San Diego Smart Grid Study
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1. EXECUTIVE SUMMARY

This San Diego Smart Grid Study is one of the first in the nation to apply the Smart Grid concepts developed by the U. S. Department of Energy's Modern Grid Initiative to a specific region. It provides preliminary analysis to determine the technical feasibility and cost effectiveness of implementing Smart Grid technologies and strategies in the San Diego Region. The objectives of the study are to (1) determine whether the future economic and regulatory climate in the San Diego region could accommodate or necessitate a Smart Grid, (2) determine the portfolio of technologies that could implement a Smart Grid, and (3) conduct a cost-benefit analysis to determine whether implementing a Smart Grid would be cost effective for the region.

Key Findings

1. Economic, technological, and regulatory trends in the San Diego region likely will create a desirable climate for implementation of a Smart Grid.
2. While the existing transmission and distribution grid includes some advanced technologies and SDG&E is planning to implement others, the project team identified 26 technologies that can be implemented to advance the current electric grid toward a smarter, more modern system.
3. Results of a preliminary cost-benefit analysis suggest that implementing Smart Grid technologies and strategies could yield benefits that adequately exceed the initial installed costs and cover the ongoing operation and maintenance costs.

1.1. Smart Grid Overview

This study is based on the definition of a Smart Grid developed and being pursued by the U.S. Department of Energy's Modern Grid Initiative (MGI).[1] The existing transmission and distribution system in the United States uses technologies and strategies that are many decades old and include limited use of digital communication and control technologies. To address this aging infrastructure and to create a power system that meets the growing and changing needs of customers, the MGI seeks to create a modern – or "smart" – grid that uses advanced sensing, communication, and control technologies to generate and distribute electricity more effectively, economically and securely. The Smart Grid integrates new innovative tools and technologies from generation, transmission and distribution all the way to consumer appliances and equipment. A modernized grid would create a digital energy system that will:

- Detect and address emerging problems on the system before they affect service,
- Respond to local and system-wide inputs and have much more information about broader system problems,
- Incorporate extensive measurements, rapid communications, centralized advanced diagnostics, and feedback control that quickly return the system to a stable state after interruptions or disturbances,

[1] More details about the Modern Grid Initiative (MGI) and this process can be found at www.moderngrid.org.

- Automatically adapt protective systems to accommodate changing system conditions,
- Re-route power flows, change load patterns, improve voltage profiles, and take other corrective steps within seconds of detecting a problem,
- Enable loads and distributed resources to participate in operations,
- Be inherently designed and operated with reliability and security as key factors, and
- Provide system operators with advanced visualization tools to enhance their ability to oversee the system.

1.2. Study Results

To accomplish the objectives of the San Diego Smart Grid Study, the project team developed a process that included the following six steps: (1) develop a scenario that describes the likely future state of the region's economic, regulatory, and technology climate, (2) assess the current state of the energy infrastructure and climate in the region (as-is state), (3) compare the current state to a future Smart Grid scenario to identify technological, regulatory, and consumer system gaps, (4) identify a core group of Smart Grid technologies that when implemented together would provide the framework for the Smart Grid concept, (5) conduct a cost-benefit analysis to determine if there is a business case for implementing the technologies identified, and (6) recommend an implementation strategy for the identified technologies, including near-term demonstration projects. We present below a summary of the results of this work.

1.2.1. Future San Diego Scenarios

To determine whether a future state of the San Diego region could accommodate and necessitate Smart Grid technologies and strategies, the project team developed a series of future probable scenarios based on spectrums of extreme states of economic, environmental and technology development. The team analyzed the impacts that such factors could have on the operation of the regional electric grid. This analysis demonstrated that under certain scenarios, a favorable climate exists for the implementation of a Smart Grid in the San Diego Region.

Based on our analysis, the most likely scenario to describe the future of the San Diego region includes continued economic growth, more environmentally restrictive regulation, and breakthrough technology in regional businesses, including the electric and gas utility. Given the current trends of regulation, the region likely will see an increasing emphasis on renewable energy, use of alternate fuels, as well as energy efficiency and demand response in all market segments. The region's economy will continue to have a large number of high-tech businesses and a high-tech lifestyle, which could drive a shift in the reliability and power quality requirements of the grid. This probable future environment of the San Diego suggests a desirable climate for the implementation of a Smart Grid.

1.2.2. Current State of the SDG&E Transmission and Distribution System (As-is State)

The project team analyzed the San Diego transmission and distribution infrastructure, communications, distributed energy resources in place in the region, related policy issues, market structure, including, existing technology applied to the grid, and the end-use (consumer-side) technologies available as resources. SDG&E validated the assumptions, provided operational data, and provided subject matter expertise on the existing and planned operations of the regional grid system. This survey is the baseline against which a future Smart Grid scenario will be compared to determine what technology and policy gaps exist.

Significant observations from this review include the following:

- There is an increasing number of customer-owned distributed generation systems installed in the region, including a growing number of photovoltaic systems.
- The existing utility communication infrastructure will not support the requirements of the future Smart Grid scenario.
- The utility is implementing technologies and systems that are necessary for a Smart Grid, including:
    - An Advanced Metering Infrastructure (AMI) initiative that SDG&E has submitted to the California Public Utilities Commission (CPUC). If approved, the project could be completed in 2010.
    - A substation automation program (multi-year) that is already in progress.
    - A field SCADA switch rollout program that is already in progress.
    - A set of broadband over power lines (BPL), advanced transmission conductors, and sensor exploratory demonstration projects are in progress.
- California state law requires the utility to follow a specific “Loading Order” when developing their resource plan. Under this law, utilities should seek new energy resources first from energy efficiency, demand response, renewable energy, and distributed generation before seeking resources from new transmission and fossil-fuel based generation.

1.2.3. Comparing the Current Electric Grid to a Future Smart Grid Scenario (Gap Analysis)

The project team compared the current SDG&E electric grid to a future Smart Grid scenario to determine what technological and regulatory changes would be necessary to modernize the region’s grid. The process was modeled after the Modern Grid Initiative for the electric infrastructure of the nation, which focuses on five key technology areas (KTA): advanced grid components, integrated communications, advanced control methods, sensing and measurement, and improved interfaces and decision support.

The project team identified twenty-six (26) technology improvement initiatives that – from a technical standpoint – could move the existing San Diego electric grid to a more modernized, Smart Grid. Through a subsequent screening analysis in the business case, the original 26 initiatives were reduced to thirteen high-value improvement initiatives. Table 1 provides a list of these initiatives.

Table 1 Final Smart Grid Improvement Initiatives

Improvement Initiative No.	Improvement Name
1	GATECH IPIC Dynflo distributed series impedance sensors
2	I-Grid Monitoring System (by Softswitching Technologies)
5	Consumer Portal
7	Ethernet over Fiber
9	4G WiMAX Fixed - Private Wireless
11	Zigbee / WiMedia / WiFi - Wireless
12	Semi-autonomous Agents
14	Advanced Visualization Methods (POM, ROSE, FFS, OPM, etc)
17	DER-based Microgrids
19	Advanced Energy Storage Systems
21	Advanced Grid Control Devices
23	Agent and Multi-Agent Systems
25	Distribution (Feeder) Automation

1.2.4. Cost Benefit Analysis (Business Case)

In the cost-benefit – or business case – phase, the project team developed and applied estimates of installed costs and associated benefits (savings) for the thirteen high-value improvement initiatives. The anticipated benefits of implementing a Smart Grid used in the cost-benefit analysis include:

- Reduction in congestion cost,
- Reduced blackout probability,
- Reduction in forced outages/interruptions,
- Reduction in restoration time and reduced operations and maintenance due to predictive analytics and self healing attribute of the grid,
- Reduction in peak demand,
- Other benefits due to self diagnosing and self healing,
- Increased integration of distributed generation resources and higher capacity utilization,
- Increased security and tolerance to attacks/ natural disasters,
- Power quality, reliability, and system availability and capacity improvement due to improved power flow,
- Job creation and increased gross regional product (GRP),
- Increased capital investment efficiency due to tighter design limits and optimized use of grid assets,
- Tax savings for the utility from a depreciation increase, and
- Environmental benefits gained by increased asset utilization.

If all thirteen improvement initiatives were implemented, the initiatives would generate $1.4 billion in utility system benefits and nearly $1.4 billion in societal benefits over 20 years. The total capital cost for all thirteen improvement initiatives would be $490 million. Table 2 presents the overall results of the cost-benefit analysis.

Table 2 Overall Costs and Benefits of Final Smart Grid Improvement Initiatives ($millions)[2]

Total Annual Benefits	**$141M**
System Benefits (20-years)	**$1,433M**
Societal Benefits (20-years)	**$1,396M**
Total Capital Cost	**$490M**
Annual O&M Cost	**$24M**

Figure 1 shows a breakdown of the anticipated benefits of implementing the 13 improvement initiatives to develop a Smart Grid in the region.

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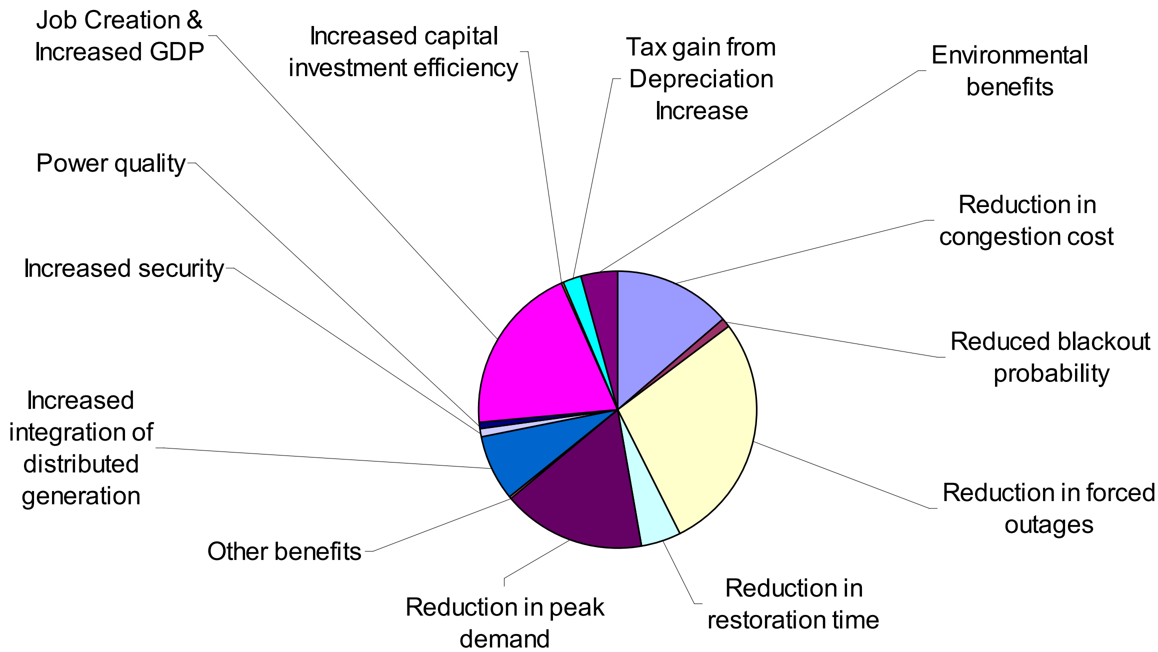
[2] We did not include simple payback in the results because the costs and benefits will be phased in over a period of up to ten years; therefore, simply dividing the total capital cost by the total annual benefits will not be a meaningful measure of cost effectiveness. For example, dividing total cost ($490million) by total annual benefits ($141 million) yields a 3.5 year payback. Because implementation of the 13 improvement initiatives would be phased in over time, expenditures likely will be made over a period of more than 7 years.

Figure 1 Distribution of Benefits for the Final Improvement Initiatives



The modeling conducted for the cost-benefit analysis included analyzing the implementation sequence of the thirteen improvement initiatives. Since each initiative has its own level of cost effectiveness and there are interrelated dependencies among the initiatives that dictate when the benefits can be achieved, the timing and staging of initiatives has an impact on the economics of the portfolio. To capture the potential differences that such timing and interdependency might have on the results, the project team modeled the business case using three scenarios for comparison. The scenarios developed were as follows:

- Earliest Positive Cash Flow – This scenario establishes the minimum time for the cumulative cash flow to go positive. Under this scenario the benefits fund future investments as early as possible.
- Maximum Benefits Early – This scenario establishes the earliest time for benefits to be the largest, which usually means the costs are front loaded.
- Optimized Internal Rate of Return (IRR) – This scenario establishes the best mix of realized IRR and net present value (NPV)

The results of the three approaches are presented in the following Table 3.[3]

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[3] Note that the business case analysis assumes that the SDG&E proposal for advanced metering infrastructure (AMI) is implemented as proposed. Based on this assumption, we did not double count the benefits that will be achieved through the AMI project (e.g., demand response savings) with the benefits that will be achieved through the proposed Improvement Initiatives. Also, several Improvement Initiatives identified in this study are predicated on the existence of AMI.

Table 3 Summary of Business Case Results[4]

Scenario	Regional IRR* (%)	NPV ($M)	Point of Positive Cash Flow** (Yrs)	First Year Annual Benefits Top $50M
Earliest Positive Cash Flow	75%	403	3.5	2017
Maximum Benefits Early	26%	508	7.0	2012
Optimized IRR	44%	416	5.5	2014

* Internal Rate of Return normally refers to a single business entity, but here we have treated the San Diego region as a single entity to enable the calculation of a regional benefit, both systems and societal. For this analysis it assumed that all stakeholders will participate in the investment (directly or indirectly through rate recovery) as well as realizing the identified benefits.

** Point of Positive Cash Flow is the collective cash flow analysis from all thirteen (13) improvement initiatives combined as a single overall program. Several improvement initiatives require continued investment for as much as 10 years, well beyond the point of positive cash flow, to achieve full implementation of the Smart Grid. The point of positive cash flow should not be used as a proxy for the simple payback of the scenario.

The business case scenarios represent three points of view. The Earliest Positive Cash Flow scenario represents a managed investment approach that utilizes ongoing savings to finance current and future investments, the Maximum Benefits Early scenario represents a societal-led view, and the optimized IRR scenario represents a compromise view.

The Earliest Positive Cash Flow scenario generates a positive cash flow in a 3.5 year period; however, the sustained large benefits (> $50M/yr) do not occur until 11 years after start. The Maximum Benefits Early scenario generates a positive cash flow in a 6 year period, and the sustained large benefits (> $50M/yr) actually occurs in the final year of the positive cash flow, 5 years earlier than the earliest positive cash flow scenario.

From a regional perspective, the scenario that seems most appropriate is the Maximum Benefits Early because it enables the benefits presented above to be realized by both consumers and the utility earlier than the other two scenarios. This scenario has the quickest entry of sustained system and societal benefits and provides the largest NPV with an attractive internal rate of return for the region.

Based on the preliminary cost-benefit analysis conducted for this study, there appear to be sufficient benefits to the utility system, to the broader region (societal), and in total, to justify a movement of the San Diego regional grid to a Smart Grid architecture. It should be noted however that the capital costs and operations and maintenance costs are substantial. This level of effort will be very challenging to a host utility, especially considering other significant projects in progress and the aggressive proposed implementation schedule.

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[4] The results presented in Table 5 represent the cost effectiveness from the perspective of the San Diego region as a whole. These results demonstrate that both the costs and benefits that can be realized from a Smart Grid are shared with the utility, businesses and residents of the region. That is to say that not all costs and not all benefits are borne by the utility.

1.3. Recommendations

1.3.1. Recommended Implementation Plan for Improvement Initiatives

Results of the cost-benefit analysis suggest implementing a Smart Grid in the region could be cost effective. Based on this result, the project team developed an implementation plan for the thirteen improvement initiatives. Deployment of the improvement initiatives can be phased in relation to improved reliability with later initiatives building on earlier successes. Table 4 presents a two-phase approach to implementing the improvements.

Table 4 Implementation Plan for Improvement Initiatives

Phase 1 (2007 – 2016)		
Improvement Initiatives	7 – Ethernet over Fiber 9 – 4G WiMAX Fixed - Private Wireless* 25 – Distribution (Feeder) Automation 1 – GATECH IPIC Dynflo distributed series impedance 2 – I-Grid Monitoring System 11 – Zigbee / WiMedia / WiFi - Wireless 21 – Advanced Grid Control Devices 14 – Advanced Visualization Methods 5 – Consumer Portal 19 – Advanced Energy Storage Systems	This grouping of improvement initiatives serves two purposes: (1) establishing the foundation for the complete Smart Grid, and (2) focuses on those initiatives most likely to improve reliability under a changing environment.
Phase 2 (2009 – 2013)		
Improvement Initiatives	9 – 4G WiMAX Fixed - Private Wireless* 12 – Semi-autonomous Agents 23 – Agent and Multi-Agent Systems 17 – DER-based Microgrids	This grouping of improvement initiatives serves two purposes: (1) expand the integration of consumer systems into the Smart Grid, and (2) provide additional options for improved reliability and economic electricity services.

* This Improvement Initiative is implemented as needed across both phases of the deployment.

Table 5 shows the recommended rank order of Smart Grid technologies and an estimated implementation time. The implementation timeline is based on an assumption that the research, development and demonstration (RD&D) projects start in the 2007 to 2008 time frame and are successful and that SDG&E's proposed AMI project is fully implemented by 2010.

Table 5 Timeline for Final Improvement Initiatives

Priority	II No.	Improvement Name	Timing*
1	7	Ethernet over Fiber	2007 – 2009
2	9	4G WiMAX Fixed - Private Wireless	2007 – 2009
3	25	Distribution (Feeder) Automation	2007 – 2011
4	14	Advanced Visualization Methods (POM, ROSE, FFS, OPM, etc)	2007 – 2009
5	1	GATECH IPIC Dynflo distributed series impedance sensors	2009 – 2013
6	2	I-Grid Monitoring System (by Softswitching Technologies)	2012 – 2016
7	11	Zigbee / WiMedia / WiFi - Wireless	2007 – 2010
8	21	Advanced Grid Control Devices	2007 – 2011
9	5	Consumer Portal	2008 – 2012
10	19	Advanced Energy Storage Systems	2008 – 2014*
11	17	DER-based Microgrids	2009 – 2013*
12	12	Semi-autonomous Agents	2009 – 2011*
13	23	Agent and Multi-Agent Systems	2009 – 2013*

* Moved the improvement initiative out one or two years to accommodate probable resource limitations based on the number of project starts and the maturity of the technology.

1.3.2. Recommended RD&D Projects

To aid in the risk management and assurance of cost-effective deployment, the project team recommends that the region conduct several RD&D projects. Table 7 presents four RD&D projects, their timing, and the specific improvement initiative that should lead the sequence.

Table 6 Research and Development Project Recommendations

RD&D Project	Timing	Leading Initiative
WiMAX Pilot	2007 – 2008	Midhaul Communications (II-9)
Adv. Energy Storage Pilot	2007 – 2008	AES Integration (II-19)
DER-based Microgrid	2008 – 2009	DER-based Microgrids (II-17)
Agents Pilot	2008 – 2009	Semi-Autonomous Agents (II-12) Agent & Multi-agent Systems (II23)

II = Improvement Initiative

1.3.3. Recommended Policy and Regulatory Changes

In addition to the technological gaps identified above, the study also identified policy and regulatory changes needed to realize the future Smart Grid scenario. The following list includes the key policy and regulatory changes identified.

- A consistent, long-term policy to provide clear and low-cost market signals (real-time pricing, critical peak pricing, etc.) to consumers and third parties interested in participating energy markets through local distribution-level programs.

- Incentives to allow the use of advanced technologies that increase capacity, improve efficiency or reliability of resources per the EPACT 2005.
- CEC support for an in-depth evaluation of the economic benefits of commercially available voltage stabilizing technologies (SVC, D-VAR, DSTATCOM, STATCOM, SuperVAR, etc) to identify and endorse the optimum solutions.
- Policies that encourage open data access, interoperability, reliability standards, and capability to operate micro-grids in intelligent islanding modes. Open communication architecture needs to be standardized.
- New rate designs (e.g., real time pricing, premium power quality) and incentives are needed to encourage consumers and SDG&E to invest in promising advanced technologies. Regulators and policymakers should determine if any existing law or policies would inhibit the development of new rate designs (e.g., residential rate caps in AB 1X).
- Policies that consider the societal benefits of infrastructure investments when determining cost effectiveness.