Energy Research and Development Division
FINAL PROJECT REPORT

SMART GRID RESEARCH DEVELOPMENT AND DEMONSTRATION ASSESSMENT: CALIFORNIA

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Prepared by: The Regents of the University of California
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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

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Smart Grid Research Development and Demonstration Assessment: – California is the final report for the Smart Grid Research Development and Demonstration Assessment: - California project (Contract number 500-10-023), conducted by The Regents of the University of California – University of California, Berkeley. The information from this project contributes to the Energy Research and Development Division's Energy Systems Integration Program.

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ABSTRACT

This report describes the database developed to track projects under the Smart Grid Investment Grant Program as well as the Smart Grid Demonstration Program. This report presents the database design developed by the UC Berkeley project team of the Smart Grid Research Development and Demonstration Assessment Project, as well as the assessment of the projects tracked by the database. The design of the database allows for the flexible and extensible storage of the results from the project, as well as the rapid retrieval of project data for meaningful comparison and presentation to the users of the database's web application.

Photos without citation are sources by author.

Keywords: Smart Grid, DOE, ARRA, assessment, indicators, database, mongoDB, web application, user interface.

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EXECUTIVE SUMMARY

Introduction

Smart grid research is being funded throughout the US by the Department of Energy, under the federal American Recovery and Reinvestment Act (ARRA) of 2009. The Smart Grid Research Development and Demonstration Assessment: California Project is funded by the California Energy Commission's Public Interest Energy Research (PIER) Program. The project team consists of multidisciplinary researchers at UC Berkeley who characterized and compared the relevant ARRA projects in California. The team also developed a database to efficiently store, sort, and retrieve the project information.

Purpose

Smart Grid projects in California contain a wealth of information; however, tracking and comparing useful metrics for these separate projects has been challenging. To meet this challenge it became apparent that an identifying, standardizing, collecting, and presenting the projects were necessary. To present the data in a cohesive and accessible manner the solution was to develop a database structure with a web application interface that could meet the current requirements of the project yet allow for future development and expansion.

This project developed a website to provide lessons learned for the public on the numerous Smart Grid projects throughout California. The team designed a database tracking the numerous Smart Grid projects in the state and has that website retrieve information from the database [http://i4energy.org/index.php?option=com_content&view=article&id=470&Itemid=245]. The database uses structured query language (SQL) for its powerful, yet flexible data management capabilities. Using the database, this project assessed 16 ARRA Smart Grid projects throughout California. Six of these projects are included under the Smart Grid Investment Grant (SGIG) program and the remaining ten are included in the Smart Grid Demonstration Program (SGDP) project.

The interface for the database provides an easy to use search area through which the user may locate projects by selecting the type of project, identifying up to three characteristics or using the provided key word search. Users are then provided with a list of matching results based on their specific search. The underlying database structures were designed for atomicity, consistency, isolation, and durability compliance to ensure transactional stability within the database. Additionally, the database was developed so that it can be hosted on any web server environment that supports SQL 5.1.44 and PHP 5.3.2, allowing a variety of hosting options.

Conclusions

Because the database design can be extended, the project team identified additional functionality that could be developed for the database in the future. These additions include comparing not only projects, but also select data categories from many different projects. The project team also identified how stakeholders or data curators can access and update the data for their projects directly through the new portal.

The project team provides assessments of each project based on the program's overall objectives. The specific objectives of the SGIG program are consumer behavior, customer systems, advanced metering infrastructure (AMI) and electrical distribution systems. The specific objectives of the SGDP program are reducing electricity costs, lower peak demand, reduce greenhouse gas emissions, strengthening energy security, and increasing renewables use.

The project team additionally provides analysis and recommendations regarding the gaps and barriers to Smart Grid technology adoption, the primary adoption barrier being identified as cost. Further analysis and recommendations are provided on integrating the new Smart Grid technologies with California's existing technologies. In addition, the 16 SGIG program and SGDP projects can be applied towards California's energy policy goals, specifically Assembly Bill 32 (AB32) and the Renewable Portfolio Standard (RPS).

The project team acknowledges the difficulty to provide general conclusions on the success of the ARRA Smart Grid projects, as the projects are in various stages of completion. The project team also encourages knowledge exchange throughout the state such as through stakeholder workshops. The team also recommends that California should continue to leverage public funds on preexisting Smart Grid work being performed by others. Finally, the project team suggests that continual project progress tracking is of great importance as it will help shape the evolving California Smart Grid.

CHAPTER 1: Introduction

The Smart Grid Investment Grant (SGIG) Program (DE-FOA-0000058), funded by American Recovery and Reinvestment Act (ARRA) of 2009, is transforming the electric transmission and distribution systems by promoting investments in Smart Grid technologies, tools, and techniques for immediate commercial use.

In addition, the Smart Grid Demonstration Program (SGDP) (DE-FOA-0000036) is composed of regional demonstration projects and utility-scale energy storage projects. In the regional studies, project teams verify Smart Grid technology viability, quantify costs and benefits, and validate new business models that can later be adapted and replicated around the country.

The Smart Grid Research Development and Demonstration Assessment: California Project is funded by the California Energy Commission and identifies any gaps that exist in the overall research agenda of ARRA SGDP and SGIG funding. This project also supports synergies among projects and identifies research and technology transfer opportunities with California's Smart Grid implementation plans during the next decade.

The project team consists of multidisciplinary researchers at UC Berkeley who characterized and compared the current and relevant ARRA projects. For each ARRA project, the team is analyzed the specific technologies being deployed, their intended impact, and the performance parameters being tested empirically. A set of assessment indicators (metrics and parameters) for the characterization was developed and is provided as an appendix.

The team also developed a database to efficiently store and retrieves the results of the project. This database design allows the database to be extended and support flexible queries so results from the project can be easily retrieved. This report describes the database design.

CHAPTER 2: Database Design

Smart Grid projects in California contain a wealth of information however tracking and comparing useful metrics for these separate projects has been a challenge. To meet this challenge it became apparent that an identification, standardization, collection, and presentation of the projects were necessary. To present the data in a cohesive and accessible manner the solution was to develop a database structure with a web application interface that could meet the current requirements of the project yet allow for future development and expansion. The Smart Grid Database came about as the result of this project and it can be seen on the i4energy community's website: http://i4energy.org/index.php?option=com_content&view=article&id=470&Itemid=245

2.1 Background Considerations

Through initial surveys into this project it became immediately apparent that although Smart Grid projects share certain categories of data they are not uniform. A key characteristic was the ability to accommodate the variegated collection of the data inherent in every project. Projects may, for instance share a common data category yet have different metric within the category. Further, certain data categories have multiple subcategories. Finally different projects might have data for different categories.

Further, the team wanted to create an extensible project that could accommodate future development. Using SQL with a PHP interface seemed to be the best solution to accommodate all of these considerations.

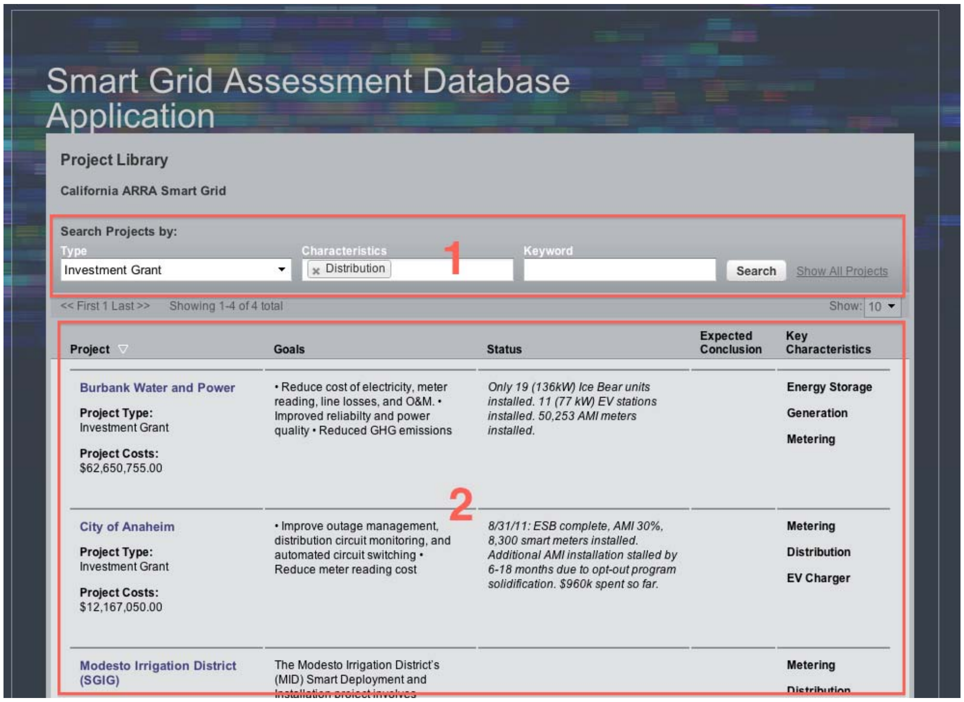
2.2 Technical Overview

SQL also formally known as a 'Structured Query Language', is a very robust and versatile way to handle data. Especially in the case of data that requires dynamic updating. A traditional SQL structure requires some initial design and development but once in place allows for timely, efficient and accurate changes to the data and additional data tables. The team used a language known as 'PHP: Hypertext Preprocessor (PHP) to present the data since PHP has a standard syntax, which integrates the other web technologies such as Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS). Furthermore PHP is an object oriented language that is portable and versatile and can implement several modules to facilitate future development.

2.3 Interface

The application site is currently hosted at http://i4energy.org/index.php?option=com_content&view=article&id=470&Itemid=245 (Figure 1).

Figure 1: Initial Presentation



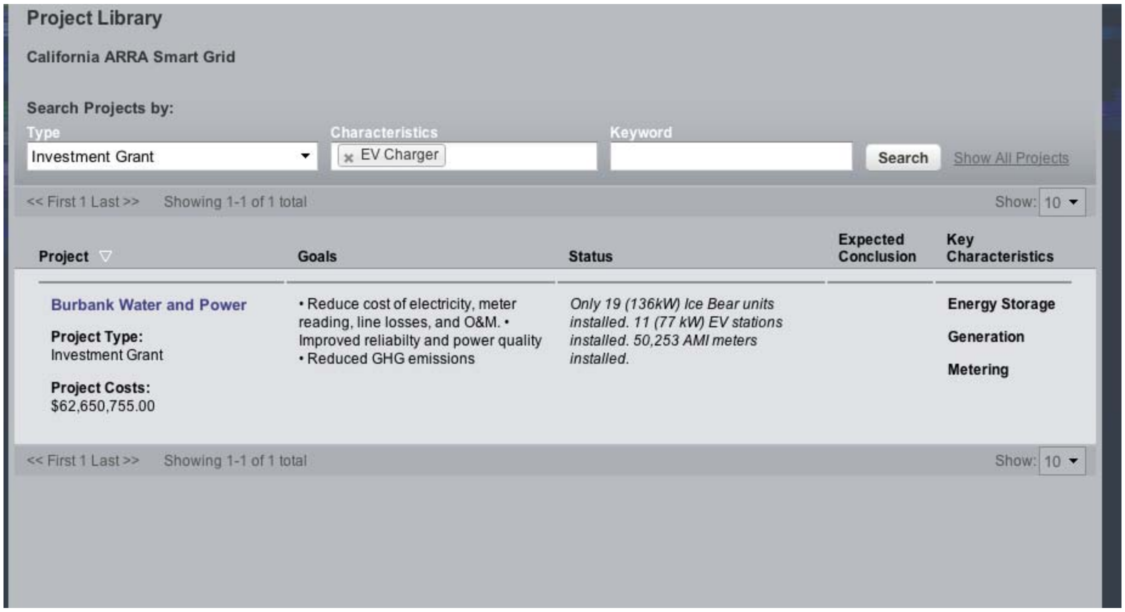
Source Provided by Author (SPA)

The initial presentation is separated into two parts:

1. Search area, which includes the type, characteristics (select up to three) and a key word search
2. A listing of all projects

Once the user has entered a series of search terms they can see the results pared down to match their query (Figure 2).

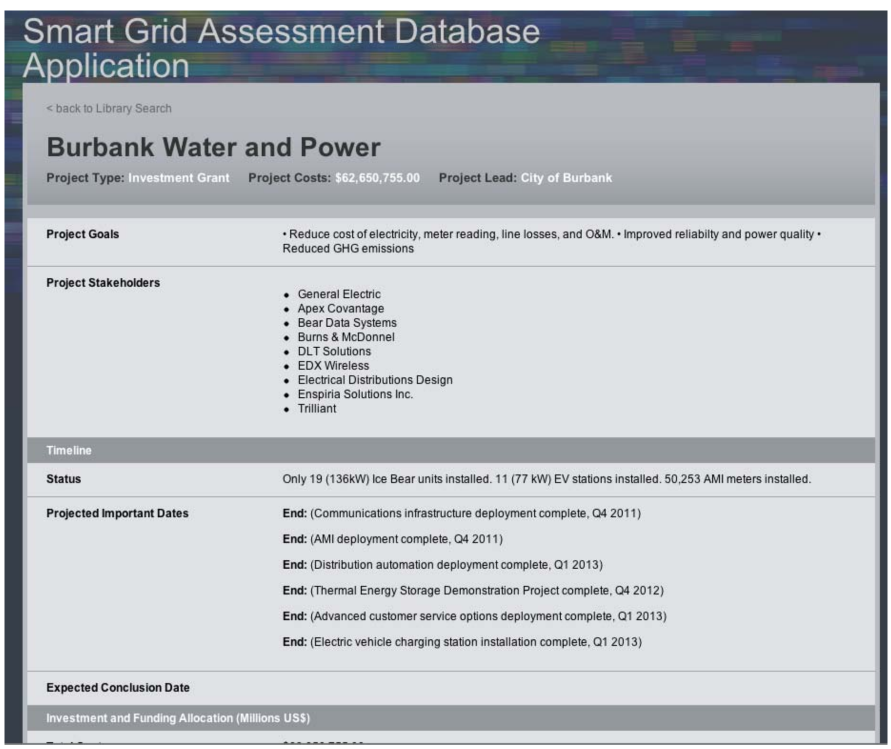
Figure 2: Example of a Search for an Investment Grant Project with EV Charger Data



Source Provided by Author (SPA)

If there is a particular project that user wants to investigate further they can select the heading and they will receive a presentation of all the data associated with the project. (Figure 3)

Figure 3: Example of Detail Data



Source Provided by Author (SPA)

2.4 SQL Database Structure

Built in SQL version 5.1.44 and consisting of 29 tables, the database uses several auxiliary tables to provide the necessary flexibility to accommodate the Smart Grid projects. The database was built using the innoDB storage engine and collated us the character encoding standard UCS Transformation Format - 8bit in binary, (utf8_bin).

The collation was a default option for strict comparison parameters, but utf8_general would be interchangeable with the existing data whereas the character encoding of ASCII would not. The functional difference is that utf8_bin performs comparisons on the binary level of character encoding, whereas utf8_general compares the characters as displayed. Therefore under utf8_bin the comparison of A=Ã would be false, but under utf8_general it would be true. Currently the team does not expect that the data will encounter characters that will change the comparison values for comparisons. Nonetheless the stricter comparison parameters required by utf8_bin enforces greater accuracy in the database development and query syntax.

Using innoDB for the storage engine was advantageous for several reasons. Most notably was the support of foreign keys, which was a key factor in the success of this database. Further innoDB is considered ACID (Atomicity, Consistency, Isolation, Durability) compliant. ACID compliance is advantageous for a database as these are the relevant metrics for determining whether a database is scalable and robust. Atomicity ensures that each transaction either succeeds of fails. Doing so means that a database will not be affected by query that is malformed due to improper coding or system failure. Consistency ensures that every transaction written to the database is valid (as defined by the database rules), which becomes important in if the team decides to implement certain constraints or triggers in the database. Having isolation means that the same result is reached whether a query executes its operations concurrently or serially. Isolation is a great means for gaining further efficiencies out of the performance of a database. Finally durability in this context guarantees that upon completion of a transaction that the result remains. This compliance will ensure that the database can be scaled if necessary and tables can be added if further functionality is required. Further functionality is further discussed in Section 4. Other storage engines were considered, specifically MyISAM. The MyISAM storage has some efficiency, however, it is at the expense of reliability. The biggest issue with using MyISAM was the lack of support for foreign keys. In a relational database the tables are connected via Primary key which must be defined for each table, however using a secondary key (the foreign key) can define the key across tables which is essential when many tables share the same unique identifier. In so doing, the team dynamically links a table to many other tables. Other factors such as the lack of transactions support and not being ACID compliant, made it clear that the MyISAM storage engine was not appropriate for development in this project.

Organizationally, the various data elements are tied together by the project. To afford the flexibility for variety within a specific category the team implemented several auxiliary tables that relate only to their specific data category. Data types for each data element were determined by examining the data expected to receive for the data category and whether it was expected to perform calculation functions with the data.

2.5 PHP Application Interface

The application interface is driven by three components of PHP (PHP: Hypertext Preprocessor) code.

- sga_projectview.php - Governs the initial presentation and maintains a persistent connection the to the SGA database
- sga_results.php - Governs the execution and presentation of user selected parameters for filtering projects.
- tabled_SGA_results.php - Governs the presentation of individual projects that a user may select.

For developing and hosting, the application was built using PHP version 5.3.2. The application also renders the presentation using several Cascading Style Sheets (CSS) style sheets. CSS is a very convenient HTML tool to enforce a consistent look and feel for a website, however the styling and design of these sheets can be customized for localization and not integral to the function of the database.

The application can be hosted in any web server environment that supports SQL 5.1.44 and PHP 5.3.2. Whereas the current status of most webhosts meet or exceed these requirements there remains some private hosts that do not meet these requirements, and as such cannot properly host or access the application. Regarding portability, the database can be easily exported and imported again to a CSV (comma separated values) file. The PHP files themselves require localization whenever the database host changes, but these changes are easily done directly in the code.

2.6 Future Work

Ultimately, the goal of this project is to allow users to easily compare metrics across various Smart Grid projects. Currently, users can select and enter search terms. However, in the future the team envisions the ability to directly select not only projects for direct comparison, but also select data categories for comparison across projects. Since the data is contained within a database structure, it would be a simple PHP/SQL code addendum to create this functionality. Further development of the database would be creating a portal whereby stakeholders can update the data directly for their project. This will require more planning and design to manage users since this portal, in form, would be a secondary application that interfaces with the existing database. Nonetheless, the essential structure is able to accommodate additional development goals.

It should be noted that the application interface that users currently see is simply one form of presentation and organization of the data. With the database in place, it is possible to present the data in entirely different ways. The current focus is to gather the data by its Smart Grid project, yet for instance, the team could just as easily turn that hierarchy around and show the data organized by metric and displaying the project as subordinate to the data category. This shows that interface is adaptable and the database is extensible. Also using the specific database scheme the team is able to scale the database in size (more projects) and also the number transactions without having to sacrifice speed or reliability.

CHAPTER 3: Assessment Indicators

3.1 Overview

The team has systematically characterized and compared the relevant ARRA projects currently under way. For each ARRA project, the team analyzed the specific technologies deployed, their intended impact, and the performance parameters being tested empirically.

The team has compiled information on a series of indicators (metrics and parameters). This data forms the foundational basis for the Project's comprehensive assessment of the different efforts taking place in the ARRA Smart Grid projects in California. Information on these indicators will be collected and publicly accessible in the web interface and database (see details in the appendix).

This report provides a description of the project's indicators, which are composed of a combination of existing ARRA[1] and CPUC[2] indicators as well as new indicators specific to this Project.

3.2 Basic Information

This chapter describes the indicators of basic project information of the diverse portfolio of Smart Grid projects being studied.

3.2.1 Project Type and Goal

These are the indicators to distinguish among the breadth of projects and to understand the commonalities and differences across the multiple objectives of each project.

3.2.2 Project Stakeholders and Suppliers

These indicators identify the key players in each project, and their roles.

3.2.3 Project Timeline

This set of indicators gives a calendar representation of the projects and their deadlines, which provide an opportunity to assess speed and timeliness in the construction and deployment efforts.

3.2.4 Funding Sources

These indicators allow us to understand the size of the investments for each project as well as provide an understanding for the percentage of public funds being invested per project.

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[1] Guidebook for ARRA Smart Grid Program Metrics and Benefits, Department of Energy, December 7, 2009.

[2] California Public Utilities Commission (CPUC) Rulemaking 08-12-009, March 20, 2012, Decision Adopting Metrics to Measure The Smart Grid Deployments of Pacific Gas & Electric Company, Southern California Edison Company and San Diego Gas & Electric Company, Attachment A.

3.2.5 Physical Characteristics

These indicators are for the projects' geographic location and size of project facilities, such as research centers, manufacturing sites, and installation sites.

3.3 Technological Characteristics

Technological indicators will focus on the different types of technologies addressed through the smart grid project portfolio. The technological indicators will help distinguishes existing, adopted technologies from game changing technologies. Technology indicators are classified under the following categories:

3.3.1 Energy Storage

Energy storage indicators are targeted at the projects involving technology for storing energy (mechanically, chemically, thermally, etc.). The indicators will provide insight as to the storage capacity and cycle efficiency, cost per cycle, and end use.

Table 1: Energy Storage Characteristics

Energy Storage (Flywheel, flow battery, compressed air, thermal)
• End-use (peak hours reduction, long-term storage, low genertion use)
• Peak power demand contribution (usage patterns)
• Lifecycle (yrs)
• Number of deep cycles
• Cycle Efficiency (%)
• Cost per cycle: (Capital/Energy)/(Life x Efficiency)
• Maximum power output/generation (MW)
• Battery life (sec, min, hrs)
• Storage Capacity (MWh)

3.3.2 Power Generation

Power generation indicators are primarily tailored for those projects involving distributed generation and use of renewable resources (wind, solar, PV, CPV, CSP, etc.). Basic information on maximum projected output and capacity factor as well as energy cost and carbon intensity are included in the power generation indicators.

Table 2: Energy Generation Characteristics

Generation (Wind, Solar - PV, CPV, CSP)
• Maximum power output/generation (MW)
• Capacity Factor (%)
• Carbon conserved ($/tC)
• Carbon intensity (gC/kWh)
• Energy cost ($/kWh)
• Area used (m^2)
• Lifetime (yrs)
• Total annual electricity deliveries from customer-owned or operated, grid-connected distributed
• Man hours to manage (hrs/day)

3.3.3 Metering

The metering indicators are tailored for projects involving testing of smart meters, power quality (PQ) monitors, and power line sensors. They will provide insights into the number and type of units deployed, data storage capacity developed, and battery life amongst others.

Table 3: Metering Characteristics

Metering (Smart Meters, PQ Monitors, Line Sensors)
• Units (#)
• Metering Type
• Data Storage Capacity
• Costs avoided ($/kWh)
• Response time
• Connection (ethernet, etc)
• Variables measured (temp, power use, time of use, etc)

3.3.4 Distribution

Distribution indicators target projects involving demand response, transmission of power, and equipment that assists and enhances power distribution throughout the grid. They will provide insight into the usefulness and future needs in this sector. The indicators are as follows:

Table 4: Distribution Characteristics

Distribution (Automated Demand Response, Transformers, Power Meters, Sensors)
• Units (#)
• Point of installation (generators, substation, lines)
• Enhancements
• Automated? (y/n)
• Operation voltage (and tolerance)
• Software Type
• Number and percentage of distribution circuits equipped with automation or control equipment
• Number of and total nameplate capacity of customer-owned or operated, grid-connected distributed generation facilities
• Percentage of demand response enabled by AutoDR (Automated Demand Response) in each individual DR impact program

3.3.5 Communications

The communications component of the indicators refers to the areas of information processing and relaying. These indicators provide a basic sense for the system's architecture, its basic workings and methods of communication. The specific indicators are as follows:

Table 5: Communication Characteristics

Communications (Information Processing & Relaying)
• Units (#)
• Equipment connected (line monitors, fault circuit indicators)
• Remote controlling (y/n)
• Data Retrieval (min, hrs, as needed)
• User (customer, utility)

3.3.6 Plug in Electric Vehicles (PHEV)

PHEV indicators are specifically targeted for the projects conducting pilots on electric vehicle charging. These indicators focus around the general size of the pilot in terms of customers enrolled, stations, and vehicles. The specific indicators are as follows:

Table 6: Plug in Electric Vehicle Characteristics

Plug in Electric Vehicles
• Number of customers enrolled in time-variant electric vehicles tariffs
• Number of electric stations
• Number of vehicles

3.4 Other Characteristics

3.4.1 Load Improvements

Load improvement indicators provide more detailed insight into the goals of the projects, mainly relating to expectations on operational efficiency improvements and reliability of the grid. The specific indicators are as follows:

Table 7: Load Improvement Characteristics

Load Improvement
Operational Efficiency (contribution to) (%)
Grid reliability and resilience (contribution to)
Contribution to flattening load curves
Power Factor improvement
Impact on Grid (# of substations affected)

3.4.2 Policy Applications

The policy indicators provide a framework to identify the policy characteristics of the projects and their implications, as well as evaluate the Smart Grid projects on the basis of their alignment with existing standards.

Table 8: Policy Application Characteristics

Policy Applications
Policy Characteristics/Implications
Salient Institutional Characteristics
Eligibility for feed-in tariffs
Alignment with Renewable Portfolio Standards
Alignment with Distributed EN Resources (DER) Interconnection Standard
Alignment with environmental standards

3.4.3 Economic Impact

Indicators for economic impact are relevant for all assessed projects and include jobs metrics as well as the potential that these projects have for future development of related projects, markets, businesses, and employment opportunities.

Table 9: Economic Impact Characteristics

Economic Impact
jobs created
jobs/$ spent
Impact on purchased goods
CCE (Cost of Conserved Energy) ($)
Potential for market place innovation/new program creation
Secondary Battery Market Eligibility (Yes/No/Maybe)

3.4.4 Lifecycle Assessment Measures

Lifecycle assessment indicators will primarily provide insight into the environmental impact of the projects, including emissions and recycling impacts, as well as material inputs for project development.

Table 10: Lifecycle Assessment Measures

Lifecycle Assessment Measures
Air pollutants (type, amount)
CO_2 emissions abatement (tons CO_2)
Recycling Concerns
Environmental hazards
Composition (e.g. Rare earth metals used)
Safety Hazards

3.4.5 Social Impact

Social impact indicators focus on the projects' impact on consumers and consumer response to project progress. Improvements in affordability and information, as well as the number of customers served are part of these social impact indicators.

Table 11: Social Impact Characteristics

Social Impact
Customers served (households)
Customers contacted directly by phone or in writing (#)
Customer response (for projects dealing directly with consumers)
Improvements in customer affordability (% cost reduction)
Improvements in customer information (new tools, web interface, etc.)
Privacy Concerns

CHAPTER 4:
Assessment of California Smart Grid ARRA Projects

4.1 Overview

The project is funded by the Energy Commission's PIER Program. The goals of this project are to characterize and compare the objectives, deployment strategies, funding sources, technologies, and performance parameters of sixteen United States Department of Energy (DOE) American Recovery and Reinvestment Act (ARRA) of 2009 Smart Grid projects currently underway in California.

This chapter provides a summary of the project's findings. It includes a review of Smart Grid project comparisons across a series of cross-cutting indicators, and proceeds to focus on identifying gaps and barriers in Smart Grid technology adoption, applicability of the project portfolio to California's energy policy goals, comparisons to related research, and recommendations for California's Smart Grid implementation plans over the next decade.

4.2 California Smart Grid ARRA Projects

Investing in Smart Grid research advances two of the primary objectives of ARRA: job creation and investment in green energy infrastructure.

The ARRA initiative includes two Smart Grid programs: the Smart Grid Investment Grant (SGIG) Program (DE-FOA-0000058), which promotes investment in Smart Grid technologies, and the Smart Grid Demonstration Program (SGDP) (DE-FOA-0000036), which promotes regional demonstration projects and utility-scale energy storage projects.

The project reviewed sixteen ARRA-funded initiatives in California, six of which are SGIG Projects and ten of which are SGDP projects. The project list is summarized in Table 12 and Table 13 below.

Table 12: Smart Grid Investment Grant Projects

City of Glendale	AMI Smart Grid Initiative
City of Anaheim	Smart Grid Project
San Diego Gas & Electricity (SDG&E)	SDG&E Grid Communications System
Modesto Irrigation District	Smart Grid Deployment and Installation Project
Burbank Water and Power	Smart Grid Program
Sacramento Municipal Utility District (SMUD)	SmartSacramento Project

Table 13: Smart Grid Demonstration Projects

Amber Kinetics	Flywheel Energy Storage Demonstration
Enervault	Flow Battery Solution for Smart Grid Renewable Energy Applications
Los Angeles Department of Water & Power (LADWP)	Smart Grid Regional Demonstration
Pacific Gas & Electric (PG&E)	Advanced Underground Compressed Air Energy Storage
Premium Power/SMUD	Distributed Energy Storage System
Seeo Inc.	Solid State Batteries for Grid-Scale Energy Storage
Primus Power Corporation	Wind Firming Energy Farm
Southern California Edison (SCE)	Irvine Smart Grid Demonstration
Southern California Edison	Fault Current Limiting Superconducting Transformer (Waukesha)
Southern California Edison	Tehachapi Wind Energy Storage Project

4.2.1 The SGIG Projects

The SGIG Projects accelerate the transformation of the electric transmission and distribution systems through investments in Smart Grid technologies, tools, and techniques for immediate commercial use. The goals of the projects involve accelerating progress toward a grid that:

- Enables informed participation by consumers in retail and wholesale electricity markets
- Accommodates all types of central and distributed electric generation and storage options
- Enables new products, services, and markets
- Provides for power quality for a range of needs by all types of consumers
- Optimizes asset utilization and operating efficiency of the electric power system
- Anticipates and responds to system disturbances
- Operates resiliently to attacks and natural disasters.

The six SGIG projects reviewed were led by utilities in Anaheim, Burbank, Glendale, Modesto, Sacramento, and San Diego. The projects began between 2010 and 2011 and are due to be completed between 2013 and 2014.

SGIG projects have great variability in terms of cost. **Error! Reference source not found.** and Figure 5: Chart portray the range in total project budgets and percentage of DOE and PIER funding. As Figure 5: Chart shows, public funding for these projects ranges between one third and just over half of funding needs, indicating the important contributions from ARRA and PIER to these projects.

Figure 4: Chart SGIG Project Budget

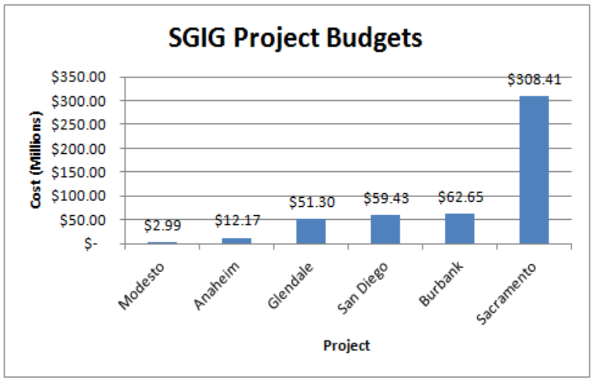


Figure 5: Chart Percentage DOE and PIER Funding

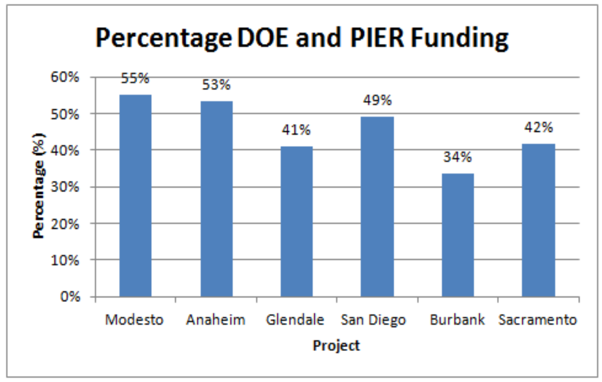


Table 14 describes the different activities carried out in each project. Advanced Metering Infrastructure (AMI) installation is a common activity across all projects and the installation process for smart meters is currently underway in every case.

Table 14: SGIG Project Activities

	Consumer Behavior	Customer Systems	Advanced Metering Infrastructure (AMI)	Electric Distribution Systems
Anaheim			●	●
Burbank		●	●	●
Glendale		●	●	
Modesto		●	●	●
Sacramento	●	●	●	●
San Diego			●	

The projects also have a great variation in the average number of jobs created per quarter: the range extends from one job to 55 jobs per quarter, with a median of 18 jobs per quarter.

4.2.2 The SGDP Projects

The SGDP Program is composed of regional demonstration projects and utility-scale energy storage projects. The goal of the SGDP projects is to develop the necessary mechanisms and information needed to align incentives and enable customers, electricity distributors, and electricity generators to support the reduction of electric power system demands and costs, increase in energy efficiency, matching of electricity demand and resources, and increase in the reliability of the grid.

Three of the SGDP Projects: 1) Irvine, 2) LADWP, and 3) Waukesha Transformer, are Regional Demonstration Projects. In these regional studies, project teams verify Smart Grid technology viability, quantify costs and benefits, and validate new business models that can later be adapted and replicated around the country. These three demonstration projects assess and integrate advanced technologies with existing power systems including distributed energy and demand response. Technical and economic feasibility assessment focus on applications including automated distribution systems, advanced metering infrastructure, and plug-in electric vehicles. The projects began between 2010 and 2011 and are due to be completed between 2012 and 2015.

Chart 3 portrays total project costs for the three Regional Demonstration Projects. As is the case for SGIG projects, public funding represents a significant portion of the total portion for each project budget: public funding contributions to these projects were 50 percent for Irvine and LADWP, and 57 percent for Waukesha (Chart 4).

Figure 6: Chart Regional Demonstration Projects Budgets Funding

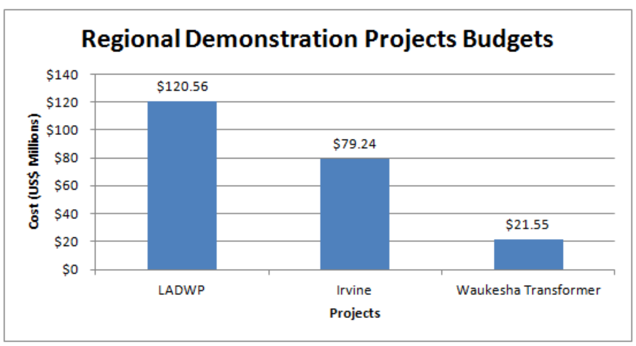
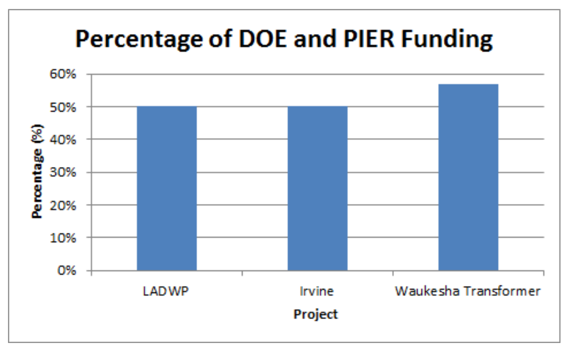


Figure 7: Chart Percentage of Public (DOE and PIER)



The Regional Demonstration Projects have a number of expected benefits, as illustrated in

Table 15. All projects seek to achieve reductions in Greenhouse Gas (GHG) emissions, with both Irvine and LADWP working on electric vehicle pilot projects as a means to contribute to this goal. All three projects seek to increase job creation, with a range of 1-9 jobs per quarter created so far, and a median of 2 jobs per quarter.

Table 15: Regional Demonstration Projects Targeted Benefits

	Irvine	LADWP	Waukesha
Electricity cost reductions		●	●
Lower peak demand		●	
GHG emissions reductions	●	●	●
Energy security strengthening	●	●	
Increased renewables use	●		
Energy Efficiency	●		●
Electric Vehicle (EV) Technology	●	●	
Organizational Capabilities Assessment	●		
Job creation	●	●	●
Contribution to US energy sector	●		●

Of the ten SGDP projects evaluated, seven are energy storage projects: Amber Kinetics, Enervault, PG&E Compressed Air, Premium Power/SMUD, Primus Power, Seeo Inc., and Tehachapi SCE. These projects seek advancements in grid-scale energy storage. Electric power system operators can use electricity storage devices to manage the amount of power required to supply customers at times when the need is greatest, that is, during peak load. In addition, energy storage devices can:

- Make renewable energy resources, whose power output cannot be controlled by grid operators, more manageable by filling in during intermittent periods.
- Balance microgrids to achieve a good match between generation and load.
- Provide frequency regulation to maintain the balance between the network's load and power generated.
- Enable deferment of transmission and distribution investments.
- Provide a more reliable power supply for high-tech industrial facilities.

Energy storage projects began as early as 2008 (with the later ones beginning in 2011), and are expected to be completed between 2014 and 2023. The budgets for these projects vary significantly. PG&E's Compressed Air Storage project has a total cost of $356 million dollars, by far the largest project in terms of cost. Chart 5 portrays the budgets for the remaining six energy storage projects. Chart 6 illustrates the percentage of DOE and PIER funding, which fluctuates between 32 and 55 percent for all projects except PG&E's Compressed Air Storage project, which stands at 7 percent public sector funding. The job creation effectiveness of these projects ranges widely between 1-19 jobs per quarter, with a median of 5 jobs per quarter.

Figure 8: Chart Energy Storage Projects Budgets

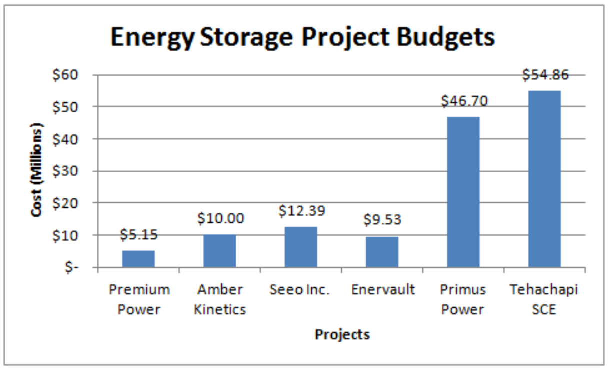
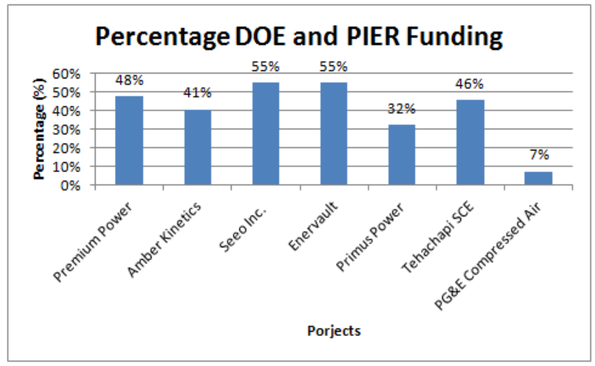


Figure 9: Chart Percentage of Public Funding (DOE and PIER)



Energy storage projects reflect a wide spectrum of technologies: flywheel, flow battery, and compressed air storage. Flywheel technology is based on energy storage in a spinning rotor connected to an electric motor that converts electrical energy into mechanical energy. To recover the energy the motor is electrically reversed and used as a generator to convert the mechanical energy of the spinning flywheel back into electrical energy. PG&E's compressed air energy storage seeks to validate the suitability of porous rock formation as a storage reservoir in California. The Enervault, Premium Power, and Primus Power projects all integrate flow battery technology.

4.3 Gaps and Barriers to Smart Grid Technology Adoption

Adopting new technologies for the Smart Grid is an enormous task. New systems may require a large number of devices to be installed in an expedient manner. For example, smart meters must be installed in bulk for the AMI system to be able to provide meaningful benefits to the utility. Large installations also require planning and integration with diverse system components.

In addition, the projects reviewed here illustrate the learning curve for all participants and stakeholders, including specific training or re-training needs for personnel. Widespread technology adoption in the future will require training with a Smart Grid focus in traditional areas, such as engineering design, planning, operations and maintenance, as well as information technology (IT) design, systems integration, and support. New fields of expertise will include those responsible for installing and monitoring smart meters and smart appliances as well as customer support employees in charge of interacting with customers to help them understand the benefits of smart meters, interpret new web portals showing their power usage and understanding new programs that may be offered.

The simplest and most substantial barrier for Smart Grid technology adoption is its cost. While the aforementioned projects were funded as part of ARRA, national or even statewide Smart

Grid integration to any degree ranging from smart meters to high renewables penetration cannot be feasibly funded exclusively or largely from public grants. Municipalities and utilities will ultimately choose investments that better align with their objectives to increase efficiency, improve quality of service, and reduce costs. Educating users and providing the adequate incentives to foster behavioral change is another key challenge for utilities.

4.4 Integration of the New Technologies with California's Existing Utility Systems

Integrating new technology into California's existing utility system is a key research objective for many of the SGIG projects. Beyond the development and commissioning of an individual new technology, these projects are investigating the effect of new technology on the grid as a system. System performance hinges on interactions (both intentional and unintentional) between and among newly introduced technologies, as well as a broad range of legacy equipment that is indispensable for maintaining secure and reliable operations. As the adoption of Smart Grid technologies proceeds, integration challenges could become more complex: the question is, will the "System of Systems" work?

A common theme in the area of integrating new technologies is the need for deep grid situational awareness. That is, the grid requires more smart meters, more complex field networks for monitoring, and better telecommunications to give both utilities and the California Independent System Operator (CAISO) visibility of grid conditions in real-time, at increasingly higher resolutions or granularity in both time and space. However, raw data must also be processed with appropriate analytics to convert it into actionable intelligence for grid operators and planners. As the quantity of data obtained from advanced meters and other monitoring devices increases, continuing challenges and opportunities will exist to utilize and leverage this data in novel and informative ways. The Smart Grid projects examined here include efforts to develop and enhance the back-office side of grid intelligence, which is often seen as substantially more difficult than the physical implementation of sensing, monitoring and metering devices. Much more work remains to be done in this area (for example, cross-referencing data and linking different analytic applications) to maximize data utilization for situational awareness.

With the exception of smart meters, which are deployed in large numbers, the emphasis in Smart Grid technology research is still mainly on the operability and interconnection of individual facilities, or relatively small numbers of devices. The SGIG and SGDP projects examined here are well on their way to demonstrating that specific technologies such as storage units can satisfactorily meet interconnection and operability requirements. In the future, as penetration levels of these devices on distribution systems increase, technology integration will also depend in large part on the interaction, aggregation and coordination of many units.

One concern with new technologies like EV charging stations, solar photovoltaic (PV) generation and battery storage is the interoperability of a substantial number of large direct-current units that interconnect through DC-to-AC inverters. At the penetration levels observed today, the integration performance of these devices seems generally satisfactory. With increasing penetration levels in distribution systems, however, a crucial integration question will be how distributed resources can be most effectively recruited to provide services to the grid. Advanced inverters are likely a key area for future investigation, especially as interconnection standards such as IEEE 1547 are being revised (e.g. to allow for volt-VAR[3] support).

Another issue specific to smart meters that continues to be discussed is cyber-security. Each SGIG project is making progress in evaluating methods to support and enhance privacy and security in the face of vastly increased data and communication volumes, which will likely be a continuing effort. Cyber security is currently being developed by projects in isolation, based on federal guidelines[4]. A California state-level venue for discussion, collaboration, and information exchange on adopting federal standards and guidelines for information security would facilitate interoperability between the various components of the connected grid.

Finally, the development and testing of standards for interoperability is a key integration problem that has not been addressed in these projects so far. As Smart Grid research, development, and demonstration (RD&D) continues, standardization with plug-and-play options will likely become an increasingly important area of emphasis. Some important work in this area has been undertaken by the Electric Power Research Institute and the Lawrence Berkeley National Laboratory (see below). Integration experiences in the ARRA projects examined here – specifically, the efforts required to perform one-off integration of diverse hardware and software components in each project – support the claim that to arrive at a truly Smart Grid in an economical manner, standardization will be absolutely necessary and promises to be a fertile area for public funding.

4.5 Applicability to California's Energy Policy Goals

Assembly Bill 32 (AB32), California's Global Warming Solutions Act of 2006, puts into law, California's greenhouse gas emissions reduction goal of 1990 levels by 2020. AB32 clearly embodies the core of current energy and environmental policy goals in California. Smart Grid Investment Grant projects and Smart Grid Demonstration projects have several characteristics which ease the transition towards meeting these rigorous requirements.

The Renewable Portfolio Standard (RPS) for utilities to provide 33 percent of electricity from renewable sources by 2020 has proved economically challenging to meet. A lack of peak shaving and load balancing, through either energy storage or automated demand response, has hampered the potential efficacy of newly constructed renewable generation. Certain projects increase the stability and capacity of existing renewables, such as Enervault's flow battery designed to maximize the output of a 180kW PV array in Snelling. Other projects with a larger scope, such as PG&E's proposed 300MW underground compressed air energy storage system, are aimed at broadening the ability to store and use future intermittent renewable electricity.

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[3] VAR – Volt-Ampere Reactive

[4] NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0, January 2010.

These fundamental changes to the nature of the grid are enhanced by projects that go beyond simple storage. Burbank's forays into widely implemented automated demand response, along with the hundreds of thousands of smart meters being installed throughout the state, simultaneously reduce emissions through peak-shaving and create a framework that can more easily accommodate non-baseload renewable generation. This automation and micromanagement of electricity consumption is a prerequisite to expanding dynamic pricing systems.

The importance of these improvements cannot be underestimated. To meet RPS requirements, utilities have already been obligated to contract renewable generation out of state. This may achieve direct emissions reductions, but it fails to spur green job creation across the state, which is an underlying AB32 objective. Immediately automating and enhancing the grid could usher in the construction of increased renewable generation on California soil.

4.6 Comparison with Related Research

It is beyond the scope of this project to do an extensive survey of related Smart Grid research across the United States. However, in California, two research organizations, the Lawrence Berkeley National Laboratory (LBNL) and the Electric Power Research Institute (EPRI) are key entities conducting related Smart Grid research, briefly summarized below.

4.6.1 Electric Power Research Institute

EPRI, headquartered in Palo Alto, California, has two related Smart Grid research initiatives: (1) the Intelligrid Program and (2) the Smart Grid Demonstration Initiative. The two initiatives are summarized with excerpts from EPRI publications.

4.6.1.1 Intelligrid Program

The Intelligrid Program evolved from the earlier EPRI Intelligrid Architecture and Methodology research towards a roadmap for a next generation power system consisting of automated transmission and distribution systems that support efficient and reliable supply and delivery of power. The goal is to create a power system capable of handling emergency and disaster situations, while also able to accommodate current and future utility business environments, market requirements, and customer needs.

The mission of the current Intelligrid Program is to accelerate the transformation of the power delivery infrastructure into the intelligent grid needed to support the future needs of society. The program is funded by over 50 companies (in 2008, 37 domestic utilities and 3 foreign utilities). The program provides strategic and innovative research applying standards, communication technology, and advanced system integration to enable advanced Smart Grid applications for operational improvements with a strong emphasis on Informational and Operational Technology Convergence.

The program understands the utilities are increasingly deploying advanced monitoring, communications, computing and information technologies to support such "Smart Grid" applications such as wide area monitoring and control, integration of bulk or distributed renewable generation, distribution automation and demand response. However, the companies face significant challenges when deploying these technologies, including:

- Selecting technologies that best meet current and future business needs and regulatory requirements while minimizing the risk of early obsolescence and vendor lock-in.
- Creating an overall architecture that integrates the many intelligent devices, communications networks and enterprise systems to utilize resources and provide information to all users
- Managing the tremendous amount of data that is generated by the Smart Grid to convert data into actionable information and effectively present the information to the people who need to take action.
- Managing a growing network of intelligent devices that have different capabilities and that use different protocols and data formats in a way that optimizes performance.
- Ensuring that the workforce has the skills necessary to design, operate and maintain equipment and systems that use new technologies

The IntelliGrid Program will address these challenges by:

- Tracking federal government and regulatory activities relating to standards, cyber security and communications, and interpret the impact that these actions will have on the utility industry.
- Promoting interoperable systems by contributing to the development of key Smart Grid standards, assessing emerging standards, conducting interoperability tests of products that implement key standards and providing information to utilities on how to implement standards.
- Defining requirements for utility communications networks and assesses key communications technologies
- Facilitating Smart Grid demonstration projects around the world to better understand and advance the use of distributed energy resources in Smart Grids.

4.6.1.2 Smart Grid Demonstration Initiative

The EPRI Smart Grid Demonstration Initiative is a seven year international collaborative research initiative demonstrating the integration of Distributed Energy Resources (DER) in large scale demonstration projects. The initiative, which began in 2008, is leveraging multi-million dollar Smart Grid investments in the electric utility industry, as well as leveraging additional funding from Energy Commission, DOE, NYSERDA, and other research organizations, for a common goal of shared learning that covers a wide breadth of technology, deployment, and program results among 23 participating utilities (12 domestic and 11 foreign), of which 15 are hosting demonstration projects.

The objective of the demonstrations is to identify approaches for interoperability and integration that can be used on a system-wide scale to help standardize the use of distributed energy resources as part of overall system operations and control.

The projects' goals include:

- Application of critical integration technologies and standards
- Integration of multiple distributed energy resource types
- Incorporation of dynamic rates or other approaches for connecting retail customers with wholesale conditions
- Integration into utility system planning and operations.

There are 15 large scale demonstration projects. Two of the projects that are in California are also receiving DOE ARRA Smart Grid funding; SMUD's SmartSacramento and SCE's Irvine Smart Grid Demonstration. The 15 projects integrate distributed generation, storage, renewable and customer resources in different configurations to accomplish the project objectives. Individual demonstrations can be focused on the integration of specific feeder types that serve residential neighborhoods; a mix of residential, commercial and industrial customers; or mostly commercial customers.

Each demonstration utilizes the communication infrastructure that utilities are installing or have in place that connects consumers and distributed generation and storage located on the distribution system of substations. The demonstration projects make use of available and emerging smart home and building technologies, such as intelligent thermostats, energy display devices, adjustable lighting and adaptable heating, ventilation, and air condition (HVAC) and white goods.

Similar to the SGIG and SGDP projects, both EPRI initiatives hold regular meetings where updates of projects are presented and collaborators can network and share their viewpoints and perspectives. In addition EPRI publishes newsletters of the projects and maintains a Smart Grid Resource web site where the project newsletters and deliverable documents are available for downloading. Since the number of EPRI collaborators and projects are much smaller scale compared to the 99 SGIG and 32 SGDP projects, the collaboration among the EPRI initiatives should be more manageable and more flexible and focused on the needs of the participating utilities and companies.

4.6.2 Lawrence Berkeley National Laboratory

Smart Grid research at Lawrence Berkeley National Laboratory (LBNL) has been concentrated in the key areas of electric storage and fuel cells, demand response, microgrids, grid reliability and policy issues. Compared to the SGIG and SGDP projects, LBNL storage research focuses on the earlier and more fundamental science aspects of batteries development and analysis, including materials synthesis, advanced diagnostics, and improved electrochemical models, rather than deployment in the field. Likewise, fuel cell research at LBNL focuses on chemical aspects such as catalysis and polymers, modeling and diagnostics to support commercialization of polymer-electrolyte and solid oxide fuel cells for automotive and stationary applications.

For more than 10 years with almost $20 million in funding from the California Energy Commission, the LBNL Demand Response Research Center (DRRC) has led research, development, and created standards in the area of automated electric demand response (AutoDR). AutoDR is defined as a set of time-dependent activities that reduce or shift electricity use to improve electric grid reliability, manage electricity costs, and provide systems that encourage load shifting or shedding during times when the electric grid is near its capacity or electric prices are high. The DRRC's objective is to develop, prioritize, conduct, and disseminate research that develops broad knowledge to facilitate demand response. One key contribution from LBNL (funded by PIER) has been the development of a communications data model, OpenADR™, to support the interoperability of many diverse load controlling units and devices. In May 2010, OpenADR™ became one of the 16 Smart Grid Standards supported by the U.S. Department of Energy and the National Institute of Standards and Technology Smart Grid Interoperability Standards effort. OpenADR™ is an example of PIER funded research successfully transferred to the private sector for the benefit of California ratepayers and businesses, as well as providing a example that has gained considerable traction nationally and internationally. DR research is also being done on policies and programs, customer response to dynamic pricing, and technical assistance to utilities and Federal and State regulatory agencies on Smart Grid technologies, rate design, and grid reliability.

Another area of Smart Grid related research at LBNL is their investigation of microgrids, defined as localized groupings of electricity sources and loads that operate connected to and synchronous with the traditional centralized grid (macrogrid), but can disconnect and function autonomously as physical and/or economic conditions dictate. Microgrid researchers at LBNL study customer adoption patterns of microgrid technology. Microgrids are not within the scope of the ARRA projects summarized here. LBNL is also part of the Consortium for Electric Reliability Technology Solutions (CERTS) that conducts research, develops, and disseminates new methods, tools, and technologies to protect and enhance the reliability of the U.S. electric power system and efficiency of competitive electricity markets. The primary emphasis of CERTS is on wide-area transmission issues.

As Smart Grid research is commonly defined and reflected in the ARRA projects, it focuses primarily on the delivery infrastructure and secondarily on the timing and pricing of electric demand, but does not explicitly link to the goal of general end-use efficiency. Arguably, this linkage – how end-use efficiency and Smart Grid capabilities can mutually support each other – is one that could bear strengthening in the future.

4.7 Results and Recommendations

Through ARRA, sixteen projects in California received Federal (DOE) funding and the Energy Commission co-funding to investigate Smart Grid storage and distribution technologies. It is important for the government, at the Federal and State levels, to continue sponsoring and financing such efforts, such that, both from a policy and technology this investigation is supported over time as these technologies mature and merge into the evolving Smart Grid. Past experience with development, demonstration and deployment of solar and wind power technologies has shown that a key factor is continuity of funding, which affords some measure of certitude for investors. The same is likely true for infrastructural Smart Grid technologies. Especially for those technologies that are slower to mature due to the complexity of systems integration, the boom-and-bust cycles of funding may not sustain the momentum needed for significant progress.

At this point, it is difficult to make any conclusions regarding how successful these projects have been at technology development and job creation. It is hence important to continue to track the progress of these projects, and the relative merit of success will become apparent only as the projects get closer to their completion date. It also is impossible to judge at this point what leverage these projects will exert on job creation outside the specific project itself. For example, the extent to which RD&D on Smart Grid technologies will ultimately leverage green-tech manufacturing jobs in the United States cannot be estimated at this early phase of the projects, and before the emerging technology becomes mature ad achieves commercial viability.

As these technologies are developed in isolation, promoting or probing standardization practices, to ensure the integration of these technologies into a larger system, should be an important issue to address. One way to achieve this is to continue to promote efforts for knowledge exchange, such as the October Workshop held at UC Berkeley.

As the Smart Grid develops and evolves over time, it is important for California ratepayers, utilities and private providers of Smart Grid products and services stay aligned with national activities. Defining and implementing best practices, open standards, long term planning and education are keys to creating successful strategies for continued Smart Grid growth in California.

Since this project looked at only the sixteen ARRA projects in California and there are at least 115 more across the country, it is not possible for this project to provide recommendations for future research simply because the recommendations may turn out to be duplicating efforts already being conducted elsewhere. However, this project recommends that California public-funded Smart Grid research leverage as much as possible, research activities that are already going on in California, such as the research at EPRI and LBNL. For example, the Smart Sacramento is one that is being co-funded by PIER. More of such co-funded projects would be beneficial to California.

The collaborative research that's taking place at EPRI is one that California should either participate in, or use it as a model for the State's own collaborative Smart Grid research. Instead of funding projects individually, the collaborative model will help ensure the research is focused on what the participants need, with less duplication of efforts. The integration is coordinated and not an afterthought.

The ability to track the overall progress of advanced Smart Grid research, is of great importance, as it provides an overall snapshot of the current state, and progress of the conducted research. Continuing this project, especially as the ARRA projects are maturing and entering into their advanced phases, will help shape the research agenda for the evolving Smart Grid and contribute to meeting California's energy objectives.

CHAPTER 5: Conclusions

The project team has successfully developed a searchable database for tracking and comparing the numerous Smart Grid projects throughout the State. Due to the evolving and varied nature of the Smart Grid projects throughout the State, the project team developed the database using SQL and a PHP interface. This choice provided the database with a high degree of extensibility that allows for the addition and comparison of future Smart Grid projects with novel characteristics. The database ultimately allows for the user to easily compare metrics across various Smart Grid projects. The database has additionally been developed not only to present and organize the data as with the current interface, but also it could be used to compare select data categories across projects. The Smart Grid Database can be accessed at: http://i4energy.org/index.php?option=com_content&view=article&id=470&Itemid=245

Through ARRA funding, sixteen projects in California received Federal (DOE) funding and the Energy Commission co-funding to investigate Smart Grid storage and distribution technologies. It's important for the government, both at the Federal and State levels, to continue sponsoring and financing such efforts, such that, both from a policy and technology perspective, this investigation is supported over time as these technologies mature and merge into the evolving Smart Grid. Past experience with development, demonstration and deployment of solar and wind power technologies has shown that a key factor is continuity of funding, which affords some measure of certitude for investors. The same is likely true for infrastructural Smart Grid technologies. Especially for those technologies that are slower to mature due to the complexity of systems integration, the boom-and-bust cycles of funding may not sustain the momentum needed for significant progress.

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The ability to track the overall progress of advanced Smart Grid research, is of great importance, as it provides an overall snapshot of the current state, and progress of the conducted research.

GLOSSARY

ACID	*Atomicity, Consistency, Isolation, Durability*: a collection of properties used to ensure database transaction/processing success.
AJAX	*Asynchronous JavaScript and XML*: A web development paradigm where data are sent and retrieved from the server in the background, allowing the client-side app to operate while maintaining a fluid and uninterrupted user interface.
API	*Application Programming Interface*: A specification for a communications format to be used by various software components to send data between them.
ASCII	*American Standard Code for Information Interchange*: a character encoding scheme based on the English alphabet
CSS	*Cascading Style Sheets*: a style sheet language used for formatting documents or web pages produced using markup languages (such as HTML).
DOM	*Document Object Model*: A convention for representing and interacting with the elements of an XML/HTML document as a tree of objects
HTML	*Hypertext Markup Language*: The primary markup language used for web page development
MVC	*Model-View-Controller*: an architecture pattern for software development in which application roles are split into three distinct functional roles. The distillation and separation of application roles into independent units allows for easier troubleshooting and less testing time.
NoSQL	A recent trend against systems that use SQL or resemble an RDBMS, focusing instead on performance through simplicity and distributed architecture.
PDF	*Portable Document Format*: a file format designed by Adobe for cross-platform representation of fixed layout documents. PDFs are particularly suited for storing print media representations.
PHP	*PHP: Hypertext Preprocessor*: A server-side scripting language often used in web development, but also for general purpose programming.

Appendix A:
Smart Grid Research Development and Demonstration Assessment: - California

Public Interest Energy Research (PIER) Program

SMART GRID RESEARCH DEVELOPMENT AND DEMONSTRATION ASSESSMENT: - CALIFORNIA

Assessment Indicators

Prepared for: California Energy Commission

Prepared by: University of California, Berkeley

MAY 2012

PREFACE

Assessment Indicators is appendix 1 for the Smart Grid Research Development and Demonstration Assessment: - California project (contract number 500-10-023), conducted by University of California, Berkeley. The information from this project contributes to PIER's Energy Systems Integration Program.

ABSTRACT

The project team has compiled information on a series of indicators (metrics and parameters) that form the foundation for the project's comprehensive assessment of the different efforts taking place in the ARRA Smart Grid projects in California. Information on these indicators will be collected and publicly accessible through a web interface and a database.

This Appendix provides a description of the project's indicators, which are composed of a combination of existing indicators from other sources as well as new indicators specific to this project.

TABLE OF CONTENTS

CHAPTER 1: Introduction

Under the United States Federal Government American Recovery and Reinvestment Act (ARRA) of 2009, the United States Department of Energy is funding Smart Grid research across the country. The Smart Grid Investment Grant (SGIG) Program (DE-FOA-0000058) is accelerating the transformation of the electric transmission and distribution systems by promoting investments in Smart Grid technologies, tools, and techniques for immediate commercial use.

In addition, the Smart Grid Demonstration Program (SGDP) (DE-FOA-0000036) is composed of regional demonstration projects and utility-scale energy storage projects. In the regional studies, project teams verify Smart Grid technology viability, quantify costs and benefits, and validate new business models that can later be adapted and replicated around the country.

The Smart Grid Research Development and Demonstration Assessment: - California Project is funded by the California Energy Commission's, Public Interest Energy Research (PIER) Program. This project identified any gaps that exist in the overall research agenda of ARRA SGDP and SGIG funding, support synergies among projects, and identify research and technology transfer opportunities in the context of California's Smart Grid implementation plans over the next decade.

The project team consists of multidisciplinary researchers at UC Berkeley. The team is systematically characterizing and comparing the relevant ARRA projects currently under way. For each ARRA project, the team is analyzing the specific technologies being deployed, their intended impact, and the performance parameters being tested empirically.

The team has compiled information on a series of indicators (metrics and parameters). This data forms the foundational basis for the project's comprehensive assessment of the different efforts taking place in the ARRA Smart Grid projects in California. Information on these indicators will be collected and publicly accessible in the web interface and database (see main report for details).

This Appendix provides a description of the project's indicators, which are composed of a combination of existing ARRA,[5] and CPUC[6] indicators as well as new indicators specific to this Project.

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[5] Guidebook for ARRA Smart Grid Program Metrics and Benefits, Department of Energy, December 7, 2009.

[6] California Public Utilities Commission (CPUC) Rulemaking 08-12-009, March 20, 2012, Decision Adopting Metrics to Measure The Smart Grid Deployments of Pacific Gas & Electric Company, Southern California Edison Company and San Diego Gas & Electric Company, Attachment A.

CHAPTER 2:
Basic Information

This chapter describes the indicators of basic project information of the diverse portfolio of Smart Grid projects being studied.

Project Type and Goal

These are the indicators to distinguish among the breadth of projects and to understand the commonalities and differences across the multiple objectives of each project.

Project Stakeholders and Suppliers

These indicators identify the key players in each project, and their roles.

Project timeline

This set of indicators gives a calendar representation of the projects and their deadlines, which provide an opportunity to assess speed and timeliness in the construction and deployment efforts.

Funding sources

These indicators allow us to understand the size of the investments for each project as well as provide an understanding for the percentage of public funds being invested per project.

Physical Characteristics

These indicators are for the projects' geographic location and size of project facilities, such as research centers, manufacturing sites, and installation sites.

CHAPTER 3: Technological Characteristics

Technological indicators will focus on the different types of technologies addressed through the smart grid project portfolio. The technological indicators will help distinguishes existing, adopted technologies from game changing technologies. Technology indicators are classified under the following categories:

Energy Storage

Energy storage indicators are targeted at the projects involving technology for storing energy (mechanically, chemically, thermally, etc.). The indicators will provide insight as to the storage capacity and cycle efficiency, cost per cycle, and end use.

Energy Storage (Flywheel, flow battery, compressed air, thermal)
• End-use (peak hours reduction, long-term storage, low genertion use)
• Peak power demand contribution (usage patterns)
• Lifecycle (yrs)
• Number of deep cycles
• Cycle Efficiency (%)
• Cost per cycle: (Capital/Energy)/(Life x Efficiency)
• Maximum power output/generation (MW)
• Battery life (sec, min, hrs)
• Storage Capacity (MWh)

Power Generation

Power generation indicators are primarily tailored for those projects involving distributed generation and use of renewable resources (wind, solar, PV, CPV, CSP, etc.). Basic information on maximum projected output and capacity factor as well as energy cost and carbon intensity are included in the power generation indicators.

Generation (Wind, Solar - PV, CPV, CSP)
• Maximum power output/generation (MW)
• Capacity Factor (%)
• Carbon conserved ($/tC)
• Carbon intensity (gC/kWh)
• Energy cost ($/kWh)
• Area used (m^2)
• Lifetime (yrs)
• Total annual electricity deliveries from customer-owned or operated, grid-connected distributed
• Man hours to manage (hrs/day)

Metering

The metering indicators are tailored for projects involving testing of smart meters, power quality (PQ) monitors, and power line sensors. They will provide insights into the number and type of units deployed, data storage capacity developed, and battery life amongst others.

Metering (Smart Meters, PQ Monitors, Line Sensors)
• Units (#)
• Metering Type
• Data Storage Capacity
• Costs avoided ($/kWh)
• Response time
• Connection (ethernet, etc)
• Variables measured (temp, power use, time of use, etc)

Distribution

Distribution indicators target projects involving demand response, transmission of power, and equipment that assists and enhances power distribution throughout the grid. They will provide insight into the usefulness and future needs in this sector. The indicators are as follows:

Distribution (Automated Demand Response, Transformers, Power Meters, Sensors)
• Units (#)
• Point of installation (generators, substation, lines)
• Enhancements
• Automated? (y/n)
• Operation voltage (and tolerance)
• Software Type
• Number and percentage of distribution circuits equipped with automation or control equipment
• Number of and total nameplate capacity of customer-owned or operated, grid-connected distributed generation facilities
• Percentage of demand response enabled by AutoDR (Automated Demand Response) in each individual DR impact program

Communications

The communications component of the indicators refers to the areas of information processing and relaying. These indicators provide a basic sense for the system's architecture, its basic workings and methods of communication. The specific indicators are as follows:

Communications (Information Processing & Relaying)
• Units (#)
• Equipment connected (line monitors, fault circuit indicators)
• Remote controlling (y/n)
• Data Retrieval (min, hrs, as needed)
• User (customer, utility)

Plug in Electric Vehicles (PHEV)

PHEV indicators are specifically targeted for the projects conducting pilots on electric vehicle charging. These indicators focus around the general size of the pilot in terms of customers enrolled, stations, and vehicles. The specific indicators are as follows:

Plug in Electric Vehicles
• Number of customers enrolled in time-variant electric vehicles tariffs
• Number of electric stations
• Number of vehicles

CHAPTER 4: Other Characteristics

Load Improvements

Load improvement indicators provide more detailed insight into the goals of the projects, mainly relating to expectations on operational efficiency improvements and reliability of the grid. The specific indicators are as follows:

Load Improvement
Operational Efficiency (contribution to) (%)
Grid reliability and resilience (contribution to)
Contribution to flattening load curves
Power Factor improvement
Impact on Grid (# of substations affected)

Policy Applications

The policy indicators provide a framework to identify the policy characteristics of the projects and their implications, as well as evaluate the Smart Grid projects on the basis of their alignment with existing standards.

Policy Applications
Policy Characteristics/Implications
Salient Institutional Characteristics
Eligibility for feed-in tariffs
Alignment with Renewable Portfolio Standards
Alignment with Distributed EN Resources (DER) Interconnection Standard
Alignment with environmental standards

Economic Impact

Indicators for economic impact are relevant for all assessed projects and include jobs metrics as well as the potential that these projects have for future development of related projects, markets, businesses, and employment opportunities.

Economic Impact
jobs created
jobs/$ spent
Impact on purchased goods
CCE (Cost of Conserved Energy) ($)
Potential for market place innovation/new program creation
Secondary Battery Market Eligibility (Yes/No/Maybe)

Lifecycle Assessment Measures

Lifecycle assessment indicators will primarily provide insight into the environmental impact of the projects, including emissions and recycling impacts, as well as material inputs for project development.

Lifecycle Assessment Measures
Air pollutants (type, amount)
CO2 emissions abatement (tons CO2)
Recycling Concerns
Environmental hazards
Composition (e.g. Rare earth metals used)
Safety Hazards

Social Impact

Social impact indicators focus on the projects' impact on consumers and consumer response to project progress. Improvements in affordability and information, as well as the number of customers served are part of these social impact indicators.

Social Impact
Customers served (households)
Customers contacted directly by phone or in writing (#)
Customer response (for projects dealing directly with consumers)
Improvements in customer affordability (% cost reduction)
Improvements in customer information (new tools, web interface, etc.)
Privacy Concerns