the development of a comprehensive implementation blueprint for the perfect electric energy system of the future—that is how to transition the existing electric energy system to the future perfect electric energy system.

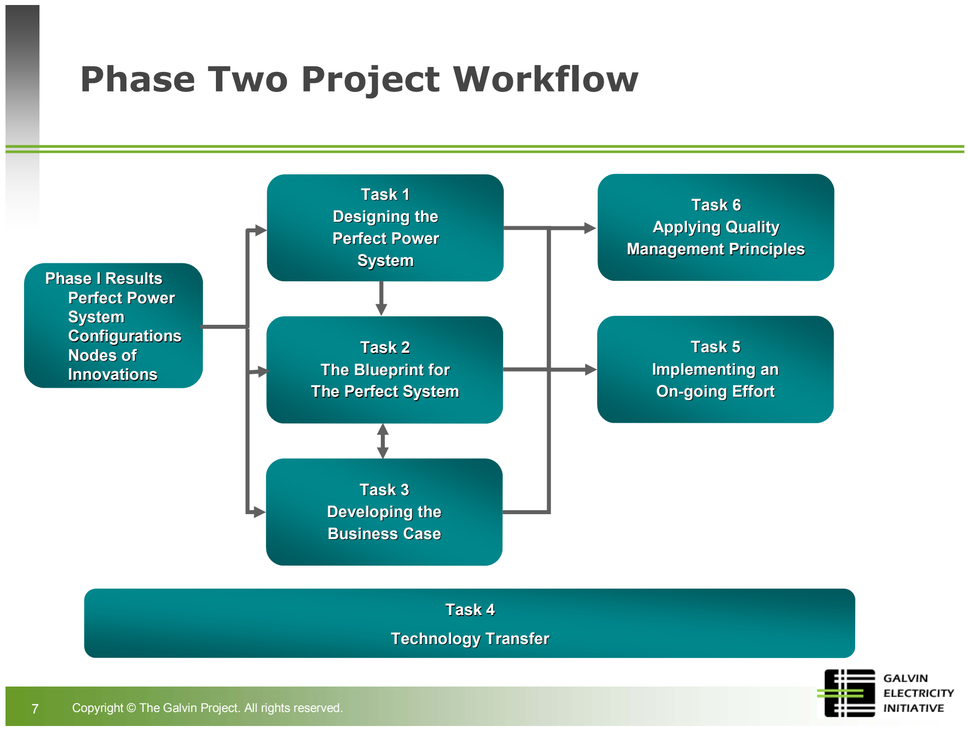


Figure 12-4
Phase 2 workflow of the Galvin Electricity Initiative

The business case development task will develop a valuation model, shown in Figure 12-5, to identify the sensitivity of the performance attributes of each innovation node. It will be based on the metrics of the four different configurations of the perfect system.

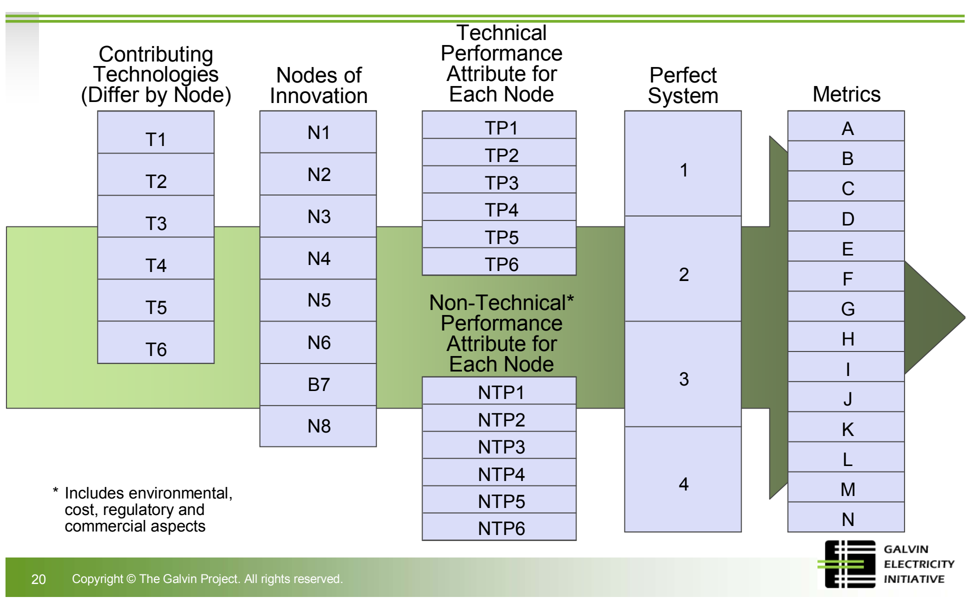


Figure 12-5
Valuation model planned in Task 2 of the Galvin Electricity Initiative

Phase 2 began in March 2006 and is scheduled for completion at the end of 2006.

Accomplishments to Date

Following are reports published in Phase 1 of the project:

- The Path to the Perfect Power System
- Scenarios of Consumer Needs in 2025
- Potential for End-Use Energy Technologies to Improve Functionality and Meet Consumer Expectations
  - Vol. 1—Summary of Results
  - Vol. 2—Evaluating Trends in End-Use Sectors
  - Vol. 3—Descriptions of Technology Application Areas
- Technology Scanning, Mapping, and Foresight
- Analysis Framework
- Developing Functional Requirements for the Perfect Power System

Contribution to the Intelligent Grid

Table 12-1
Reference metrics analysis for Galvin Electricity Initiative

Categories	Galvin Electricity Initiative
Applications	
Visioning and Concepts	• Perfect Energy Service Delivery System • Four configurations defined for the perfect energy service delivery system
Business Case	• *Economic analysis of Galvin alternatives (Phase 2)*
Functional Requirements	• Preliminary power systems requirements (Phase 1) • *Characterization of power system performance and performance gaps (Phase 2)* • Descriptions of the attributes of functionality required for each of the contributing technologies
Guidelines and General Framework	• Scenarios of Consumer Needs in 2025 and needed technologies (Phase 1) • Innovation Opportunity Nodes (Phase 1) • Analysis of barriers to the implementation of a perfect energy service delivery system (Phase 1)
Services (Bridge Between Products and Needs)	
System Architecture	
Transverse Services	• *Blueprint for implementation of a perfect energy service delivery system (Phase 2)*
Infrastructure (Products and New Technologies)	
Standardization and Users Groups	
Technology Analysis	• Electricity Technology Space Map™ that evaluates existing and emerging technologies (Phase 1) • Detailed identification and analysis of Innovation Opportunity Nodes (Phase 1)
Software and Hardware Development	
Product Integration	
Demonstration	

Legend: Italic indicates an expected deliverable of a planned project.

13
INTELLIGENT GRID R&D MAPS

This chapter presents maps, charts, and graphs depicting the budgets and project applications of the grid R&D programs profiled in this study. Initial findings reveal complex positioning of the programs, with each covering a wide area of sectors and focusing on the various requirements of application, architecture, or technology issues, depending on program objectives.

The comprehensive map contained in Figure 13-1 illustrates the intricate network of deliverables these programs offer. It provides details on the nature of each deliverable as it corresponds to the colored boxes in the map. This information can be used to identify applications for research results and to uncover opportunities for collaboration.

Several charts and graphs in the chapter provide comparisons of the program budgets for smart grid research. These comparisons, which use the same metrics as the project maps, are based on publicly available information and, in some cases, estimations of budget allocations as stated in each program profile. The numbers included in these charts and graphs are based on real expenditures but have been weighted to preserve confidentiality.

The chapter concludes with a map created by NETL showing a different representation of U.S. programs focused on the modernization of electric delivery.

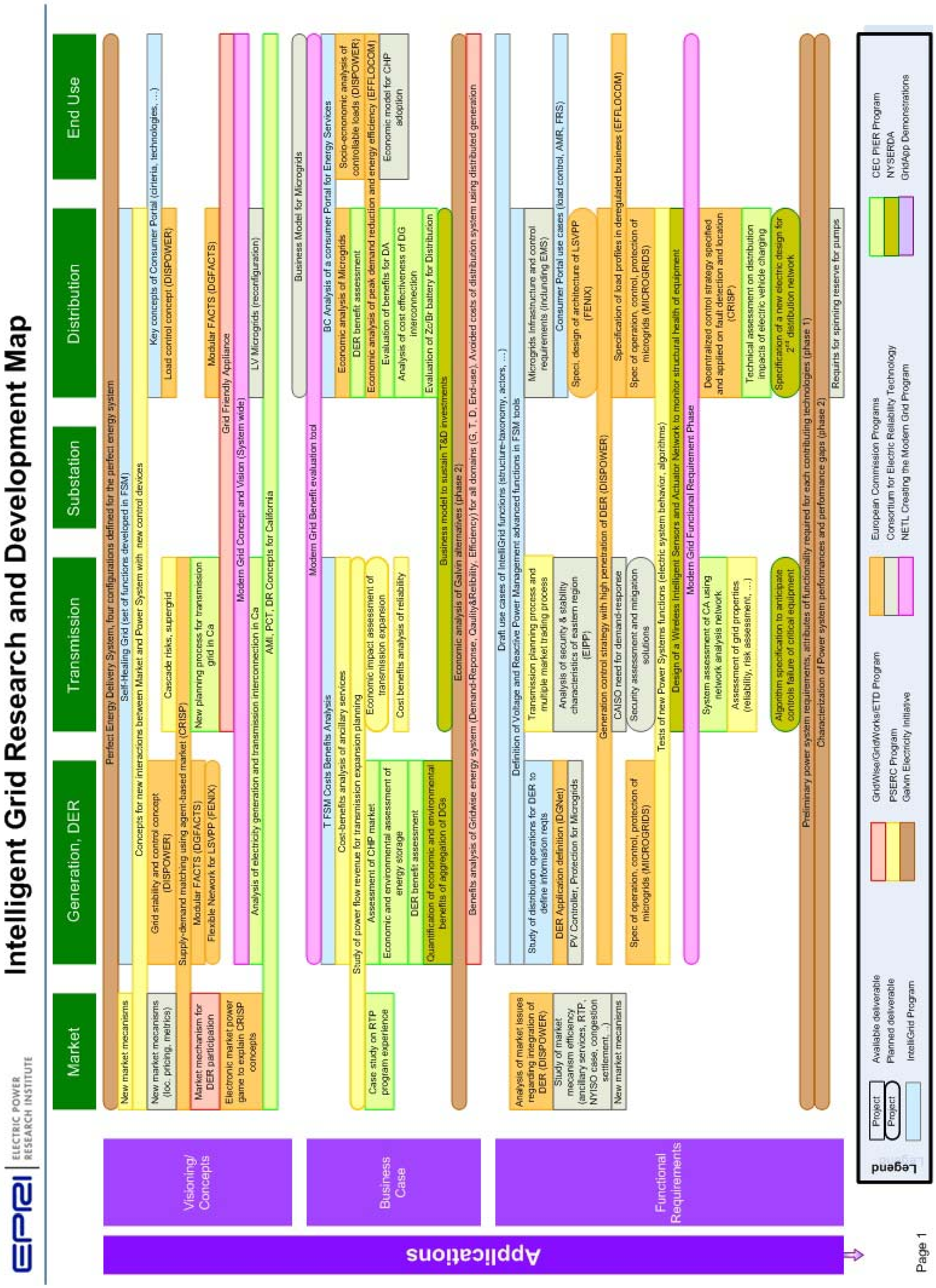


Figure 13-1
Comprehensive map of intelligent grid R&D programs (next 3 images)

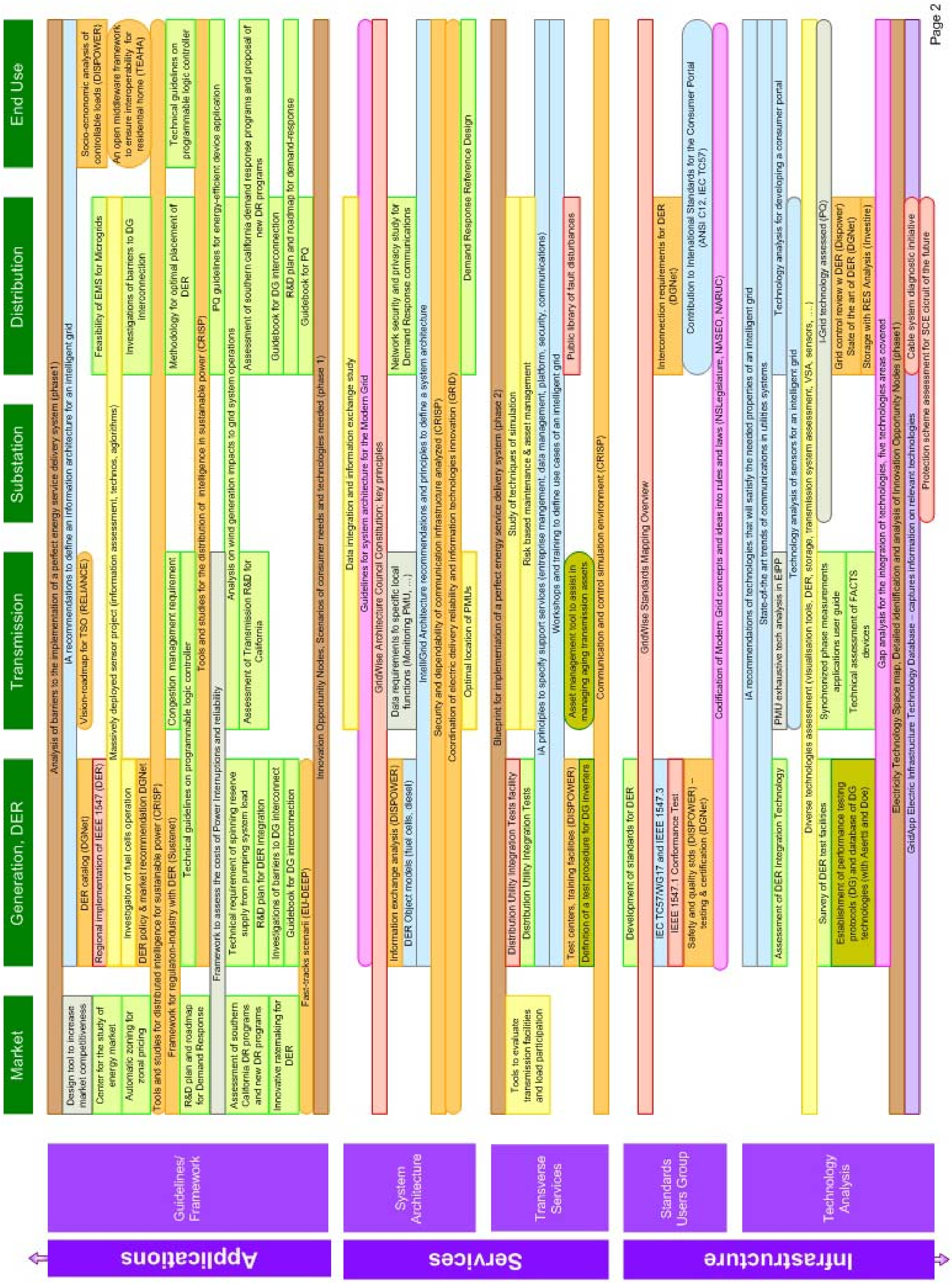


Figure 13-1 (continued)

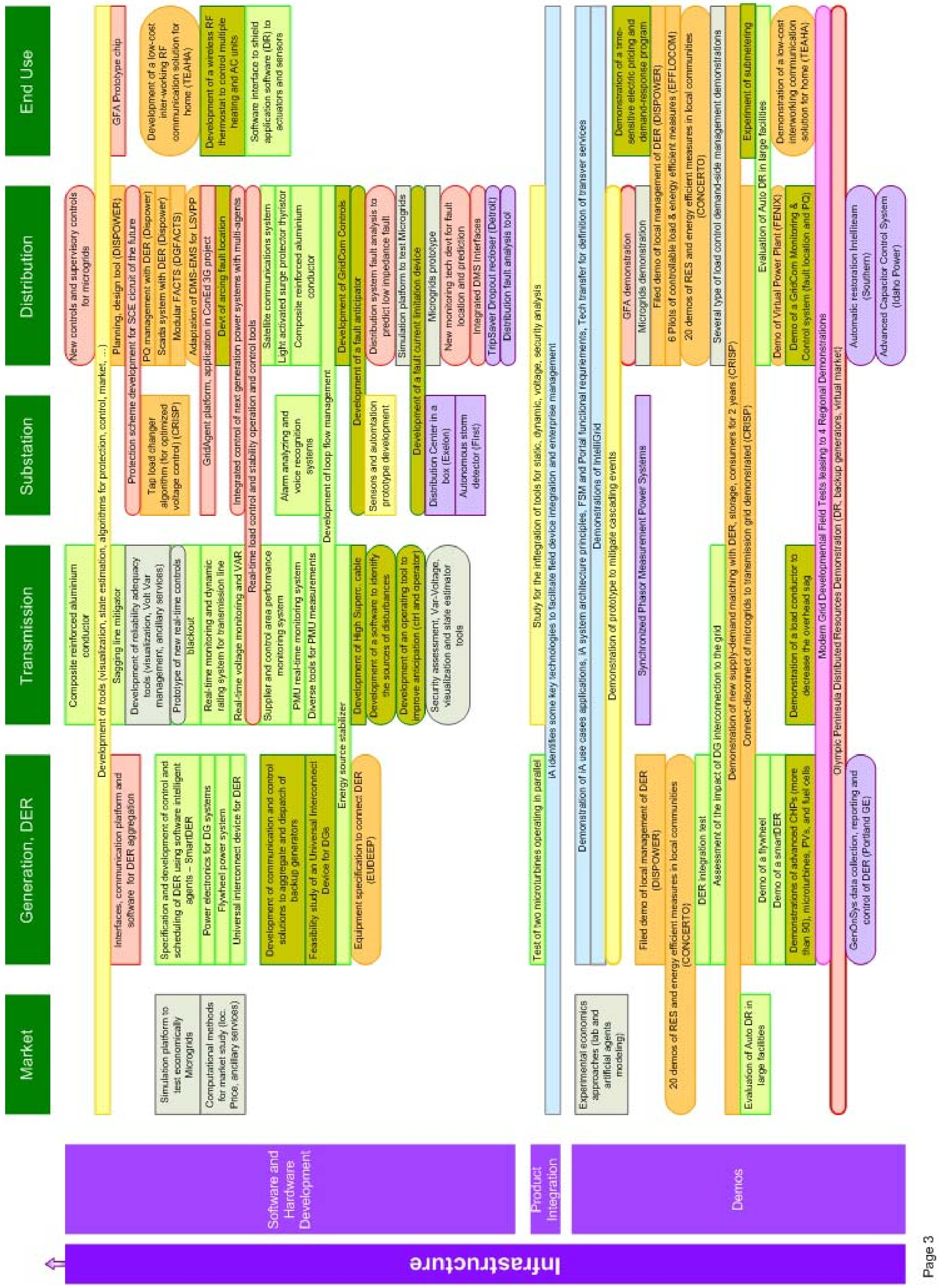


Figure 13-1 (continued)

From this map, IntelliGrid, GridWise, CEC–PIER, CERTS, and the European Commission programs were short-listed for further comparison, based on number of projects or significance of results. Figure 13-2 was developed to promote discussion and to clarify positioning. It shows the interrelationships between the R&D efforts of the programs.

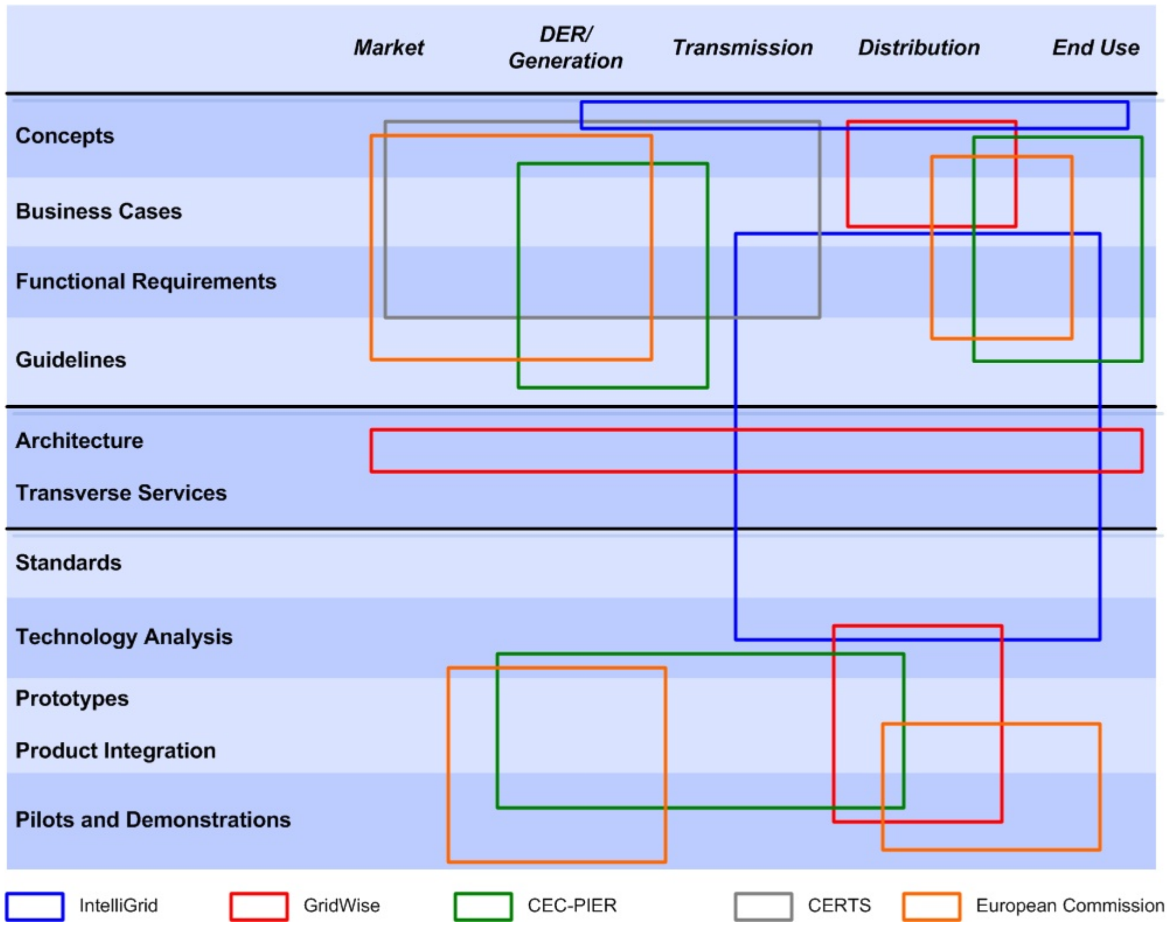


Figure 13-2
Interrelationships of grid R&D programs, short list

Budget Analysis

Further analysis involved the use of publicly available, cumulative budget information to compare the efforts of each program. Figures 13-3 and 13-4 illustrate relative allocated funding, as estimated for each industry sector and each category in the study. The units of these graphs are weighted, rather than in U.S. dollars, since the purpose of this analysis is to determine the commonalities and differences between programs while preserving the confidentiality of numbers disclosed by each organization.

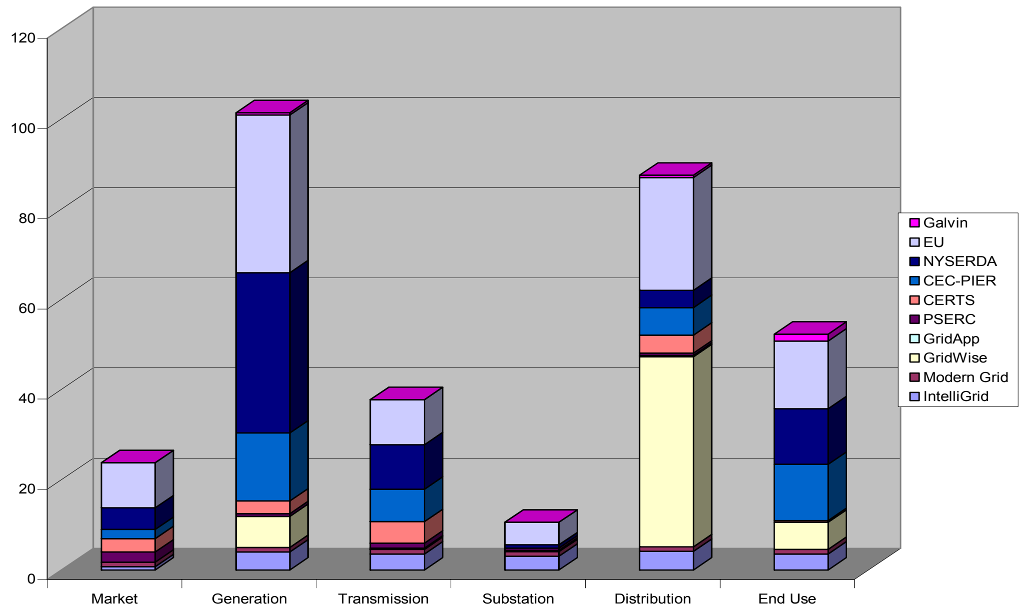


Figure 13-3
Relative comparisons of program funding, by sector of application

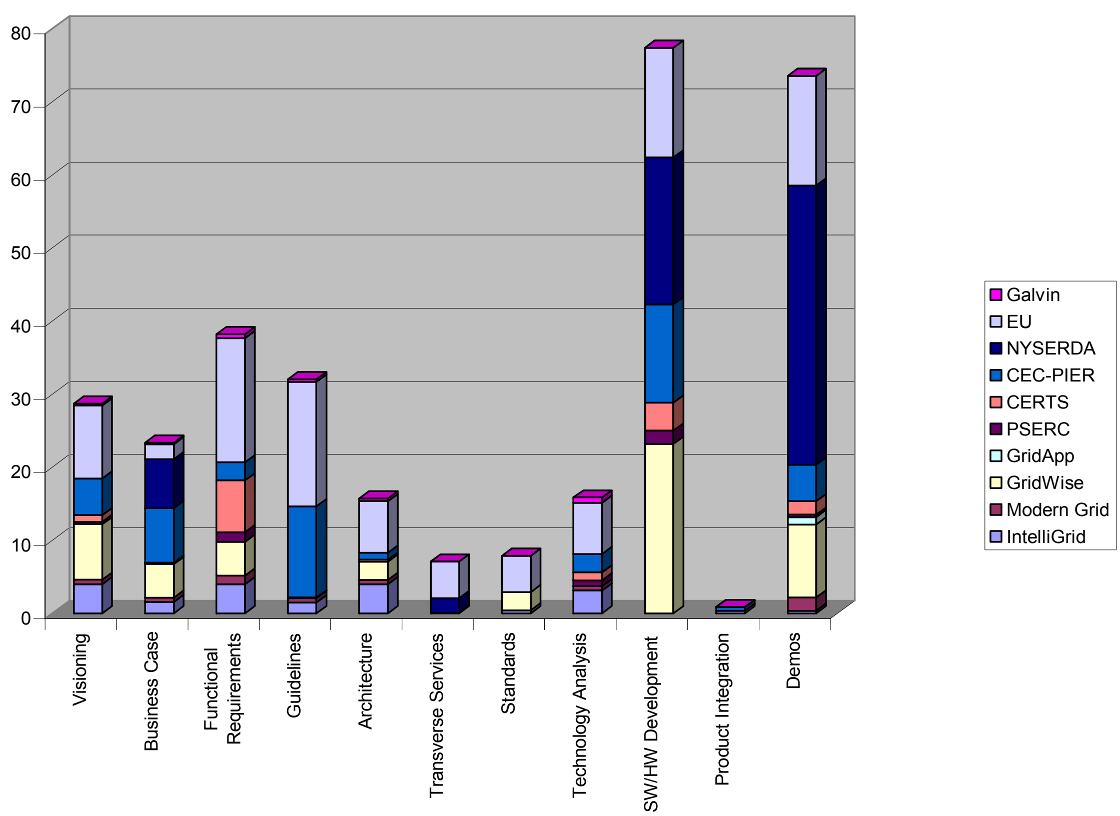


Figure 13-4
Relative comparisons of program funding, by systems engineering sub-category

Comparative Efforts

Based on estimated budget allocations for each program, a comparative chart was built to highlight the differences and commonalities of the programs. Figure 13-5 shows the relative research efforts of each program by sector of application.

IntelliGrid and The Modern Grid Initiative have split their efforts relatively evenly among all sectors, while GridWise has focused on distribution issues. PSERC and CERTS have made the largest investments in market-related research projects. Public organizations CEC–PIER, NYSERDA, and European Union are addressing the integration of distributed energy resources. At the Galvin Electricity Initiative, the focus is on end-use applications. With only a limited number of projects at GridApp, no conclusions could be drawn.

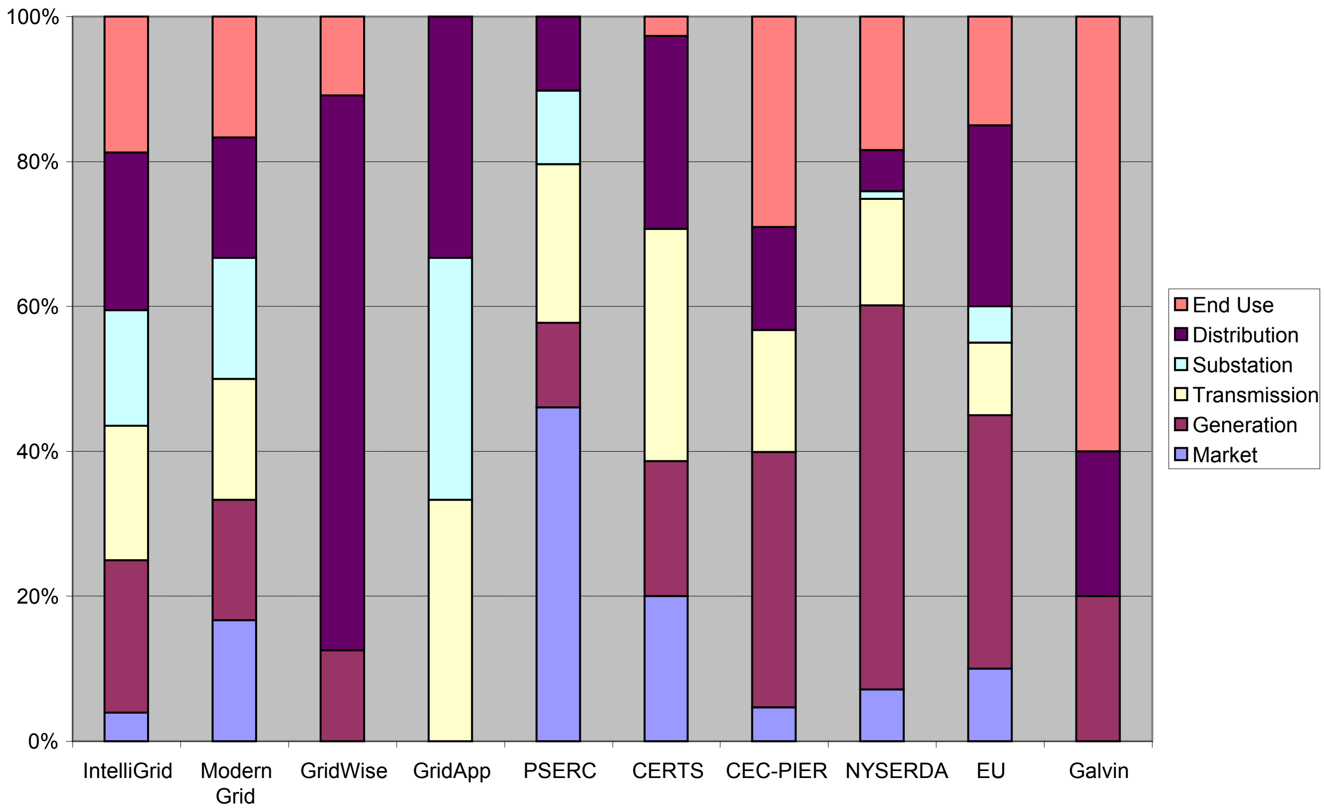


Figure 13-5
Sector applications per program

Figure 13-6 highlights the relative R&D efforts of each program by systems engineering sub-category. At GridApp the focus is exclusively on demonstration and technology development, as stated in its mission. GridWise and NYSERDA place a heavy emphasis on software and equipment prototypes. CERTS develops a number of projects that address functional requirements and electric engineering issues. The remaining programs split their research among the sub-categories, from concept to demonstration.

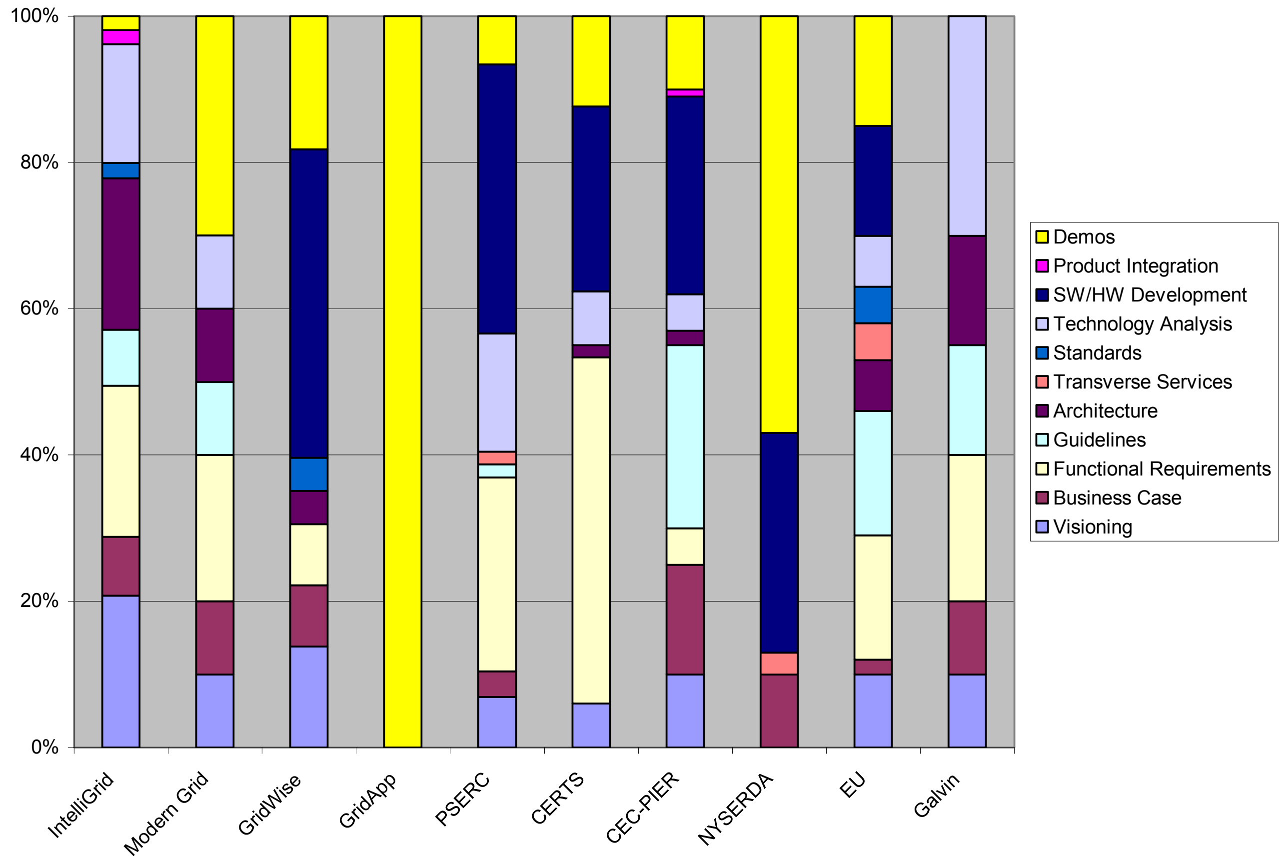


Figure 13-6
Systems engineering sub-category applications per program

Another way to characterize the program efforts is to compare them in absolute values. Figures 13-7 and 13-8 present these views by sector of application and by systems engineering sub-category, respectively.

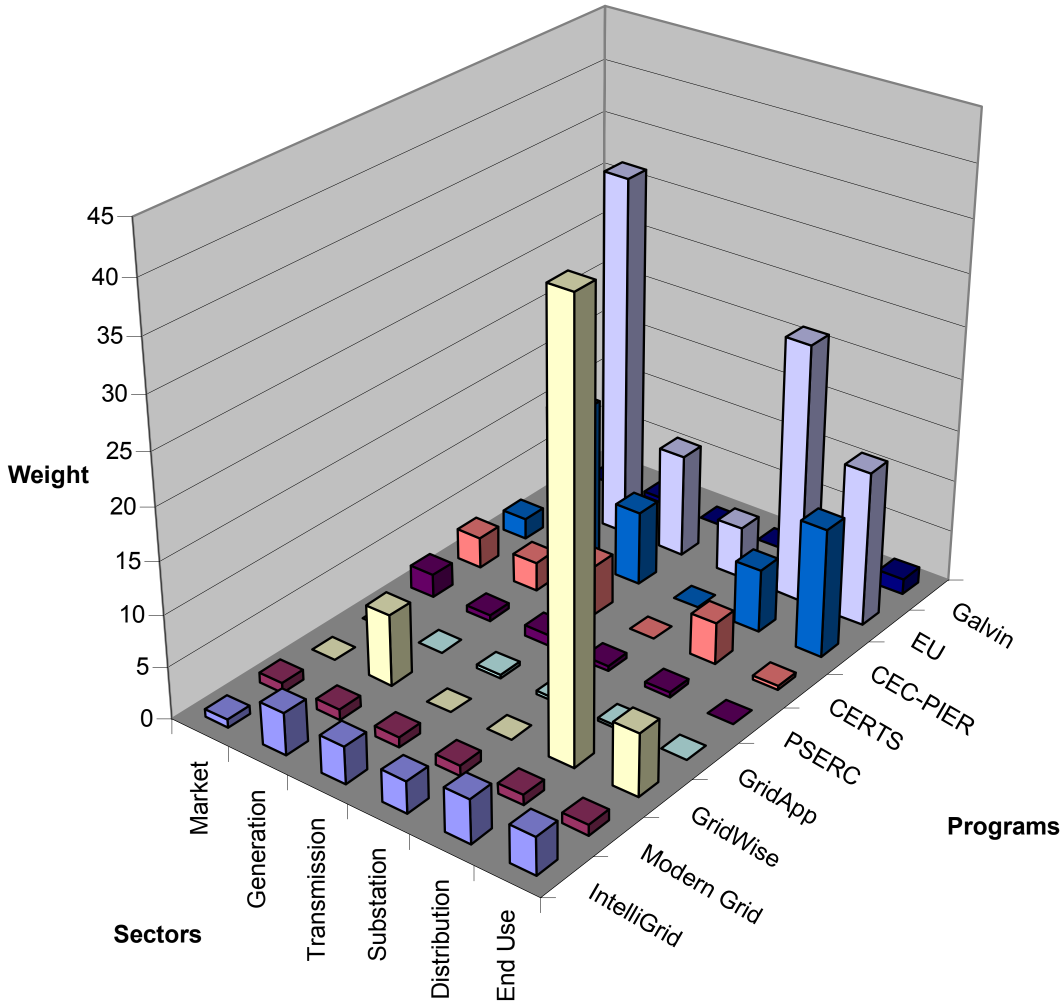


Figure 13-7
Program efforts per sector of application

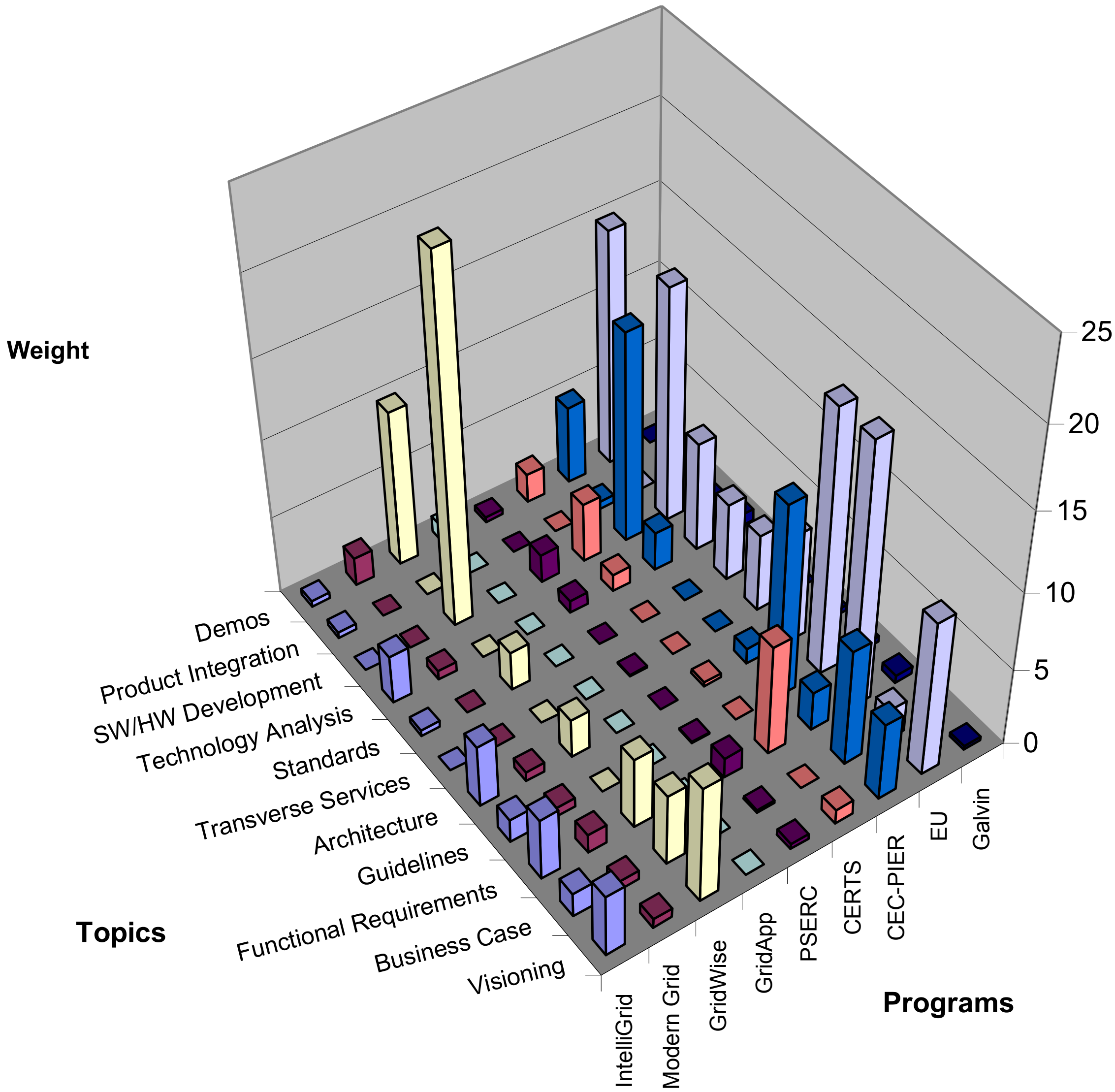


Figure 13-8
Program efforts per systems engineering sub-category

Other Available Maps

To date, just one program has developed a map of intelligent grid R&D activities. This map, created by NETL and shown in Figure 13-9, was presented at the Northwest Regional Summit of The Modern Grid Initiative in April 2006, and at the GridWise Exposition in Palm Springs, California, in May 2006.

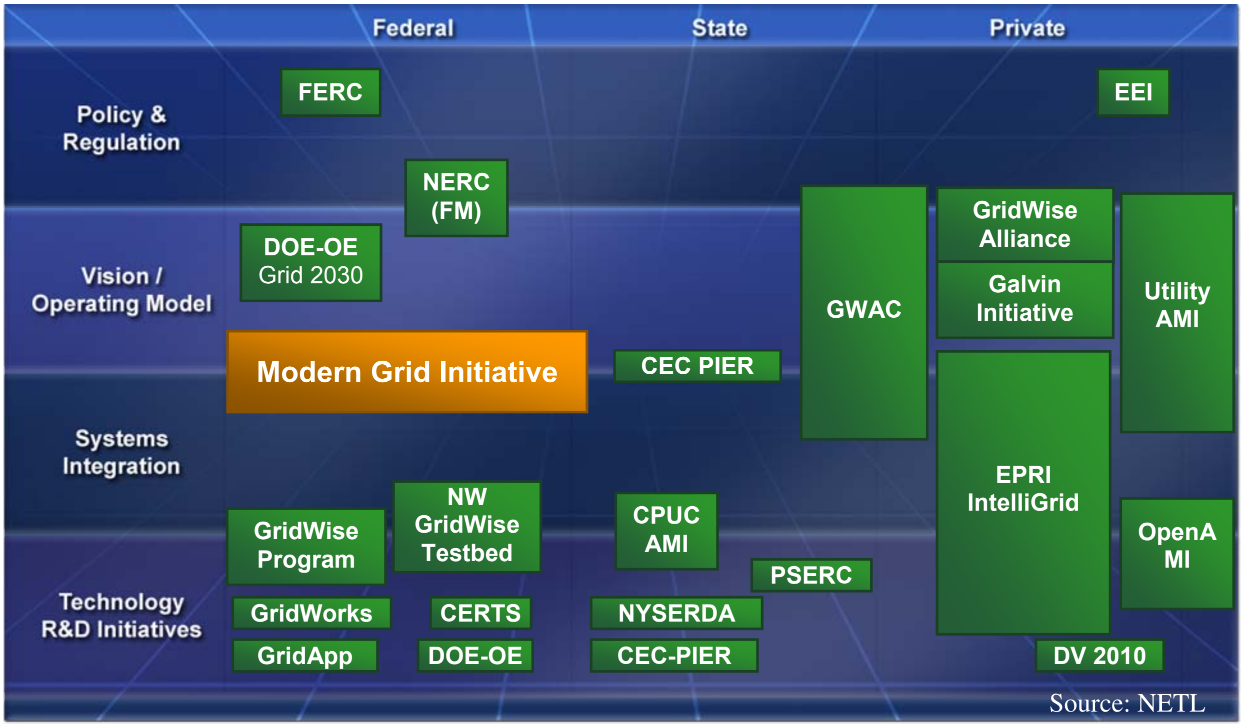


Figure 13-9
NETL map of intelligent grid R&D programs in the U.S.

14
HANDSHAKE ACTIONS

IntelliGrid has engaged in dialogue with all of the research programs profiled in this report and has established relationships with several of them. These relationships are intended to identify joint, or “handshake” actions that define common principles for coordination and collaboration. These actions enable each program to gauge how their research results might complement another program’s efforts. They also serve to minimize overlaps between R&D projects.

IntelliGrid continues to identify new opportunities for handshake actions. Following is a summary of existing relationships between IntelliGrid and the grid R&D programs.

1. GridWise
   - An IntelliGrid program manager sits on the GridWise Architecture Council and on the review panel for the DOE Distribution program.
   - IntelliGrid joined the GridWise Alliance in 2006. The executive director of the GridWise Alliance has attended several IntelliGrid Steering Committee meetings since 2005.
2. The Modern Grid Initiative: EPRI and NETL have exchanged mutual invitations to their high-level meetings, with a NETL delegate attending IntelliGrid Steering Committee meetings and an IntelliGrid representative participating in part of the Modern Grid Regional Summit.
3. PSERC: EPRI is a member of PSERC, and the two organizations have held several meetings to explore potential research collaborations. Each program sends a representative to the PSERC Industry Advisory Board and the IntelliGrid Steering Committee.
4. European Commission: IntelliGrid has made several contacts to exchange information with the European grid R&D program. Recently, the European Commission and DOE collaborated on an article, to be published soon, that reports on European and U.S. views of smart grids.
5. CEC–PIER: CEC was a member of the IntelliGrid Consortium from 2002 to 2005. EPRI supplies research results to CEC on a specific basis.
6. Galvin Electricity Initiative: The former CEO of EPRI is leading this initiative, and EPRI serves as a contractor for the program.

What's Next?

Handshake actions come in two types: multilateral (or joint) agreements between multiple organizations, and unilateral (program-based) actions that give each program the authority to engage. IntelliGrid currently is developing both types of actions.

Applying Common Principles for Coordination

The *Profiling and Mapping of Intelligent Grid R&D Programs* report provides a unique collection of shared information on the wide-ranging efforts of the grid research community. A multilateral effort with the purpose of applying this information would provide added input, while ensuring unambiguous implementation of results. IntelliGrid has been in discussion with DOE about engaging grid R&D organizations in a structured commitment to improve program integration.

The first step in this direction is a workshop, which will be sponsored jointly by developers of smart grids and will be held at the beginning of 2007. This workshop will assemble an agreed-upon set of principles for achieving coordination among programs and will identify a collaborative project that organization will agree upon. On the heels of this workshop will be working group meetings, whose goal will be to transform the common principles into an action plan and track their status. Information contained in this report will feed coordination activity and could lead to refinement of common mapping activities and discussion of online mapping tools.

Updated and Expanded Profiles and Mapping

The information contained in this report is dynamic in nature. Future versions are planned to update program profiles and mapping. Online tools also will be used to facilitate real-time updates.

The next phase will add several research organizations not included in the initial mapping project. Also planned are analyses of intelligent grid R&D programs in Canada, Asia, and Europe. Information gathered in this unilateral effort on the activities of other public research organizations, manufacturers, electric utilities, and standards bodies will help to improve the positioning of worldwide research and further align developers of the intelligent grid.

Among the organizations under consideration are

- The Distribution Vision 2010
- Canadian Electric Association
- SINTEF (Scandinavian Research Organization)
- U.K. Department of Trade and Industry Research Portfolio
- The Reliable and Smart Utility (Center for Smart Energy)
- Smart Energy Alliance (Hewlett-Packard, General Electric, Cisco, Oracle, CAP, and Intel)

- Distribution Systems Testing, Application, and Research Programs (DSTAR)
- Standardization activities under the banner of the International Electrotechnical Commission
- Standardization activities under the banner of Institute of Electrical and Electronics Engineers

Map of Drivers of Intelligent Grid Projects

As research programs are driven by tactics that implement strategic drivers, identifying these drivers and linking them to each research project could provide valuable information on project similarities. They also could lead to agreements among research organizations on project direction and could be followed up by new co-funded projects. IntelliGrid will engage an effort to identify these drivers and provide a tool to connect them to the research projects.

A

APPENDIX – GRIDWISE AND DOE ORGANIZATION

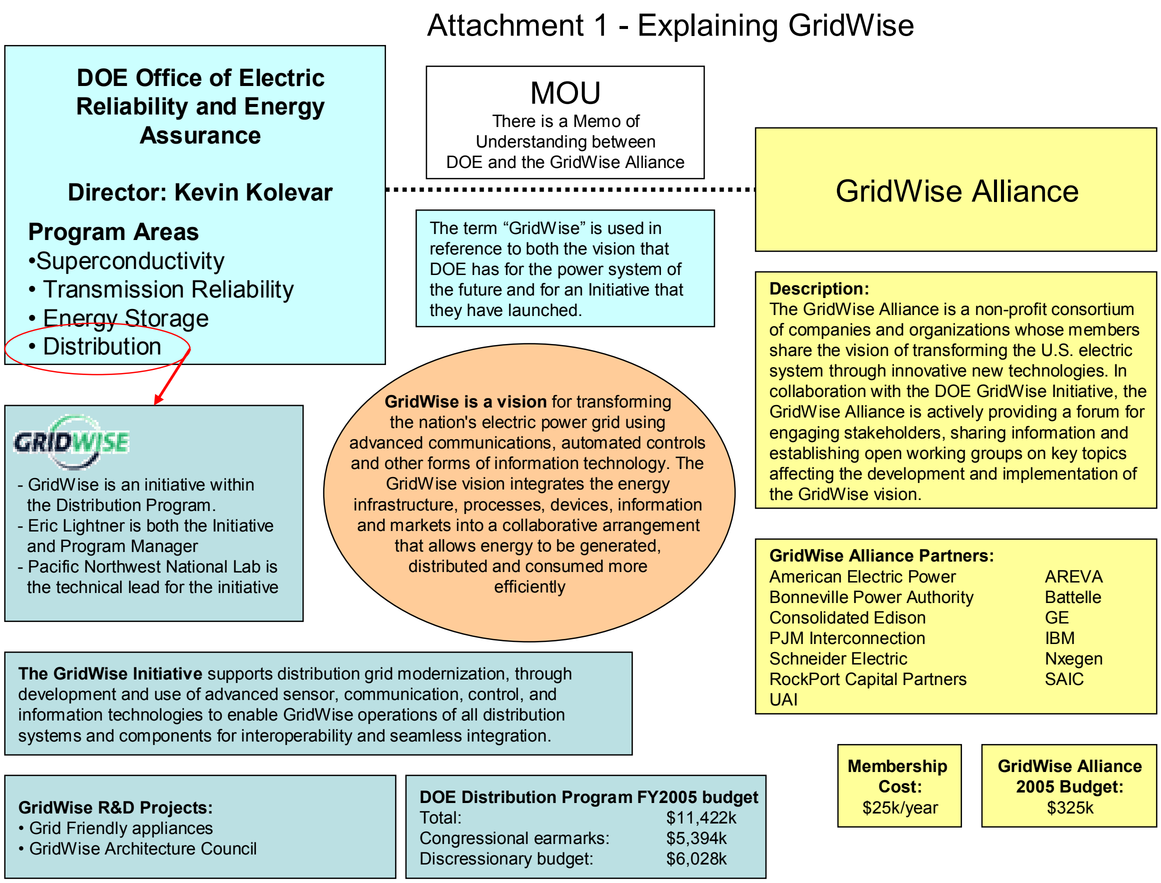


Figure A-1
Organization and links between GridWise and DOE

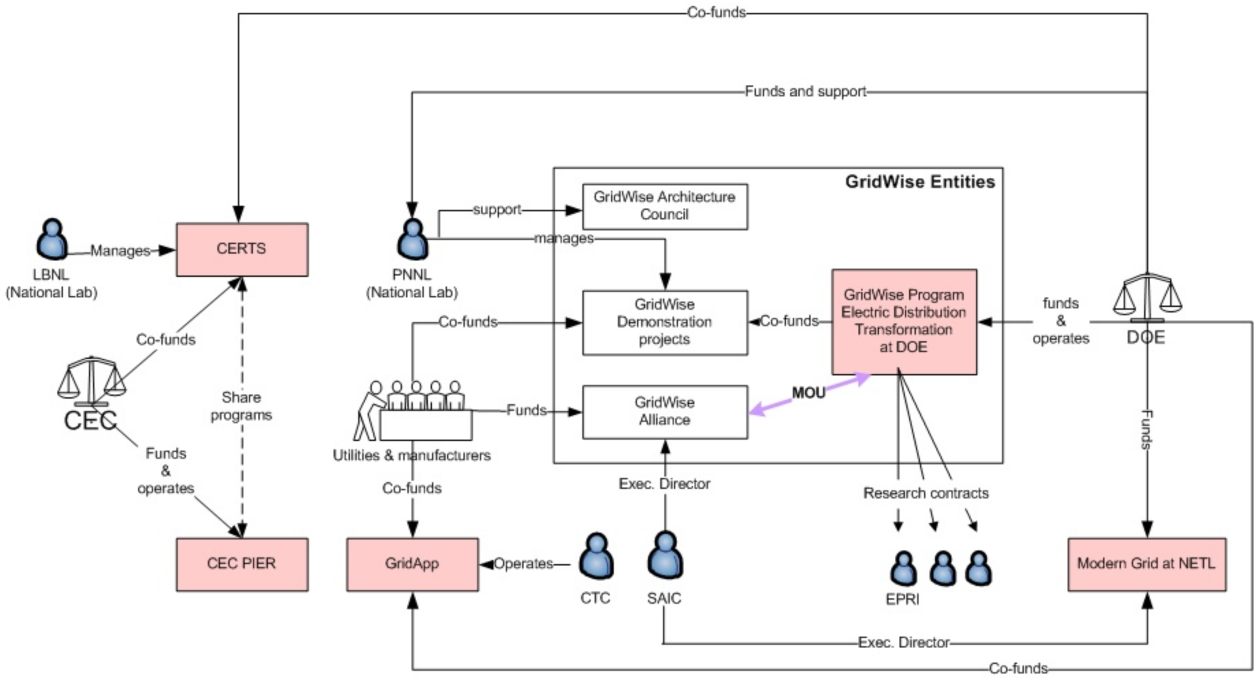


Figure A-2
Relationships between U.S. public research programs working to transform electric delivery into the intelligent grid

OETD At-a-Glance

Activity	*Scope*
Superconductivity	Conducts RD&D activities in high temperature superconducting (HTS) materials for electric power systems.
Transmission Reliability	Conducts RD&D activities in information technologies, software programs, and reliability/ analysis tools to support grid reliability and efficient markets.
Electric Distribution Transformation (EDT)	Conducts RD&D activities for advanced interconnection standards and communications and controls to integrate distributed energy resources (DER) with the electric power distribution system.
Energy Storage	Conducts RD&D activities in storage technologies and systems, including batteries, flywheels, and ultracapacitors.
GridWorks	Conducts RD&D activities in cables and conductors, substation and auxiliary equipment, and power electronics.
GridWise	Conducts RD&D activities for advanced sensors, communication, information, and control technologies to create a smart automatic electric power network.
Electric Markets Technical Assistance	Provides technical assistance and analytical support to states and regions that facilitate reliable, competitive wholesale and retail electric markets.
Presidential Permits/Export Authorization	Manages the regulatory review of electricity exports and issues Presidential Permits.

Figure A-3
Summary of the DOE OETD Research Program

B
APPENDIX – INTELLIGENT ENERGY – EUROPE

Intelligent Energy – Europe (IEE), a program of the European Union, has a total budget of €250M, which it uses to co-finance international projects, events, and startups of local or regional agencies in four main fields:

1. Energy efficiency and rational use of energy, in particular in buildings and industry (SAVE)
2. Promotion of new and renewable energy sources for electricity, heat, and biofuels (ALTENER)
3. Energy aspects of transport, fuel diversification, biofuels, and energy efficiency (STEER)
4. Promotion of renewable energy sources and energy efficiency in developing countries (COOPENER)

Within these four areas, funding is available for projects that enhance the capacity for more intelligent use of energy and wider use of renewables. Project efforts can include input into European policy development, creation of certification and labeling systems, monitoring of market conditions, promotion of sustainable energy, sharing of best practices, and capacity building. To date, IEE supports nearly 90 international projects for energy efficiency and renewables, shown in Table B-1, with more to be added soon.

Table B-1
IEE projects

COOPENER Projects (Community cooperation with developing countries)	ALTENER Projects (Renewable energy sources)	STEER Projects (Energy aspects of transport)	SAVE Projects (Energy efficiency)	Horizontal Projects (Integration of energy effciency and renewables)
These projects focus on capacity building and training in developing countries. The underlying aim is to strengthen local policies and legislation and to encourage sustainable energy services for poverty alleviation and sustainable development. Links are drawn to the EU energy initiative for poverty alleviation and sustainable development in Africa, Asia, Latin America and the Pacific.	These projects help increase the use of new and renewable energy sources and to speed up policies for sustainable energy. The emphasis is on the promotion of both central or local production of electricity and/or heat, and on its integration into local energy systems.	These projects promote the more sustainable energy use in transport (i.e. increased energy efficiency, new and renewable fuel sources, and the take-up of alternatively propelled vehicles). The specific focus is on alternative vehicle propulsion, policy measures for the more efficient use of energy in transport, and strenghthening the knowledge of local management agencies in the transport field.	These projects exploit the immense potential for energy savings, particularly in buildings (construction and use) and industry. The emphasis lies on 4 themes: Multiplying success in buildings, retrofitting of social houses, innovative approaches in the industry, and energy efficient equipment & products.	These 'horizontal' projects (i.e. projects concentrating on the 'Horizontal Key Actions' of the IEE Programme) deal with the various aspects and themes addressed by the IEE Programme in a more integrative way. They inlucde projects for energy effciency and renewables in specific local settings, but also projects which complement more sector-specific actvities through monitoring, evaluation, promotion and work on financial issues.
Project Acronym and Description	**Project Acronym and Description**	**Project Acronym and Description**	**Project Acronym and Description**	**Project Acronym and Description**
APPLES Provision of Local Energy Services	**5 EURES** Five European RES-Heat Pilots	**COMPETENCE** management agencies in the	**AUDITAC** development for Audit methods in Air	**AID-EE** European Directive on Energy
BEPITA Implementation for Training in Africa	**Biomass Partnerships** markets through plant partnerships	**e-ATOMIUM** In Union Member states	**BESS** Management Schemes in SMEs	**EurObserv'ER** EurObserv'ER Barometer
DEA Development and Energy in Africa	**BioProm** the non-technical barriers of project-	**TREATISE** agencies and actors in transport and	**BESTFACADE** Facades	**EUROCONTRACT** the Promotion of Energy
ENABLE health, education and water sectors	**BIO-SOUTH** the production and use of biofuels for		**BUDI** market for energy performance	**EuroWhiteCert** European energy efficiency Policy
ENEFIBIO barriers to encourage SME energy	**Boosting Bio** Boosting Bioenergy in Europe		**COGEN CHALLENGE** Development and Documentation of	**FEEDU** education
IE4SAHEL Sahel	**CLEAN-E** Clean Energy Network for Europe		**DEEP** Measures in the Public Buildings	**FINANCE** National Association Networking in
IMRPOVES-RE impact of rural electrification	**DG-GRID** sustainable electricity supply through		**DEXA-MCP** Application of the Motor Challenge	**ODYSSEE-MURE** EU15 and Norway
INSABA Advisory	**EARTH** Training for Heating		**E-Check in Craft SME** Checks in Small and Medium Craft	**PRIME** (2nd application)
MEPRED Pilot Project: Mainstreaming Energy	**ECOHEATCOOL** study		**EEBD** vocational Web training tool for the	
MIRREIA Capacity for Rural Electricity	**ELEP** European Local Electricity Production		**EMS-TEXTILE** Practices in the Textile Industries of	
PEPSE Sustainable Energy	**ELVA** RES Heat in local communities		**ENPER EXIST** Energy Performance Requirements	
PROVEN PROVEN in Rural Africa	**Engine Earth 2** Renewable Energy for Heat following		**EPA-NR** Existing Non Residential Buildings	
SIE-Afrique II systèmes d'informations	**E-TRACK** Electricity		**EPLABEL** certificates for display in public	
TIE-ENERGIA Empowerment: Strengthening	**EUBIONET II** analysis of fuel supply chains and		**E-Tool** energy performance of existing	
	Green Energy Cluster markets through establishment of		**EULEB** Energy Architecture	
	GREEN LODGES LODGES		**GREENBUILDING**	
	GreenNet-EU27 of RES-Electricity in an extended		**IMPACT** Assessments and Certification	
	K4RES-H Europe		**Intelligent Metering** Metering and Behavioural Change	
	OPTRES renewable support schemes in the		**KeepCool** Promotion of "sustainable cooling" in	
	PROBIOGAS and Heat Production in EU Countries-		**OPTIPOLYGEN** POLYGENeration in the Food	
	PROPELLETS systems in the market		**Passive-On** Winter and Summer Comfort	
	PV POLICY GROUP		**PEP** Houses	
	QUOVADIS Validation of standards,		**PU-BENEFS** Energy Efficiency Services in Public	
	REALISE FORUM in selected electricity markets Forum		**RECIPE** Plastics Engineering	
	RES Market-places Places for Investors and Regional		**STABLE** Energy Certification: Improving	
	RES-e Regions European regions		**ST-ESCOs** Energy Service Companies (ST-	
	RURASU RES In Heat Systems And Integrated		**TOWARDS CLASS A** Buildings As Shining Examples	
	SOLARGE Multi-Family Houses and Hotels in		**Vent Dis.course** Vocational Training Material for the	
	ThermalNet biomass conversion for power, heat			
	WINEUR Urban Environment			

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APPENDIX – PSERC MAP

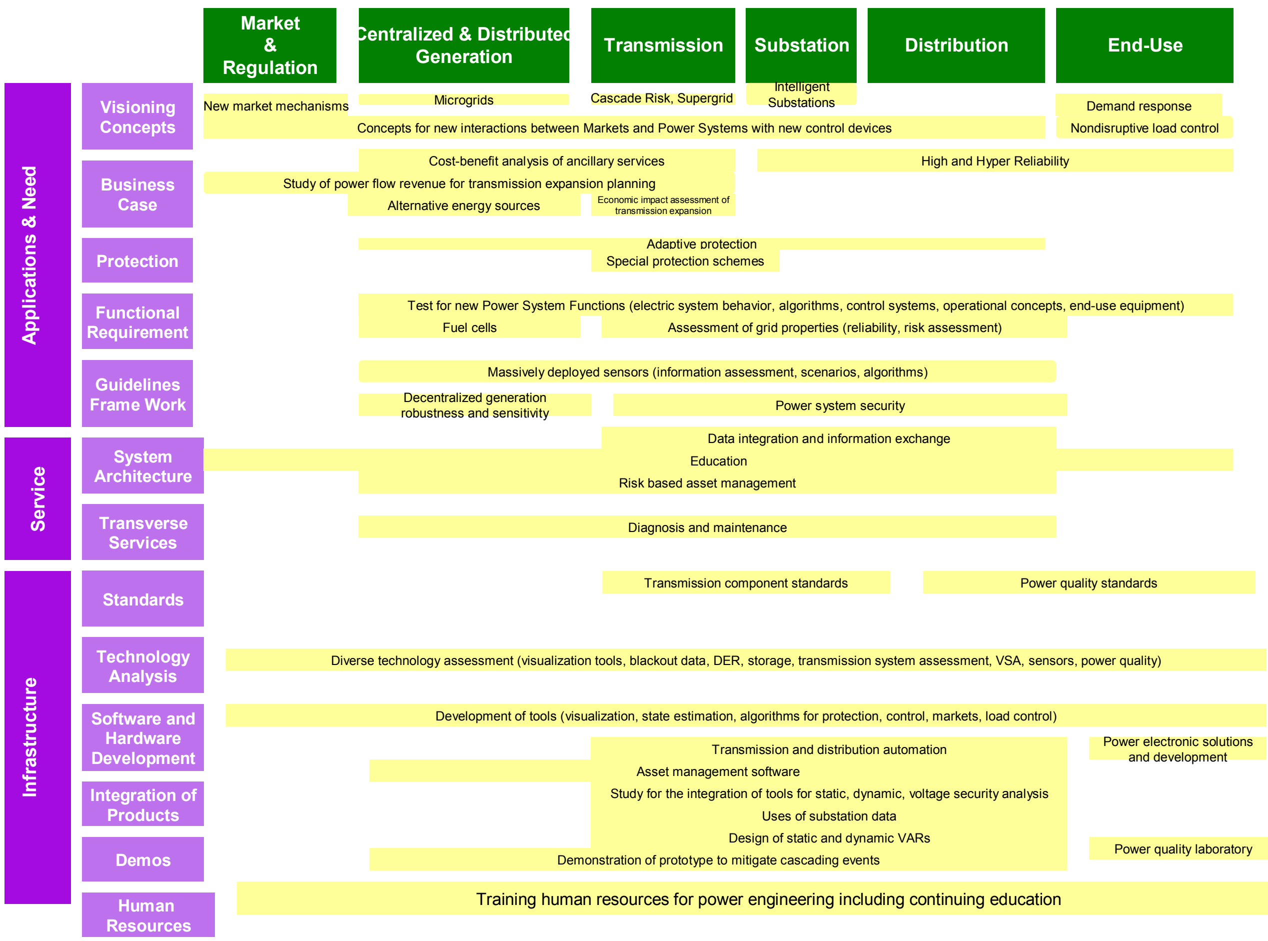

Figure C-1
PSERC program map of current and completed projects (provided by PSERC to IntelliGrid)

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REFERENCES

1. 2006 EPRI Portfolio – IntelliGrid Program www.epri.com/portfolio/program.aspx?area=32
2. IntelliGrid Consortium – Master Plan
3. "Modern Grid Overview," presentation at IntelliGrid Steering Committee meeting, Sacramento, California, November 1–3, 2005
4. "Developing the Modern Grid," presentation at DOE Workshop meeting, Mesa, Arizona, November 9-10, 2005.
5. The Modern Grid Initiative website, www.themoderngrid.org
6. "A Systems View of the Modern Grid" v1.0, May 1, 2006
7. "Modern Grid v1.0: The Modern Grid Initiative," March 2006
8. "Electric Distribution R&D," presentation at IntelliGrid Steering Committee meeting, Washington, D.C., August 3, 2005.
9. GridWise at DOE website, http://www.electricdistribution.ctc.com/index.htm
10. GridWise Architecture website, http://www.gridwise.com
11. "GridWise at DOE," presentation by Eric Lightner at 2006 GridWise Expo, May 16–18, 2006
12. GridWise at PNNL website, http://gridwise.pnl.gov
13. "Electric Distribution R&D Program Overview," presentation by Eric Lightner at Electric Distribution R&D FY06 Annual Program and Peer Review meeting, May 2006
14. "Advanced Grid Application Consortium," presentation to Electric Distribution R&D FY05 Annual Program and Peer Review Meeting, April 2005, http://www.electricdistribution.ctc.com/pdfs/advanced%20application_crane.pdf
15. "Autonomous Storm Detector," presentation to Electric Distribution R&D FY06 Annual Program and Peer Review meeting, May 2006
16. Advanced Grid Applications Consortium website, www.gridapp.org
17. PSERC Resources, November 2005, www.pserc.org
18. Research Projects of the Power Systems Engineering Research Center, December 2005, www.pserc.org
19. Consortium for Electric Reliability Technology Solutions website, http://certs.lbl.gov
20. California Energy Commission – Public Interest Energy Research Program, http://www.energy.ca.gov/pier/programs.html

21. Public Interest Energy Research Program – 2007–2011 Electricity Research Investment Plan, Draft Report, CEC-500-2006-016-D, March 2006
22. New York State Research and Development Authority: A Three-Year Strategic Outlook, 2005–2008, http://www.nyserda.org/Energy_Information/strategicplan.pdf
23. New York State Research and Development Authority website, www.nyserda.org
24. Combined Heat and Power Market Potential for New York State, Final Report 02-12, October 2002
25. GridCom Monitoring and Control Project, http://www.nyserda.org/programs/transportation/PowerSysProj_6467.asp
26. European Union 6th Framework Program, http://europa.eu.int/comm/research/fp6
27. Towards Smart Power Networks – Lessons Learned from European Research FP5 Projects, 2005, EUR21970
28. Technology Platform for the Electricity Networks of the Future, http://europa.eu.int/comm/research/energy/nn/nn_rt/nn_rt_dg/article_2262_en.htm
29. European Union Research Publications, http://europa.eu.int/comm/research/energy/nn/nn_pu/article_1078_en.htm
30. DGNet Project Results, www.dgnet.org
31. DISPOWER Project, www.dispower.org
32. Distributed Energy Projects in Europe, 2004, http://europa.eu.int/comm/research/energy/pdf/dis_energy_en.pdf
33. EU HVDC Project, http://www.le.ac.uk/eg/research/groups/power/highvolt/HVDC/HVDCLinks.html
34. Intelligent Energy – Europe, http://europa.eu.int/comm/energy/intelligent/index_en.html
35. 2006 Work Program, Intelligent Energy Europe, http://ec.europa.eu/energy/intelligent/call_for_proposals/doc/call_2006/wp2006_fr.pdf
36. "The Galvin Electricity Initiative," presentation at IntelliGrid Steering Committee meeting, Sacramento, California, November 2005
37. "Transforming Electricity Service Reliability and Value for the 21st Century," Work Plan Summary, Galvin Electricity Initiative, July 2005
38. Galvin Electricity Initiative website, www.galvinelectricity.org
39. Galvin Electricity Initiative – Results of Tasks 1 to 4, March 2006
40. Galvin Electricity Initiative – Task 5, "Developing Functional Requirements for the Perfect Power System," March 2006